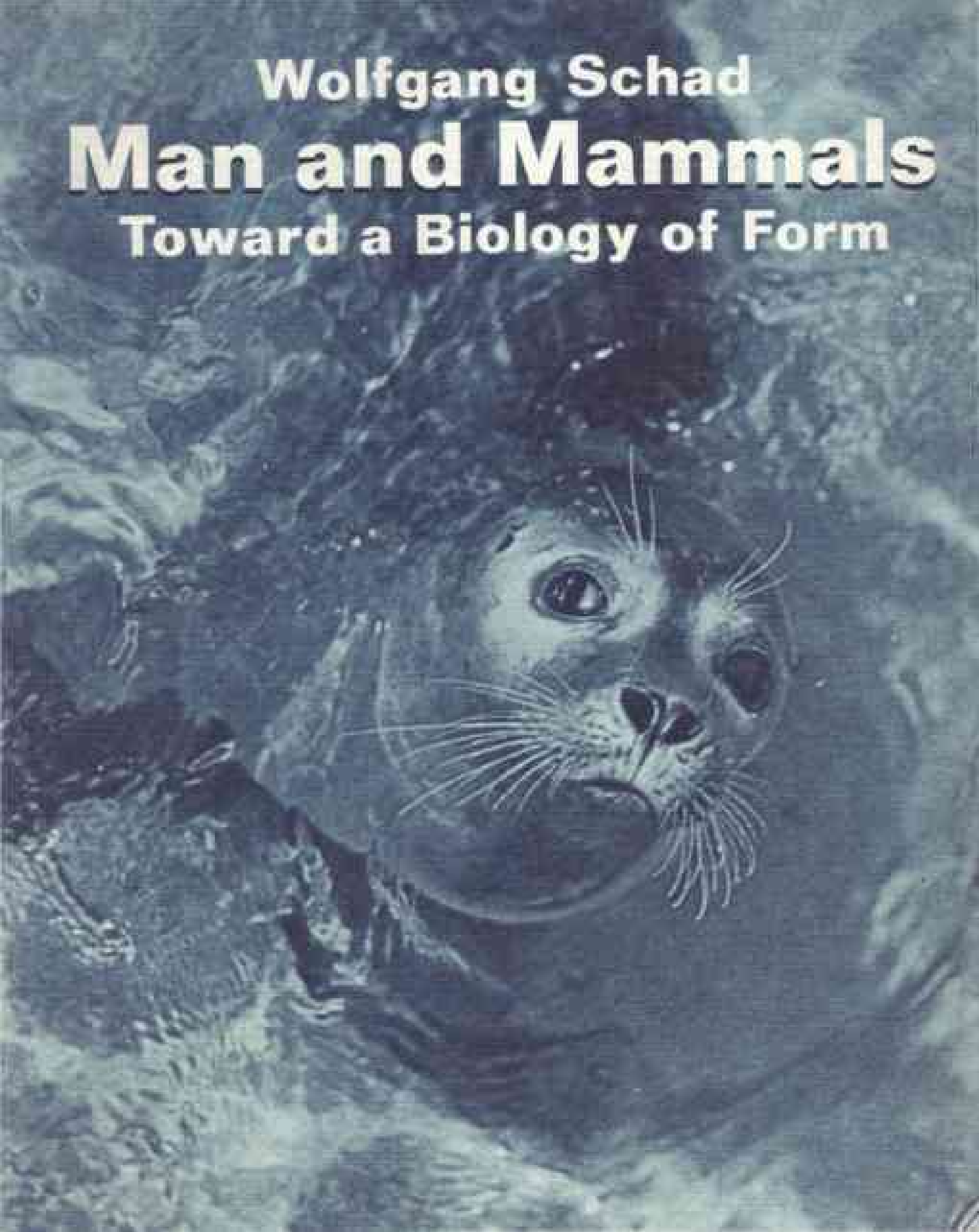
Wolfgang Schad

Man and Mammals

Toward a Biology of Form



MAN AND MAMMALS

Toward a Biology of Form

WOLFGANG SCHAD

Translated from the German

by Carroll Scherer

Illustrated by
Christian Brügger
and
Ulrich Winkler

Originally published in 1971 as *Säugetiere und Mensch, Zur Gestaltbiologie vom Gesichtspunkt der Dreigliederung.*

ISBN 0-914614-10-X
Library of Congress Number 6-52049
 Published 1977
Printed in Western Germany for the Waldorf Press by the Ernst Klett Verlag, Stuttgart

WALDORF PRESS
Publishers

ADELPHI UNIVERSITY, GARDEN CITY, NEW YORK

Contents

Foreword

It is my belief that *Man and Mammals* will delight and instruct ordinary readers, and it is my hope that it will set before serious students of biology not only a host of problems that deserve further inquiry, but valid clues to the most fruitful method for such inquiry. This book should be read in homes, in high schools and colleges, as well as by professional students of zoology and animal behavior. Its methods and conclusions are an important step towards the holistic biology that will give us a better perspective than we have at present on man's place in the natural order and will open the way to auspicious new beginnings in animal husbandry, medicine, agriculture, and education.

By concentrating on the living form and structure of the mammals—their morphology—Schad studies these animals in their wholeness, just as they appear in the natural world. To him, every aspect of living form reveals something significant about the animal's nature as a whole. He raises questions so fundamental that many of them must have occurred to us before, perhaps in childhood.

Why, for example, do the cattle have horns and the deer antlers? Why shouldn't mice or lions have such organs as well? Why do leopards have spots? Why are zebras striped?

Is there some meaning in the contrast between the nervous, tiny, beady-eyed rodent, with its tenuous hold on life, and the large, self-sufficient, rather complacent ungulate—the cow, for example—whose grasp on life is so strong? And what of the carnivores, medium-sized but aggressive, **who** must belong, we feel, somewhere between these other two groups?

Why should carnivores eat meat, mice grain, and cows grass? And how can an animal of the cow's enormous size sustain itself on such a poor diet?

Why are the whales so thoroughly adapted to water that they were thought for centuries to be fishes, rather than mammals? Why does the porcupine, a rodent, live in a burrow deep underground, while the tiny harvest mouse weaves an intricate nest of grass high up in the bushes?

What is man's relation to the natural world? Is he a highly developed animal, or does he have an ingredient the animals do not have, that gives him a unique potentiality and opens him to greater responsibilities?

Schad's answers to these questions and many others are often surprising, and always fascinating. His approach to the mammals is humane, but objective. His observations are accurate, beautifully illustrated, and easily validated by any careful observer.

Such an approach is certainly not without precedent. As early as the eighteenth century, Goethe presented a method of observing nature lovingly, scrupulously, non-theoretically, asking only that the observer have patience and the expectation that perception will become thought and phenomena will eventually organize and declare themselves as idea. More recently, scientists such as Adolf Portmann, of Basel, have interpreted the external form of an organism both in relation to its biological function *and* to what Portmann has called its "self-expression," by which he understands a kind of signature of the animal's essential nature.

What is new in Schad's method is the extensive system of classification he builds upon the basis laid by Goethe and especially by Rudolf Steiner. The Goethean-Steinerian approach to natural phenomena requires the observer to be objective, as a scientist *must* be; but at the same time it calls upon him for an intuitive power of sympathetic identification. Every step forward in this kind of knowing strengthens the observer's rapport with the created world that confronts him, even as it awakens his own potentialities for experience.

It must be emphasized that the intuitive relationship to the animal kingdom which this new approach calls for is by no means either subjective or sentimental. On the contrary, because the cognitional effort involves the full participation of the whole man, it leaves sentimentality behind. And because it seeks to have its thinking issue directly *from* the observed fact rather than be added *to* it, its claim to objectivity must be respected.

Such objectivity is almost frightening to current scientific thought; yet a child, on his level, perceives the world in this way: knowing nothing, he simply looks; simply looking, he *sees* what is really there. Of course, we cannot stop at childhood; nor can we idealize innocent gazing to such a degree that we refuse to *understand* what we see. First comes accurate observation; this awakens sympathy and stimulates to further perception. As sympathy broadens and deepens, it feels itself taken hold of by an objective reality. In the patient, expectant mind this reality eventually coins itself into thought. Such thought appears less as a hypothesis to be tested *against* observation than as the form that sympathetically made observations take of themselves when by the necessity of their own nature they pass over into idea.

The basic idea at the heart of this book is one formulated by Steiner. He proposed that the proper way to understand animal forms is by first comprehending the *human* form, for to his intuitive perception the nature of man showed itself to be a kind of compendium or summary, on a higher level, of the entire animal kingdom; and for him this truth came to expression in the harmonious, omnipotential form of man's body. So understood, man is the central and balanced configuration of which each mammalian animal species appears as a partial, one-sided development.

In the second chapter of this volume, "The Human Organism as Threefold," Schad sets forth and elaborates with physiological and anatomical detail his concept of the organization of the human form. He uses this concept as the basis for the new, threefold classification of the mammals that forms the substance of his book. The rodents, for example, he finds to be peculiarly related to man's upper pole, the 'nerve-sense system'; the ungulates, to the lower pole, which he designates as the 'metabolic-limb system'; and the carnivores, to the middle, or 'respiratory-circulatory system.'

It is the author's contention that through a consideration of animal morphology—which includes the color, size, and shape of each species; the characteristics of its embryonic development; its diet, habitat and behavioral 'personality'—one gains an understanding of what it means to say of the animal kingdom, as Oken did, that it represents "man dismembered." Indeed, using this threefold concept as a key or cipher, Schad sheds extraordinary light upon what has hitherto remained, despite all our biological knowledge, a bewildering array of mammalian forms.

Inevitably much of the material presented in Wolfgang Schad's courageous study will come as a surprise to many scientists. But any nature lover who allows it to stimulate his own observation will find his eyes opening to new wonders. Through it he will learn to see in the tangible form of living organisms the external expression, the finished result, as it were, of the intangible formative element, the living ideas, that underlie these forms.

John F. Gardner
Director, Waldorf Institute
Adelphi University
Garden City, New York

Preface

This book arose out of two activities. First, I have always found joy in observing mammals in the wild, just as I chanced to meet them, so that I might come to know them better and develop a sympathetic understanding for them in all their uniqueness. Second, I wanted to see if I could find in the mammals, the animals most closely related to man, the threefoldness Rudolf Steiner had discovered in man's organization. Eugen Kolisko, Hermann Poppelbaum, and Friedrich Kipp had already made beginnings in this direction, but it remained to apply the idea of threefoldness to a comprehensive study of the mammals as revealed in their form.

My primary method of studying mammalian form was always the attentive, sympathetic observation of the living animal in its own natural surroundings. Only after making such observations did I supplement my direct experience of these animals with existing factual information about their anatomy, physiology, and ecology. Because I proceeded in this way, it was necessary for me to limit my study primarily to the mammals of Europe, with the exception of the bats. As it happened, non-European ungulates received more attention than the profusion of rodent species found outside of Europe; yet my selection was not made subjectively, in an attempt to 'prove' the idea of threefoldness as some kind of preconceived schema. Rather, the reverse has been true: the animal forms themselves bring proof of threefoldness; it is a reality inherent within them.

In earlier times, men believed that the living world was made by God, its transcendent creator. Today it is customary to trace its existence back to the non-living world of matter, which is governed by immutable physical laws. Each of these conceptions may be valid up to a point. Yet both are insufficient for the study of life, since neither seeks to understand the living organism as a whole, but only those aspects of it which seem to support one or the other premise, divine or material. The threefold approach seeks to derive the living organism from nothing but itself. Such objective observation reveals an ordered diversity that always permits antagonistic opposites to exist within it. Moreover, this universal order requires balancing, mediating, regulating functions to exist, in which the opposites come together. Polarities and their active mediation are the fundamental processes that constitute every living organism. Threefoldness is therefore one of the universal signs of life.

In writing this book I have tried, insofar as possible, to make my material readily understandable to the general reader. Thus, the first three chapters are based primarily upon simple descriptions and deal with abstract philosophical questions only when this seems unavoidable. Chapters IV through IX set forth the diversity of mammalian forms, while Chapters X through XIV present an overview that is possible only in light of the detailed descriptions contained in the previous chapters. Each chapter builds upon the others, so that no single one forms an independent unit. Thus, the divisions marked by chapter headings are often only superficial. Chapter VI, for example, "The Ungulates," contains much that pertains to the rodents' form; Chapter VIII, "The Antlered Animals," a description of the carnivores' coloration; and Chapter IX, "The Giraffes," general discussions of both mammalian coloration and limb formation.

Many details of the present, American edition of this book have been revised. For example, the highly technical discussion of early embryonic development has been dropped from Chapter X, in order to make the entire chapter accessible to the general reader. Most of the illustrations have been improved, and some new drawings and photographs have been added.

I welcome ongoing criticism of this book. Of course, in order to judge fairly, one must entertain with an open mind all the arguments that are presented here, many of which are quite new. It may happen in time that one interpretation or another will need to be revised; nevertheless, I have endeavored to present only what I thought could stand the test of time.

I should like to thank John Gardner, president of the Waldorf Press, for publishing this book, Carroll Scherer for translating it, and Ulrich Winkler for making the new illustrations. They have made it possible for this book, first published by the Center for Educational Research, of the Association of Waldorf Schools in Germany, to become available to English-speaking readers.

Wolfgang Schad

Man and Mammals

I Method and Theme

If we observe the world of nature as it unfolds before our eyes, and at the same time study natural science with its abundance of information, we shall sooner or later, consciously or half-consciously, come to the following realization: Today the immediate observation of nature and the study of natural science have generally become separate activities.

Natural science started at the beginning of the modern age, when men established a closer contact with the visible and tangible world that surrounds them. The first scientists—such as Leonardo da Vinci, Harvey and Linnaeus—trained their powers of observation to that end; soon these powers of observation were enhanced by the microscope and telescope; today the field of observation includes the knowledge that electron microscopes and radiotelescopes supply. At the same time, ways of thinking were developed that reduced the meaningful content of thought to patterns and eventually to mathematical formulae, a kind of shorthand thinking that needs no imaginative picture. The scientist no longer uses his eyes to look directly at nature but views it only through instruments designed to increase his ability to see. He is less and less inclined to think about the abundant phenomena before him; instead he calculates correlations, probabilities, and approximations, in order to find out whether or not even considering a given object is worth his while. Instruments of observation intervene between man and the world of phenomena around him; computers have replaced his power of judgment. The advantages are obvious: in space, the area of the world that can be investigated has widened; in time, the results of investigation are quickly available.

What are the disadvantages? Those to whom specialized methods of observation and thinking are unavailable become less and less able to follow the thought processes that have led to the results attained by scientists. These results are relevant to most people only because they affect civilization, since they do not influence most people's conscious thinking. Thus the achievements of today's scientific investigation have been gained at the expense of an excessive degree of isolation from the understanding of the common man.

Strangely enough, today's specialist loses contact even with the object of his own research, with nature itself. The perfection of the crutches he uses for his senses and for his thinking has placed him in the position of no longer studying nature as such, but only that part of it which can be caught in the meshes of his instruments (Bünning). He does not pursue a science of nature in its own right, but attends only to what he isolates from it by his special methods. In this respect, the term 'natural science' has become a misnomer (Heisenberg)[1].

The theme of this book results from the above observation. Its purpose is to place in the absolute center of inquiry the direct perception of the animals most closely related to man, the mammals, just as they stand in their natural environment. We shall approach them with confidence that their very lives openly and plainly convey most of what is necessary for our understanding of them. As we recognize the unique quality of each animal form, it raises a question whose answer, like the meaningful word of an uncomprehended language, can be supplied only by the living form of the animal itself.

It is strange, yet indicative of the developments mentioned above, that science has taken little interest in the manifest shape of the living animal. We know a great deal about genetic factors, basic physiological processes, predictable instinctive reactions, and the group behavior of animals. But no one can tell us why well-known animals like cattle, deer, and rhinoceroses have head protuberances, while horses, donkeys, and tapirs do not. Neither molecular biology nor behavioral research pays sufficient attention to the significance of an animal's shape. One view regards it as randomly acquired adaptions, while the other sees it as the product of environmental influences. But human consciousness will never rid itself of the suspicion that a living being's form expresses more than conventional scientific methods can discover. An animal is visibly material, but it is also living form, and it expresses soul faculties as well. How are these three things related to each other, and how does this relationship show itself in the bodily form? Such are the questions that arise whenever we observe animals.

We shall limit our discussion to the *living form,* which we ourselves must draw out from the multitude of its individual manifestations. In undertaking such a task, we owe it to ourselves to be clear about the nature of our method. This method is basic, for it determines the way we shall answer the question that underlies every biological study: *What is life?* Everyone knows what life is, in that he lives. Yet this unconscious proof of existence does not satisfy our desire to know. Many interpretations of life have been made, but they cannot replace the reader's own outlook and judgment. Of course, the same is true of the following effort.

Life is always formed. It is always a definite, present form, yet it also changes through the course of time. In general, we consider those phenomena to be alive to which we ascribe an *ordered* relationship with space and time, although we may not always comprehend fully what this relationship is. In a living being such a relationship is always a matter of the present moment. Ortega y Gasset once said, "*Life* means the same as *the present.*" There is no life that is not presence: in and of the present. In the lifeless world, we are dealing only with past and future. In inorganic matter, these qualities of time pass over from the one to the other by an infinitely small step, *i. e.,* by a nothing. In that we live and perceive the world of life, however, we know the present, and we experience, as it were, the presence of the present moment.

This peculiar relationship between life and time is the source of many of the difficulties biologists deal with. Most follow one of two trends of thought and arrive at either a causal-mechanistic or a teleological-finalistic explanation. The causal way of thinking observes the effect upon the present of causes that lie in the past. It considers a phenomenon to be merely the predetermined product of its past. The teleological way of thinking proceeds in the opposite manner. It regards a phenomenon as a transitional stage toward an expected future, a future that will provide the explanation of the present; an aim, a purpose that will be realized only in the future, is therefore the cause of the present phenomenon.

Neither explanation encompasses fully the complexity of a living organism, although both may lead to certain results. There are areas of science where these explanations can be applied to better effect. For example, laws that make it possible to deduce present effects from past causes make much of the inorganic world comprehensible. The causal method of thinking has been effective also in clarifying certain relationships in nature whose processes *are* based entirely upon past events. Teleological interpretations, on the other hand, are helpful where the future creates the conditions of the present, as is true of all basic psychological phenomena. Desires, yearnings, longings and cravings are always directed toward future conditions; their manifestations can be understood only when this future is taken into account. They are characterized precisely by being the preliminary stage of an expected future.

The dying *matter* that is always present in an organism can be explained causally; a teleological explanation should be used in so far as *psychological* processes take place. The manifestations of the organism's *life,* however, stand between its lifeless and its animated aspects; this fact becomes evident in the special relationship of life to time. Life is determined in the first instance neither by its past nor by its future, but by its own present. At every moment, it exists by the natural necessity of its present being. Today we try to imitate life in cybernetics; every feedback brings effects that become causes, bending time into cycles. Nevertheless, every mechanical pattern still operates in a causal way.

It is no less comprehensible to accept the conditions of life in the present than it is to explain the inorganic world on the basis of past causes, and psychological phenomena on the basis of an expected future. No one has ever felt it necessary to prove that most facts in physics are determined by their past. They simply are so[2].

In life, causes and effects take place simultaneously and complement one another. For this reason the organism always presents itself as a whole. Correlations, not causes or aims, determine the order of the life that forms a single whole, because life exists only as a continuing present.

The processes of life, therefore, cannot be understood by either causal or teleological ways of thinking; they must be discovered as an active connection existing necessarily among phenomena in the present. It follows from this basic discovery that in trying to understand an animal, we must take form as the main thing the animal can tell us about itself. For form is simply the way any living being reveals to us its present order in space. Yet this present order is only one aspect of its life, because life is also ordered in time. We can keep a stone in a box and it will not change for centuries unless external factors act upon it. A living animal, however, cannot be preserved unchanged. It has its own rhythm and course of development in time, never modified beyond a certain point by outer factors. So we must study not only the organism's order in space, but its order in time as well.

Strangely enough, our consciousness is accustomed to distinguishing between space and time, between a living being's shape and the course of its life. But in life itself space and time permeate one another: every living shape changes continually—and we can see this change if our observation is sufficiently accurate. Life in time does not simply unfold in irreversible stages but occurs in cycles, so that it becomes a surveyable tableau. Thus ontogeny and phylogeny, as ways in which a living being's 'shape in time' may be described, must complete the mere 'shape in space' dealt with by traditional morphology. In Chapters X and XIV this shape in time will be taken into account.

The natural world thus has many different relationships with time. These distinctions become quite evident when we examine our own scientific knowledge of reality: the chemo-physical world is determined by factors from the past, the animated world awaits the future and tries to attain it, while organic life conditions itself during every present moment.

Insofar as an animal has to do with these three ways of being, all three methods of science can be and have been applied to its study. Yet, the method we have just described, that of studying life as revealed in form, has often been omitted in favor of the other two. We shall therefore focus our attention upon this method and restrict our study of the mammals to their biology of form.

It is not our intention to oppose mechanical or psychological methods of mammology, but to supplement them with insights neither method has been able to provide. We shall not analyze mere details for their own sake, nor shall we attempt to reestablish a vitalism that loses touch with visible reality. It was Gebser who stated that the biology of form finds its place between mere mechanism and vitalism.

This biological method, which focuses upon the visible forms of life, is based on Goethe's way of observing nature. Though some of his procedures may be dated, Goethe's fundamental attitude in the matter of biological research is timeless. He did not measure nature by man, but said, rather, that "*man* must prove *worthy* of the products of nature." Mankind requires, for the study of life, a training that will lead not only to more exact observations and clearer concepts, but above all to the continuous interweaving of both. As the result of Goethe's pioneering effort, the direct observation of immediate phenomena takes its rightful place in human cognition.

The greatest achievement would be to understand that everything factual is already its own theory. Do not look beyond the phenomena; they are themselves the teaching (Goethe, 1829).

On a walk through the woods we meet a deer. We watch it leap across our path, run for a moment, then stop and observe us with large eyes, head thrown back, ears erect. Or we see it afar as it wanders over snow-covered meadows. Or perhaps we have only a glimpse of it through the window of a train, as it stands in the evening light at the edge of a forest. Although the deer is so much a part of its own environment, we feel an inner connection with it. This animal, with its experience of joy and fear, is closer to us than the tree beside it or the anonymous forest behind it.

Our relationship to birds and mammals is closer than to any other animals. Like men, birds and mammals maintain a constant body temperature. In flight birds overcome the other animals' heaviness and too-close connection with the earth. The delicate coloring of their feathers, the great diversity of their voices, their skillfully wrought nests, are prototypes of beauty and craftsmanship. Moreover, they can be observed freely, particularly during the day. Mammals are seen much less frequently; most of them become active only during the twilight hours or at night. They tend to hide; their coloring, compared with that of the birds, is simple and inconspicuous. In Europe their species number only one third as many as those of the birds. When we wander through fields and woods, we can always observe birds; mammals are rarely detected, though they also live all around us.

When we see the many species of mammals move laboriously, close to the ground over which the birds glide so easily in flight, or when we see them spend the greater part of their lives asleep under the roots of the same tree in whose branches these winged songsters lead a carefree and joyful life; when we compare the birds' varied, expressive song with the mostly uniform and often raucous call of the mammals, it may seem to us that the stage of the latter is less perfect than that of the birds.

In the visible world, however, the outwardly happier being is not always the more perfect one. The richest inner life is often hidden by outward poverty; the most active course of inner development, by the appearance of outward calm.

Thus in 1837 Gotthilf Schubert, a scientist well-known in his day, described the higher rank of the mammals. What shows itself in the outer appearance of birds is evident as inner activity in mammals. Although the bird's song is beautiful in rhythm and melody, its virtuosity seems relatively impersonal and almost stereotyped in form. The voice of the mammals, on the other hand, sounds awkward and raucous, but the emotion behind it is more evident and considerably more individualized. A painful urgency is expressed in the hungry bellow of a cow, the roar of a stag during rut, the sharp bark of an angry deer, the screech of a cat defending itself. The mammal's unpretentious appearance is merely a cover for the most active inner life experienced by the animal world. In the birds we observe an impersonal yet all the more enchanting receptiveness to the world that surrounds them; in the mammals, a strength of soul that separates itself from the environment and enjoys its inner life. Something of each lives in us and connects us with them.

The mammals are the animal kingdom's most highly developed group. Let us recall some characteristic qualities of their organic construction. They are the only animals whose skin has hair and sweat- and milk-glands. Milk represents a transition between the prenatal nourishment supplied by the mother's blood and the food the environment later on will provide. Milk leads harmoniously from the one form of sustenance to the other: though it stems from the maternal organism, the infant receives it from outside. It represents both an inner and an outer nourishment; yet, since such a differentiation cannot actually be made, we may also say that it is neither one. Rather it is a universal kind of food that simultaneously nourishes the body of the newborn and establishes harmony in his soul. Schmid reports, for instance, that the fawns of deer and chamois, after a terrifying experience, seek and find solace in suckling the milk offered by the mother; he speaks of 'comfort suckling.' Through suckling, a strong inner contact is maintained between mother and child, even after birth; and it is from this contact, after all, that the name of the entire mammal group is derived[3].

Not only the skin with its glands, but all other organs develop characteristic traits in the mammals. For instance:

Mammals grow two sets of teeth.

The auricles develop externally, the three auditory ossicles develop in the middle ear, the cochlea in the inner ear.

The lower jaw is formed by *one* pair of bones.

There are paired occipital condyles at the base of the skull.

The cecum is unpaired.

Bladder and rectum end separately[4].

The red blood corpuscles are not nucleated.

In almost all mammals, a special organ connecting the embryo with the mother's blood stream develops from the growing fetus during pregnancy. This is the placenta; its function is to provide nourishment for the growing embryo. It is absent only in the oviparous monotremes and in all of the marsupials except the bandicoots[5]. All other mammals are known as 'placental mammals.'

Zoologists noticed early that man shares these organic characteristics with the mammals. Goethe first established beyond doubt that the human and mammalian organisms belong to a common type. In 1784 he discovered the human premaxillary bone, when many zoologists were denying its existence in order to defend the idea that man has a unique bodily structure. Although some scientists had noticed this bone earlier, its existence was fully accepted only after Goethe's discovery (Schad, 1965). Since that time man has been classified as a mammal; in accordance with a suggestion Linnaeus made in 1758, man and the closely related apes were then placed as 'the first' (*i.e.*, the primates), at the head of the system.

The zoological position of man, however, has since been corrected. Besides man and the apes, monkeys and lemurs are also primates. Other closely related groups are the ungulates, carnivores and rodents. The only additional groups of mammals indigenous to Europe are the insectivores and the bats. In Europe the insectivores are represented by the shrews, moles and hedgehogs. Because of their many primitive characteristics, they are regarded as mammals in a very low state of development.

Anatomists and systematists have made a strange discovery. Small, squirrel-like animals with pointed noses have been found in Southeast Asia. These are the tree shrews. They were long considered insectivores, but closer examination has shown that their inner organization corresponds closely to that of the lowest primates, the lemurs. At first they were classified sometimes with the insectivores, sometimes with the lemurs, but today they are generally regarded as a transitional form between the two (Plate 106). Thus the primates and insectivores actually form a single related sequence. Today, however, the group once judged highest in evolution is classed, like the insectivores, as physically the least specialized (in this sense, the most primitive) of mammals. The position of the human organism in the sequence of nature thereby changes: it is no longer at the head, but much closer than had been assumed, to the root of the basic mammalian type.

Thus a systematic ordering calls attention also to such specific biological characteristics of man as his five-digited limb formation, his simple stomach and intestinal tract, his relatively unspecialized dentition, the shape of his head, in that it retains the embryonic stage. The relative simplicity of these features characterizing the human organism has often been noted and described[6]. Man has fewer one-sided specializations of the physical body than do most mammals. The science of man called 'anthroposophy' regards this absence of highly developed physical specialization as the necessary correlate of man's psycho-spiritual attributes, which so greatly surpass those of even the highest animals (Steiner, 1918 a).

In comparison with a human being, the rodents, carnivores and ungulates, who will be central to our presentation, are more highly developed physically. Their great specialization has led to remarkable physical achievements, far surpassing those of man. They have more sensitive sense organs, quicker reactions, greater mobility, better tools (the nails that have developed into claws and hooves, for example, or the hands that have become paddles for digging or swimming), and a more highly developed metabolism.

In the psychological realm, they have more reliable instincts. No animal possesses all forms of specialization, of course; each has a few, usually combined with the reduced functioning of other organs. Each animal is fully viable, however, since its specialized character is matched and supported by an equally specific environment.

It is understandable that man should have no such close instinctive connection with a particular environment. Thus even in prehistoric times the species man is found to have inhabited every continent—a distribution unusual among the higher forms of life. Man's independence of one-sided environments must be seen in correlation with his arrested bodily development. But even man's unspecialized organism is highly differentiated, and this fact provides us with an important clue. For the measured harmony that exists among the human body's several distinct organic systems shows us how unity and diversity come to form one whole. We shall find in the human organization the basic form that unites the extraordinary variety and diversity of all the mammals.

Rudolf Steiner's contribution to the approach to biology through the study of form was decisive. Although he devoted himself primarily to man's psycho-spiritual capacities, his interest in the natural sciences led him to the question of how man's transcendental and physical organizations are related. In 1917 (b) he published his discovery of the threefold form of the human organism and its significance for the connection between the living body and soul-spiritual nature of man. We shall take Steiner's concept of the threefold differentiation of man's physical organization as the basis for our discussion of the mammals[7].

The impact the threefold idea will have on the scientific comprehension of the entire realm of living nature cannot yet be fully foreseen. It has been most fruitful, so far, in anthroposophical medicine, pedagogy, curative pedagogy, pharmacology, and agriculture, being the basis of the considerable work already done in these fields (Kolisko, 1921; Grohmann, 1961). Though the many discoveries about the human organism to which the threefold idea has led have not yet received wide attention, the following presentation uses them to fill the need for a better understanding of the mammals.

II The Human Organism as Threefold

When we contemplate man's physical body, we must ask the question basic to every organism: Is it an autonomous system, independent of the environment, or is it essentially identical with environmental processes and laws? To what extent is it a 'closed' or an 'open' system—and if it is both, *how* can it be both at the same time?

When we observe the human organism directly, we see that it is organized into the trunk, the head, and the limbs. The head raises itself quite distinctly above the rest of the body, while the limbs are closely connected with the trunk. Rudolf Steiner classified man's physical organization, however, not only in terms of its visible components, but also according to its functional processes. The head rests upon the body. It has little mobility within itself and has solidified for the most part in the bony skull capsule. In contrast with the rest of the body, it is moved but little. Above the runner's flailing limbs and panting breast, his head quietly keeps the goal in view. In the head are gathered most of the sense organs: those of sight, hearing, balance, smell, and taste. Through these senses the organism opens itself fully to the surrounding world. The nervous system, too, connected as it is with the sense organs, has its center in the brain and is the means by which the organism can orient itself and find its way in the environment. Thus the head is the center of what we may call the nerve-sense system, through which the organism perceives and adjusts itself to the requirements of the surrounding world.

The limbs and the organs of the abdominal cavity, by contrast with the head, show a strong bodily activity that is expressed both in actual physical movement and in an intense, chemically active metabolism. The organs of the abdominal cavity change food, which at first is alien to the body, through such an 'active' chemical working that it is transformed into the body's own substance. Thus the main function of the metabolic organs is to maintain physiologically the organism's autonomy against the environment. The abdominal cavity, the body's largest, is also the least protected by bones; any hardenings in the soft organs it encloses (*e. g.*, gall stones, kidney stones, and bladder stones) are a sign of disease. This fact stands in contrast to conditions in the head, where, for example, crystalline formations in the pineal gland of the brain (brain sand) are considered normal. Though the skeleton comes again strongly into the picture in the construction of the limbs, the placement of the limb skeleton is obviously polaric to that of the cranial bones. While the latter form a shell directly beneath the skin and are part of the external skeleton that protects the soft organs within, the bones of the limbs have just the reverse character: arm and leg bones are part of the internal skeleton; they do not enclose but are surrounded by the softer parts. It is noteworthy that while nearly all the head bones have fused to form the rigid cranium, the limbs are equipped with many joints and their bones branch out into the multiplicity of the fingers and toes. These make possible the organism's independent movement in the environment. The metabolic-limb system, as we are considering it, includes also the organs of propagation.

Between the relatively immobile nerve-sense system and the highly active metabolic-limb system stand the organs of the chest region. Lungs and heart are characterized by their rhythmic pulsation. In both, contraction and expansion, tension and relaxation, alternate constantly. The poles of the organism, therefore, are also present in this region: but they do not simply stand next to one another in the middle; rather, they reach an active balance through their rhythmical alternation in time. Thus we may speak of this system of respiration and circulation as the rhythmic system, or simply the middle system.

It is typical of this system that the polaric tendencies within it are in no way reduced to a passive neutrality; on the contrary, their dual character becomes part of an actively mediating process. The two sides of the organism mutually complete one another in the process of *rhythmic* alternation. Hence we find not one main organ in the chest area, but two: the lungs and the heart. The lungs, within this middle system's rhythmic activity, tend to resemble and represent the upper processes of the body. Through the trachea, for example, open at its upper end, the lungs approach the head region in such a way as to establish a direct connection with the outside world. In shape, the lungs merely fill up the free area of the chest, almost as if they had been poured into it from outside. Their head-like passivity appears also in the fact that they are incapable of self-initiated motion, being moved by the thorax and diaphragm. Since the lungs share something of the head's tendency toward stasis, their rhythm of breathing proceeds much more slowly than the pulsation of the heart: 18 breaths a minute, on the average, compared with 72 heartbeats.

The heart, on the other hand, exhibits traits that remind us of the region polaric to the head. Its position is lower in the chest space than that of the lungs. It is a self-moving organ that has a shape of its own. As from a center, the heart unifies the blood circulation, which is closed off from the outside world. The largest of the arteries originating in the heart, the aorta, turns down towards the lower part of the body, where there exists a direct connection of blood with the processes of metabolism. Only through the circulation of the blood do the lungs have access to the upbuilding processes of metabolism within the organism, while on the other hand only through the lungs does the blood have contact with the outer atmosphere. The actual balance is accomplished primarily through the harmonious mutual complementation of breathing and heartbeat in the time ratio of 1:4 (Hildebrandt). *Out of this reciprocal relation between the lungs and the heart, the middle system builds itself.*

The thorax itself is shaped by polarically opposite forces that come to light in the spatially alternating sequence of ossifying and dissolving processes—that is, of ribs and intercostal space. The temporal rhythm of the middle system here passes over into a spatial shape whose gradual modification shows that rhythm in life is never a simple repetition of the same impulse but an alternation between two opposing ones. The rib cage shows the modifications we might expect, in that it is narrowest near the head, as well as more ossified (Plate 95). On the other hand, as the ribs descend towards the metabolic region, they progressively fall short of encircling the trunk: they become gradually shorter and straighter, until the last two pairs 'float' freely and point downward. The sternum extends only part way down the chest cavity and appears to dissolve in the xiphoid process. The manubrium, or superior part of the sternum, is, as we might expect, the most highly ossified of the three sections.

When we observe that the thorax in its upper part has only limited ability to move, while in its lower section mobility is much more pronounced, especially because of the action of the powerful diaphragm muscle, we once again see how both the shape and function of the thorax mediate between the head organization on the one side, and the metabolic-limb organization on the other.

An understanding of the threefold form of the human organism demands that the three systems not be pictured as parallel, separate organizations, working one beside the other. For this idea is no mere schematic notion. Rather, like every genuine idea, it is an actual process, and thought must actively experience it as such[8]. It is therefore not easy for simplistic thinking to find its way into this idea. Rudolf Steiner himself called attention to the living interpenetration and interaction of the three systems in his book *Von Seelenrätseln* (Riddles of the Soul) (1917 b):

> It is of utmost importance to see clearly the relationship between the function of the nerves, the breathing rhythm, and the activity of the metabolism. These three forms of activity do not lie *beside* one another but *in* one another. They permeate and pass over into one another.

Nerve-sense processes, though centered in the head, are found throughout the entire organism. Similarly, though rhythmic processes are to be observed everywhere in the organism, they have their center in the region of the chest. Metabolic processes also take place in every part of the body, but they predominate in the limbs and in the organs of the abdominal cavity. These facts should not be confusing. On the contrary, the more we discover of threefoldness in the processes of every system, organ, and tissue, and even of cellular construction, the more we find that the great complexity of the organism is made understandable only by a point of view capable of bringing order into the diversity it must necessarily take into account.

The head is clearly dominated by nerve and sense functions, yet in the mouth region functions of the metabolism and limbs are also found. Just here, in the lower jaw, the bones of the head become moveable: covered with muscles, they even take on the character of the limb skeleton! We encounter the first organs of the digestion in the mouth: in the saliva are digestive enzymes, and the mouth's mucous membrane is able to absorb sugar and transmit it directly to the blood. In the mouth, indeed, the otherwise inward metabolic organization establishes direct contact with the outside world.

A rhythmic system is also present in the head, particularly in its air-filled cavities. These are found in the middle section of the cranium, between the sensory area of the face and the brain itself. They include possibly the larynx and certainly the cavities of the throat and nose, as well as the more ossified air-filled cavities in the upper jaw, middle ear, and frontal and sphenoid bones. Here, in a delicate way, the head's own respiration takes place. When the lungs exhale, air is pressed into the head's cavities; when the lungs inhale, the cavities of the head exhale (Schmücker). These cavities are lined with a moist inner layer that also absorbs air. So the middle region of the head also takes part in the breathing process and participates in its own way in the rhythmic functions. Although it is the larynx that uses the air of exhalation to produce sounds, these are magnified into speech and song in the area of throat, mouth, and nose, whereby the air-filled cavities of the head serve as resonance chambers. Thus speech is actually created in the middle region of the head, between the nerve center of the brain and the sense area of the face.

Turning now to the opposite pole of the body, we observe how in the metabolic organs of the abdominal cavity the organism expresses most strongly, in a purely biological way, its estrangement from the surrounding world. Through digestion, as centered in this region and as carried over into the blood, the organism transmutes foreign matter into its own substance, nourishes its various organs, and establishes an individual protein autonomy that shows itself as 'immune' reactions.

The limbs, as we have mentioned, however closely they are connected functionally with the metabolic organization, still form a certain contrast to it. In them, the activity of the lower organism turns again towards the environment, in an active, creative way. Thus the skeleton, although polaric in form to the shape of the skull, in that it is rod-like and buried under flesh rather than plate-like and lying on the surface, nevertheless comes again to the fore.

While on the one hand digestion internally prepares the body's own substance, and the limbs, by contrast, produce changes in the outside world, the system of propagation lies between these two. In it, through a genuine metabolism, new living substance will be formed—substance that in this case does not accrue to the parent organism but will be delivered over to the outer world, without itself becoming outer world, since it will carry within itself its own inwardness. The growing organism, of course, arises only in part from maternal substance; for the rest it derives from the father. What might be called the 'foreign' substance of the sperm is neither destroyed, as in real digestion, nor yet rejected through immune reactions: sperm and ovum complete one another, to form a single whole. So the reproductive system, just because of its intermediate character within the lower organization, has a dual, male and female, form. In both shape and function, the ovaries and uterus have more the character of metabolism; the male genital organs, that of the limbs. In male animals the limbs' influence on the sex organs frequently leads even to the formation of bone *(os priapi)*.

The three main systems of the complete organism form such a perfectly organized unity because each system in turn also has a tripartite form. In each part the character of the whole is present, so that each shares functionally in the whole. This threefold organization may be characterized as 'order in diversity.' Rudolf Steiner himself avoided conceptual rigidity by giving each system a double name:

Nerve-sense system
Respiratory-circulatory system
Metabolic-limb system.

Thus the active polarities that exist *within* each of the larger systems are already indicated by Steiner's choice of words.

On the basis of the foregoing discussion, we may supplement Steiner's grouping as follows:

Nerve, speech and sense system
Respiratory-circulatory system
Metabolic, reproductive and limb system.

The upper and lower systems show their own threefoldness quite distinctly, while the middle system does not. This fact deserves our attention. No additional mediating organ or function is necessary between the respiration of air and the circulation of blood, because it is in the rhythmic *interaction* between the two that the rhythmic system is actually created. Hildebrandt recently studied this relationship between breathing and heartbeat and found that it varies greatly with every physical movement and psychic reaction. On the other hand it always tends toward a healthy norm of 1:4, as may be observed in normal deep sleep, during which the body recovers from the exertions of the day, or in convalescence from an illness. Since it is able both to adapt itself to stress and to recover a normal state of equilibrium, this interaction really forms the basis of the entire organism's health. There is no need for a third organ because both the lungs and heart, as the mediating organs of the body, also have the ability to establish harmony between themselves.

In a slightly different way these organs also mediate between the central functions of the upper and lower systems. Thus, respiration is closely connected with the speech organization, and circulation with the function of propagation. And the duality characteristic of the middle system is also found in the organs of these other systems. Thus, as we have mentioned, while the larynx produces the actual sounds of speech, it is in the air-filled cavities of the head—particularly in the mouth, with its palate, tongue, teeth and lips—that these sounds become speech. Similarly, propagation takes place by means of two different processes: the begetting of the germ and the actual pregnancy, through which a new organism is created. The former is a masculine function, the latter, a feminine one. Thus, there must be two sexes rather than one or three. This duality of all middle systems is so basic that we may state the following rule: *If we find a threefold structure in an organism, the polarities within it are real ones; if we find only dualities, the two work together and constitute a middle system.*

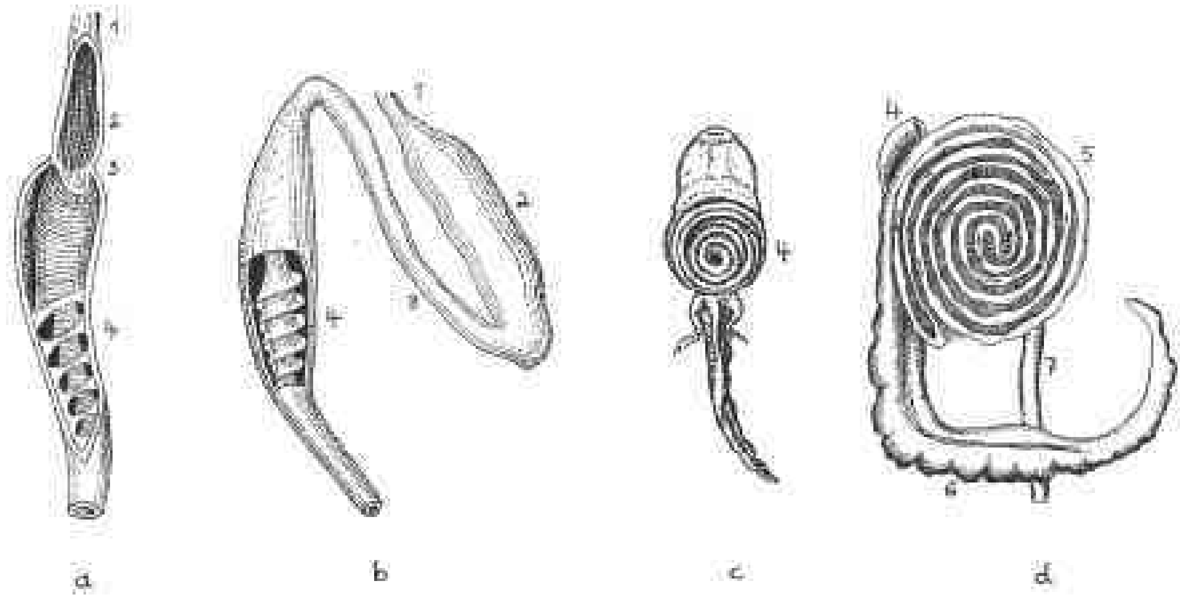
The heart is not a heart because the polarity of arterial and venous blood is neutralized within it, but because the two kinds of blood come together here in greater quantities than anywhere else in the body—and they do so without being mixed.

If, initially, we have designated the whole upper system as being directed outward towards the world, and the lower system, by contrast, as being self-enclosed, with the rhythmic system mediating between the two, this relationship is an essential characteristic of threefoldness in the bodily organism as a whole. Yet, as we have also seen, this overall pattern can be followed into the parts and functions of the whole. The organism makes its contact with the outer world in three quite different ways: primarily via the sense organs but also through breathing and limb activity. Similarly, it establishes its private existence, its independence of the environment, chiefly through the digestive processes, but also in two other ways: through the closed circulation of the blood and the wholly encapsulated nerve center. The speech organization, as we have said, is strongly related to breathing; reproduction, to the circulatory system. In the harmony of breath with heartbeat, the wholeness of the organism establishes itself ever anew, and yet at the same time makes possible the body's many-sided diversity.

The human organism, then, is as much a member of the surrounding world as it is an independent world of its own; and in its mediation between the two kinds of existence, self and world, it forms a living counterbalance against the extremes of either. It always gives the lie to any one-sided explanation of its reality.

The threefold organization in human beings provides a reliable basis for the whole biology of form. Primarily, physical form is the way in which space is taken up and filled. How then are the three organic systems related to space? By no means uniformly. The *outer* shape of the human body is bilaterally symmetrical in appearance; the right half is the mirror image of the left, and vice versa. This bilateral symmetry applies particularly to the sensory system, which is concentrated in the head but also extends to the skin covering the body. We may indeed regard it as the formative principle of the system that is open to the outside world. This symmetry can most accurately be described in the triaxial system of coordinates, because the organism itself, in its arrangement of these organs, distinguishes between right and left, above and below, before and behind.

The organs of metabolism, on the other hand, are invisible from the outside and they orient themselves quite differently in space. Both in their individual shapes and in their positions in relation to the body's axis of symmetry, these organs show definite asymmetries. Liver, gall bladder and cecum, for instance, lie to the right; stomach and spleen, to the left. This asymmetry is generally characteristic of the way in which the nourishing organs of metabolism fill space. Even these asymmetrical organs, however, originate, during the embryonic stage of development, as bilaterally symmetrical forms. Apparently the embryo is at first an organism entirely open to its surroundings. Then, after about the seventh week, the asymmetry of the digestive tract begins in the form of a spiral twist (Starck, 1955) that persists in the curves and loops of the colon. Many vertebrates show intensified spiral forms in the formation of the intestinal tract. This is the case in sharks,



1. The spiralization of the intestine, which in man occurs only as a simple twist of the colon, can be seen very well in various animals: a) primitive fish *(Polypterus)*, b) the spotted dog fish, a small shark *(Scyllium)*, c) tadpole of the frog *(Rana)*, d) the sifaca, a lemur of Madagascar.
1. esophagus, 2. stomach, 3. pylorus, 4. small intestine, 5. colon, 6. cecum, 7. rectum.

tadpoles, and even lemurs among the primates. In other animals and in man asymmetry increases during the course of the organism's growth, so that the small intestine in particular (ileum and jejunum) forms many convolutions. Other asymmetrical organs, such as the liver, gall bladder and pancreas, develop from the upper part of the primitive gut, which itself undergoes further development to become the duodenum. In a living organism, spiral forms always indicate the transition to total asymmetry.

In the inner ear three-dimensional and spiral forms approach each other. In the utricle three semicircular canals are placed at right angles to each other; here the organism indicates quite clearly that it knows three-dimensional space. In the cochlea, however, it shows that it is also familiar with spiral space. The one organ helps us to find direction in the outer world, while the other allows us to take part in the more inward, emotionally affecting world of sound, music and speech. This direct juxtaposition of the two polaric forms within the ear is unique in the whole body (Schad, 1969 b). Yet, since the ears are sense organs, open to the world, their placement on the body occurs bilaterally.

Inside the head, the brain itself is quite separate from the direct influence of the outer world. Sheltered within the most completely ossified cavity of the body, it floats weightlessly in its own fluid, biochemically isolated from the rest of the body by the blood-brain barrier. The brain, like the organs of metabolism, is closed off from the outer world. Is it therefore asymmetrical in form? There is much evidence to indicate that it is, both in shape and in function. For despite the fact that during embryonic development the initial convolutions of the brain are formed symmetrically at certain regions, the second and third generations of convolutions, which develop just before and soon after birth, become increasingly asymmetrical. (Observations of uniovular twins have shown that inheritance largely determines the frequency of convolutions, while it does not seem to govern their asymmetrical form [Geyer].)

Functionally, the left hemisphere of the brain appears to be connected with the right side of the body, and vice versa. The tendency toward right- or left-handedness, for example, is dictated by the asymmetry of the brain. In right-handed persons the left side of the brain is dominant, and the reverse holds true in the opposite case. Modern brain research has also discovered that in right-handed persons the left cerebrum underlies intellectual, rational, and verbal abilities, while the right half mediates the imaginative, musical, artistic and intuitive capacities. Thus, to a much greater extent than the sense organs, open to the outside world, the brain tends toward asymmetry. This asymmetry of the brain is so basic that morphological and functional equality of the two sides can even lead to verbal and mental disorders (Rauber-Kopsch, Delacato).

As we have mentioned, the body's asymmetry reaches its culmination in the metabolic system's digestive organs. But the limbs, so closely allied to this system of metabolism, nevertheless become bilaterally symmetrical in turning to the outer world!

It would be instructive to trace this relationship between living function and spatial shape into all aspects of the human form. Yet here we must restrict ourselves to the consideration of a few additional examples. These may at first appear to be exceptions to our basic rule, but close observation reveals that they, too, are consistent with our findings. The kidneys, for example, are found in the abdomen; yet they are paired. Strictly speaking, however, they are not true abdominal organs, since they lie outside the abdominal cavity proper, behind the peritoneum. In addition, they are related functionally to the dissimilatory processes of the nerve-sense system, in that they work increasingly in states of excitement, and do not work at all during deep sleep. The organs of propagation function in a bilaterally symmetrical way in coition, but the processes of ovulation, conception, and implantation, as well as the physical position of the embryo within its sheaths —far below consciousness—occur asymmetrically within the mother's body.

What spatial forms do we find in the central, rhythmic organs, the lungs and heart? We speak of a left and right lung, a left and right ventricle of the heart. The two organs are not altogether bilaterally symmetrical; yet at the same time, they cannot be characterized as entirely asymmetrical. Instead, they form a remarkable intermediate stage between the two forms of space. During embryonic development the heart and lungs are at first bilaterally symmetrical. The heart originates in the fusion of two parallel vessels; the partition between the two disappears, and the tubular heart then forms bulges that arrange themselves asymmetrically, over, under and beside one another. After a complicated series of fusions and divisions, the heart eventually metamorphoses into a shape that is once again more or less symmetrical: the four-chambered heart with its left and right auricles and ventricles. The two sides of the heart are separated by the slightly twisted septum that, precisely because it is twisted, describes a medial plane that does not divide quite symmetrically. The left side of the heart has thicker muscles than the right, and these run spirally down towards the heart's apex, where they form a regular whorl. The heart lies more or less in the center of the body; yet, again, not exactly in the center; rather, displaced somewhat to the left. The apex of the heart points down towards the left and front, and the base, correspondingly, points up towards the right and back; so the heart's axis of symmetry in relation to the outer shape of the body is slightly askew. What a remarkably intermediate kind of 'symmetry'!

The lungs originate as an unpaired outgrowth of the esophageal rudiment. This outgrowth divides into the paired bronchi, out of which develop the slightly asymmetrical lobes—two on the left and three on the right. These lobes finally take up the available space in the chest cavity as symmetrically as the heart permits. So the lungs are bilaterally symmetrical externally, where they touch the inner walls of the chest; on the other hand, near the central limits of the chest cavity (the mediastinum), in the vicinity of the heart, they are clearly asymmetrical. In the trachea, open at its upper end, the respiratory tract is entirely symmetrical, while the aorta, leaving the heart, turns downward and to the left in a definitely asymmetrical figure. Together, heart and lungs fill space in such a remarkably differentiated way that they perfectly combine symmetrical and asymmetrical formations.

It is curious how little the connection between life-functions and symmetry of form has been noticed up to now. In the anthroposophical literature there are hints, in connection with the concept of threefoldness, to be found in König (1927-28) and Paede (1948). Portmann has described an important connection in the lower animals, between symmetrical form and perviousness to light: transparent, and therefore sense-active, organs are always formed symmetrically, while metabolic organs and gonads, even in extremely transparent animals (such as jellyfish and salps), are always protected from the light by an opaque sheath, and are therefore active only in darkness. Asymmetrical organs are always shielded from the light[9].

Clearly, the living functions of an organ cannot play themselves out in space arbitrarily. The organism works not only in the three-dimensional space we usually recognize, but in three distinct conditions of space of which the three-dimensional is only one. Our waking day-consciousness is founded upon the symmetrical nerve-sense system; thus it is no wonder that we have an especially clear conception of this one kind of space. We must, however, consider the reality of space to be more manifold. Space is not the abstraction of an empty vessel that contains the world, nor even a subjective way of viewing things. It is a phenomenon of the natural world that mathematicians from Rieman to Weyl and physicists since Faraday and Maxwell have been investigating. These scientists perceive that space is more than what we have in mind when we speak of the three dimensions and their rectangular axes. Many mathematicians have felt it necessary to conceive of other possibilities of space, and physicists, too, admit that space can be explored not only through thought but also by means of experimental investigation and observation. So in the field theory of Faraday, space includes physical energy in magnetic, electric, and gravitational fields without corpuscular transfer (Westphal). At this point we must dare to presume that in the realm of biology, too, space must be treated as an empirical subject whose manifold possibilities cannot be predicted in the way that earlier philosophers, such as Kant, have tried to do. Our preliminary attempt to understand space is founded upon our assumption that it can be deciphered in its full reality only from the living organism.

As we have mentioned, most of us prefer the idea of rectangular space because our clarity of consciousness is dependent upon those organs in the human body that are symmetrically arranged. Steiner (1919) mentioned a similar connection when he said that our geometry arises out of the unconscious movements that the human body makes with its limbs in space.

But when we observe the various ways in which space is taken up by our organs, we must assume that the whole reality of space can be explored only if we develop our consciousness to penetrate or encompass those processes of life that are hidden from our present understanding. And because it is in the unconsciousness of our asymmetrical, metabolic organs that the processes of life are most active, it seems only reasonable to assume that the mystery of life as a whole cannot be understood within the boundaries of Euclidean geometry. The biology of form must pave the way for a deeper understanding of space, and this it does by establishing an empirical basis for its further study. We must study *the way life organizes itself in space.* And it is just the idea of threefoldness that gives us the possibility of feeling our way into this question of the diverse relationships of life to space.

Steiner's discovery of the threefoldness of man is not limited solely to the physical organism, however. We may use this idea equally well to describe the connection between a living organism and its own psychological, or soul, faculties. Here we differ from conventional scientific opinion, which ascribes all psychological activity to the brain. The physical correlate of man's thinking is, of course, the brain. And it is also true that the brain registers and monitors man's other psychological activities. But according to Rudolf Steiner's view, the entire body, with all its organic systems, is the instrument of the soul; and its diversity of biological processes supports a corresponding diversity of soul activity.

When something is mentally represented, a neural process takes place, on the basis of which the psyche becomes conscious of its representation; when something is felt, a modification is effected in the breathing-rhythm, through which a feeling comes to life; and in the same way, when something is willed, a metabolic process occurs that is the somatic foundation for what the psyche experiences as willing. It should be noted, however, that it is only in the first case (representation mediated by the nervous system) that the experience is a fully conscious, waking experience. What is mediated through the breathing-rhythm (including in this category everything in the nature of feelings, affects, passions and the like) subsists in normal consciousness with the force only of representations that are dreamed. Willing, with its metabolic *succedaneum,* is experienced in turn only with that third degree of consciousness, totally dulled, which also persists in sleep (Steiner, 1917 b).

Although such a description runs counter to current scientific opinion, it has long been understood by traditional wisdom. The heart has always been recognized as the realm of man's feelings, and it is certainly no accident that willful, aggressive courage is often called 'intestinal fortitude,' or, less delicately, 'guts.'

It may be no surprise to us that the head, relatively immobile, impassive, rigid and bony, is the physical correlate of the cold clarity of man's unimpassioned thought. Yet it should be no more surprising that the urgent impulses of the will, rising out of the darkness of our unconscious, should be associated with the warmth and unconsciously creative activity of the viscera and limbs. And between these two areas—the rigid, immovable cranium and the active, life-supporting metabolism and limbs—lies the chest, which mediates between them and participates in the activities of both. In this rhythmic activity of the chest, the feelings find their physical correlate. Here, too, tradition has been wise, in describing the heart as the seat of man's emotional life. We need only recall the differences in heartbeat and rate of respiration caused by our experience of fear, grief, joy, or passion to understand that this is so.

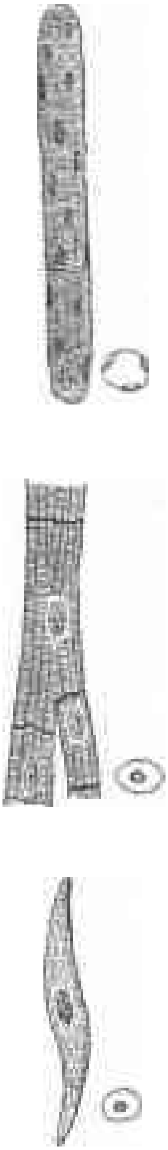
In this application, too, the idea of threefoldness may at first be difficult to comprehend. But we hope that its wisdom will prove revealing and be substantially supported in the chapters that follow.

In closing, we shall cast a glance at the threefold structure and function as these appear in the musculature of the human body. We perform consciously influenced movements only with those muscles that are attached to the skeleton or at least to cartilage (for example, the muscles in the larynx). Each such muscle extends *axially* between two points of contact where it is firmly attached. If the muscle contracts, the two parts of the skeleton are moved towards one another. One of the first microscopists, Anton van Leeuwenhoek, found as early as the seventeenth century that the fibers of such voluntary or skeletal muscles, under strong magnification, show striations.

Diametrically opposed to this skeletal musculature is the intestinal or involuntary musculature. Here there is no striation; the muscles are 'smooth.' These muscles never have contact with a bone; their fibers return *spirally* upon themselves. Frequently these are circular muscles such as those that surround the stomach, intestines, gall bladder and uterus. These muscles do not move parts that lie outside themselves but rather the fluid or plastic contents enclosed within them. Remote from waking consciousness, these smooth muscles work as it were in a condition of deep sleep.

The lungs, as we might expect, are moved by *both* of these polaric types of muscle. The muscles of the chest and diaphragm are striated, and can also be set in motion deliberately. In the inside of the lungs, however, there are in the bronchioles circular smooth muscles, less subject to conscious influence, that are able to regulate the flow of air into the alveoli where the exchange of gases takes place. (Every asthmatic person knows that it is impossible to control the spasms of these muscles.)

The muscles of the heart cannot be associated solely with either of the polaric types. In overlapping spirals, they surround the heart and form a regular whorl at its apex; above, at the base of the heart, they become less moveable, more sinewy at the cardiac valve, and, indeed, in some animals, such as cattle, they may even be attached to a heart bone (Vaerst). The heart muscles are delicately striated; yet they are not genuine skeletal muscles, because in their structure they have much in common with the smooth



2. *From the top down,* fibers of skeletal, cardiac, and involuntary muscles of man, shown lengthwise and in cross section.

muscles. Like these, they are uninuclear, if indeed in a characteristically different way[10]. Even in microscopic detail they show how it is precisely in the heart that the organism realizes a musculature that is intermediate between the consciously moved skeletal muscles and the intestinal muscles that work in deep unconsciousness. Speaking psychologically, we may say that in the heart we are neither conscious nor unconscious: we dream. Thus, in this case as well as in those we have earlier considered, *soul capacities, life-function and physical form correspond to each other*. A mere contrivance for the transportation of blood could as easily be symmetrical as completely asymmetrical. Yet the very shape and structure of the heart reveals that this organ does not exist merely to move the blood; in it all the polarities of the body are brought together and balanced on a higher level of form and achievement.

III Threefoldness in Mammals

Man's organic systems are found also in the mammals, yet they relate to one another in very different ways. Among the mammals, in the most varied ways, one or another system is especially well developed. Thus high degrees of specialization have been attained, so that in agreement with the views of modern zoology, we may consider many of these animals to be physically more highly developed than man. The rodents, carnivores and ungulates, in particular, rank above the insectivores, primates and man. Their superabundant variety of form seems to defy any attempt to group them in an ordered system. Yet the order inherent within each organism may itself supply the key to order among them. This inherent order enables us to discover in diversity an underlying unity that in no way contradicts the abundant variety of nature.

When we start from the concept of the threefold human being, we find that the mammals demonstrate what great differences are possible in the relationships among the three main organic systems. The cow, with its highly developed digestive processes, and its hoofed anterior and posterior limbs adapted primarily to a single purpose, brings one of these organic systems into strong relief. Its whole organization is determined by the special qualities of the metabolic-limb system, and this emphasis is characteristic of all ungulates. Mice, in their nervous sensitivity, show the greatest possible contrast to the bovine nature. Their extremely delicate sense organs so dominate the other organic systems that we may call the mice and all other rodents nerve-sense animals. It is more difficult to generalize about the carnivores, such as cats, dogs, and lions, but we hope that the following will make it clear that these animals live primarily out of the processes of respiration and blood-circulation[11].

Rodents	*Carnivores*	*Ungulates*
Nerve-sense functions predominate	Rhythmic functions predominate	Metabolic-limb functions predominate

What is brought to near perfection in the one-sided developments of the mammals yields in man to a delicate balance that is seen in the mammals only when they are taken together as a whole. Only in an undisturbed landscape, when in biological equilibrium with one another, do the mammals show the balanced relationship that appears in the single human body.

The anatomy of the hoofed animals shows a considerable hypertrophy of the limbs. In contrast with the penta-digital type of limbs developed by most mammals, the ungulates' hands and feet have retrogressed to a few bones; the latter, however, are very strongly formed. This specialization of the limbs extends even to the powerful enlargement of the nail into a hoof, which gives the group its name. The limbs of horses and cattle support large bodies, full of power, and in stamping and galloping, these animals live out in a physical way the powerful soul forces within them.

Polaric to the limbs of the ungulates are those of the rodents. Tiny and delicate, they hardly deviate from the original five-fingered form. The fingers and toes are narrow and long, with nails shaped like tiny claws. The forepaws of the squirrel, for example, are adept at grasping, handling, and feeling. Its limbs have definitely acquired a sensory function. Long sensory hairs on the face, and shorter ones over the entire surface of the body, project beyond the warmth-providing coat and enable the rodent, trembling and twitching, to find its way in the surrounding world. In many rodents even the inside of the cheek in the mouth cavity is covered with hair. Agile and quick in its reactions, a rodent lives in constant agitation, alarmed pauses, and rapid flight. Even in sleep nervous spasms run over its small body. Rodents must sleep often, for in all animals it is always the nerve-sense system that in the waking state so exhausts physiological functioning that this can be restored only in the unconsciousness of sleep. The organs of nutrition, which function outside consciousness, are indeed never awake, and it is for this very reason that they are able to continue working day and night. Thus the rodent in particular, so active in its senses, requires periods of rest even during the day, when it sleeps for short intervals in order to be wakeful again.

Hoofed animals, on the other hand, require little deep sleep. One or two hours, sometimes less, suffice for horses and cows, elephants and giraffes (Grzimek, 1956). In these metabolic animals the processes that build up the body predominate even during the waking state, so that these animals tire much less readily than the rodents do. Contented peace and restfulness suffuse the cow's placid gaze, especially when, ruminating for hours, she devotes herself entirely to her food. Her eyes, and the eyes of all ruminants, lack the yellow spot *(macula lutea),* the part of the retina with clearest sight. To them, the world appears diffused. They experience much more fully smell and taste, the senses connected with metabolism. A cow is never so completely awake as a mouse; the unconscious processes of digestion predominate even in its state of half-wakefulness.

The digestive tract of these animals is highly developed, especially in their most characteristic group, the ruminants. A large, four-part stomach completely fills the anterior abdominal cavity. The intestines are extremely long: 22 times the length of the body, or about 200 feet (60 meters). The principal nutritive substance of the grass, herbs, leaves, straw and twigs eaten by the ungulates is cellulose, a food rather poor in nourishment, and extremely difficult to digest. Twice it is thoroughly chewed, mixed with saliva, and fermented. Only with the help of the micro-organisms that flourish in the stomach, do the ruminants manage to assimilate a food so difficult to digest and to build from it such extraordinarily powerful bodies. They even have a surplus of nourishing substances left over for others. From time immemorial, the ruminants have been able to serve as a source of nourishment for man: cows, goats, sheep, reindeer and camels have supplied milk since prehistoric times. Even their dung deserves mention as an especially valuable fertilizer for the plant world.

The typical rodent prefers nourishing food rich in energy. It likes especially the concentrated fats and oils of nuts and seeds, as well as kernels rich in carbohydrates. Fruit it likes less, and it will accept plant stuff composed chiefly of cellulose only when nothing else can be found. Among the extremely sensitive rodents, the physiological capacity of the metabolism is so weak that it requires easily digestible, energy-rich food—food of a kind that meets the metabolism halfway and readily supports it. Nutritive substances are vigorously and hastily extracted from the contents of the intestines; the desiccated, impoverished droppings that remain form hard, tiny pellets that provide almost no manure for the plant world.

While the ungulates' food consists mainly of cellulose, and the rodents prefer food especially rich in energy, the carnivores take into themselves the protein found in the meat and blood of their prey. This food, of course, also requires a powerful digestive activity, but it lies much closer to the carnivores' own bodily substance than does the cellulose that nourishes the ungulates. The three groups, therefore, may be summarized as follows (the important role of exceptions will be discussed later):

Rodents	*Carnivores*	*Ungulates*
Nourishing food rich in energy	Foods similar to the body's own substance	Foods difficult to assimilate
Fats, oils, starch	Protein	Cellulose

There is an inverse relationship between the quality of the food ingested and the bodily size of the animal eating it: in mice, rich, nourishing food produces a body that contains almost no fat deposits for use as energy reserves. The opposite is true of the ungulates; they take in relatively poor food and yet develop from it substantial fatty deposits that are stored in subcutaneous tissue (producing ham in pigs), around the mesocolon, and around the kidney (producing beef suet in cattle). The ungulate gathers the substances taken over from the plant world and unconsciously works to enrich the energy they contain. While the nervous constitution characteristically breaks down substances, the metabolic one rebuilds and augments them. The nutritive processes of the carnivores represent an intermediate state. When a leopard devours a gazelle, a true change of substance does of course take place during digestion, but the change from one form of protein to another hardly alters the chemical energy level.

The formation of the teeth is of great importance for the biology of form. Let us first consider the human mouth. Its most tactile and sensitive part is the front: the surface of the lips and the tip of the tongue. Here, food is touched and examined, then bitten off with the incisors and taken in. Next, it is thoroughly chewed and tasted. The processes that follow become more and more unconscious and uncontrolled. The chewed and ensalivated food is moved back to the region of the posterior tongue and the soft palate, automatically bringing about the act of swallowing. The food then passes into the completely unconscious part of the physical organism. Thus the three parts of the oral cavity are arranged as follows: in the anterior part, the conscious nerve-sense pole is predominant; in the rhythmic chewing and tasting, the middle system prevails; in the unconscious throat area, the metabolic system predominates.

This threefold structure is expressed visually in the formation of the teeth. The incisors of man are thin and slender, with narrow cutting edges; the molars in the back are broad, with wide crowns and slightly curved grinding surfaces. In position and shape the canines, with their rounded yet pointed structure, take their place between the other two.

The following table shows the basic tripartite structure of the teeth:

Incisors	*Canines*	*Molars*
Nerve-sense oriented	Dominated by the middle system of breathing and circulation	Metabolic-limb oriented

The teeth are formed twice. First, the milk teeth develop; there are two incisors, one canine and two molars in both sides of each jaw, making a total of twenty teeth. At the time of the second dentition, the roots are dissolved and the crowns shed. The permanent set of teeth adds three molars in each section of the mouth in addition to the twenty teeth that are replaced, so that the adult comes to have thirty-two teeth. Because of their position, the replaced back teeth are called premolars and the newly formed ones, molars. Molars and premolars are very similar in shape.

Let us turn again to the animals. Kipp thoroughly studied the threefold aspect of the mammals' teeth (1952). The rodents, since they are primarily sense oriented animals, show a highly specialized development of the anterior incisors; they have two long gnawing teeth shaped like chisels in both the upper and lower jaws. Canines are lacking. We find very few molars in typical rodents (mice, rats, hamsters), and these are called molars since they have no precursors, for the milk teeth are skipped even in the embryonic stage.

In carnivores the canines are predominant and are often many times as long as the other teeth. The incisors are rather small, and those next to the canines are sometimes even shaped like them, as in the lion (Plate 105) and the fur seal (Plate 114). The molars, with their pointed crowns, also take on some of the characteristics of the canines; the largest of them is in fact called the laniary or 'tearing' tooth.

In ungulates, on the other hand, the molars are particularly well developed. With their varied, complicated formations of cusps and crescents, these teeth are both large and numerous in the posterior oral cavities of horses, rhinoceroses, pigs, hippopotami, camels, giraffes, deer, sheep, and cattle. The teeth of the ruminants are especially characteristic; in these the processes of the nerve-sense and rhythmic systems are so completely dominated by the forces of digestion that the cow's upper jaw has no incisors or canines at all! The incisors and canines of the lower jaw form a broad, shovel-like plate that cannot be used for biting, but only for tearing. The molars predominate. Thus the characteristic forms of mammals' teeth become understandable:

Rodents	*Carnivores*	*Ungulates*
Incisors accentuated	Canines accentuated	Molars accentuated

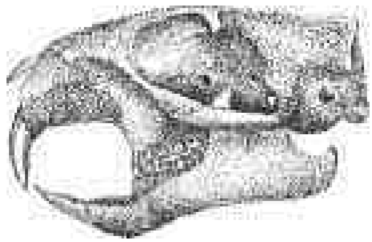
It is significant that all rodents and most ungulates lack canines, the intermediate tooth form. Between the incisors and molars of these animal groups there is a large gap (diastema) that is usually much larger than the space canines would occupy.

Naturally, the jaw's principal direction of motion in eating is vertical—a coming together of the upper and lower teeth. Yet in the rodents, the direction of the chewing motion is mainly forward and backward, while among the ungulates it is more lateral. Among the carnivores this motion is entirely vertical. The mandible joins the cranium correspondingly. G. H. Schubert remarked as early as 1850 that:

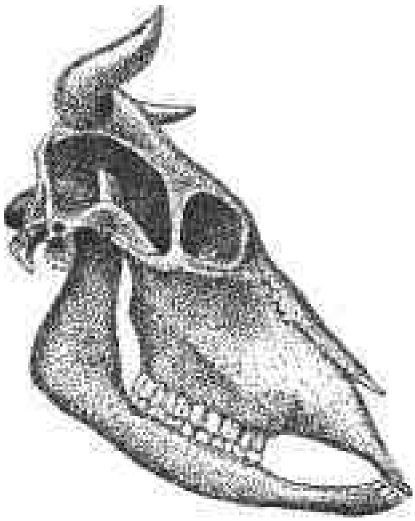
> Three main directions of moving the jaws against one another differentiate the carnivores, rodents and ungulates: the vertical, or up and down; the direction along the length of the head, forward and backward; and finally, laterally from side to side. They are all combined in man, who is almost equally capable of them all.

Turning again to man, we notice the special harmony of his dental structure. All tooth forms are present; no one form is predominant over or larger than the others; there are no gaps. Yet the teeth are not all alike. They are progressively modified in a sequence that is continuous, yet brings out a threefold differentiation. If one asks how the nerve-sense, rhythmic, and metabolic-limb systems are organized in relationship to one another in man, he will find a complete answer in the arrangement of the human teeth.

3. *From the top down,* dentition and skull formation of a rodent, carnivore, ungulate, and man (not drawn to scale).



Marmot



Cow

Lion

Man

Another phenomenon essential to the biology of form is the *size* a living organism builds up in space. This question touches upon a different side of the problem of space in the living world than that of the relationship of symmetry to asymmetry. Here again we can observe how specific is the relationship of a living organism to space. Every plant and animal species takes up a more or less characteristic amount of space. An oak, although its final height remains quite variable, grows to a size that is different from that of a bean plant. The size of any adult animal, especially among the more highly developed ones, is relatively fixed. Does the size of an animal have some understandable relationship with its other special characteristics? Goethe touched upon this point in his studies on bone structure (1759). He wrote:

> At this point an observation must be made that is significant for natural history in general. The question arises: Does size influence shape and form, and to what extent? . . . At first sight we might assume that it should be equally possible for a lion as for an elephant to attain a length of twenty feet. . . . Experience shows us, however, that a fully developed mammal does not exceed a certain size, and that when size increases, form starts to disintegrate and monsters develop.

In ordinary experience, we unconsciously take for granted that the natural size of each organism is subject to some kind of order. Physics tells us that size and volume do not increase at equal rates; when height grows in one dimension, volume increases in three. The larger an animal is, the stronger its skeletal structure must be in order to support its weight. Thus the largest of mammals, the whale, can live only in water; on land it would be suffocated by its own weight, as sometimes happens when great whales are stranded. Very small animals, on the other hand, such as ants, can carry objects much heavier than their own bodies; or, like grasshoppers, they can jump quite high in relation to their size (Slijper, 1967).

Still, the living form of an animal cannot be predicted on the basis of some geometrical ratio. Thus we find the same skeletal shape in both the African elephant and the dwarf elephant recently discovered by Accardi in the Pleistocene caves of Sicily. Fossil remains of this animal show that its size was equal only to that of a large dog. This example may be somewhat extreme, so we turn first to the mammals most familiar to us. Is there some way of discovering in them the underlying principle that governs their size? To this end, we list the following representatives of the three main groups:

Rodents	*Carnivores*	*Ungulates*
Mice	Wild cats	Cattle
Rats	Lynxes	Bison
Dormice	Foxes	Deer
Squirrels	Wolves	Moose
Ground squirrels	Seals	Horses

We notice at once that each group tends to have a common size. Ungulates usually develop large bodies; rodents, extremely small ones. Once again the carnivores occupy the middle position. For the individual structure and function of an animal, the amount of space its organism takes up is not a matter of indifference. The space it occupies is distinctly relevant to its style of living. Strongly sense oriented animals take up only a small space, those dominated by the metabolic-limb system fill out large forms, and representatives of the rhythmic middle system occupy an intermediate position in their relationship to space. Once again space shows its biological importance.

It is now necessary to go beyond the general threefold classification of rodents, carnivores and ungulates, and to examine the more specific animal forms of single families, genera and species. The reader must decide for himself whether or not the idea of threefold structure and function can explain many of the secrets these organisms bear within them. The following chapters may be regarded as offering supporting evidence. In them we shall test in detail whether our approach can prove fruitful, particularly when applied to phenomena that remain unexplained by previous work in mammology. The mammals indigenous to Europe will be dealt with most fully, but our observations will include non-European representatives of the mammalian world as well. Our discussion of form will center around three motifs: size, coloration and shape.

IV The Carnivores and Whales

The adult's experience of nature is quite different from the child's. We may scarcely recall what it was in the forest that occupied us so completely as children. As adults, we attend to the distant view over a broad valley, while the child finds pine cones, a blade of grass, a flower. We love to gaze out over the sea, while the child sees only the shells along its shore, in all their singularity. We take notice of the breadth of the landscape more than the flower growing next to us, the view from the peak more than the vein in the rock on which we stand. Livius reports that Philip of Macedon, the father of Alexander the Great, climbed Mount Haemos in Thrace in order to see the Black Sea and the Adriatic at the same time. "Philip of Macedon wishes to encompass with one glance what as a rule can be seen only in succession; in the world of the senses he seeks to experience what is normally achieved only in thought" (Huseman). We love unity; the child, diversity.

The child's experiences, however, are by no means fragmentary. He has an almost dreamlike awareness of the deep relationships uniting all things. The opposite may be true, as well. The adult, too, sometimes has unique impressions; he, too, can suddenly be struck by a 'quite common' plant in its incomparable existence, so little noticed before. The child, living in pure observation, dreams the universal. Because the adult often takes note of the phenomena before him only insofar as they confirm his own concepts, judgments and theories, he 'dreams' the greater part of his perceptions' content. It is almost frightening to consider how much of the 'all too familiar' remains utterly strange and inaccessible to us. To observe nature aright, we must ultimately recapture the child's joy in each phenomenon, without sacrificing our ability to comprehend the universal principles that underlie it. Only when we have trained our perceptions in this way shall we be attracted once again by a weasel or a fox, a seal or a dolphin, rediscovering their unique existence.

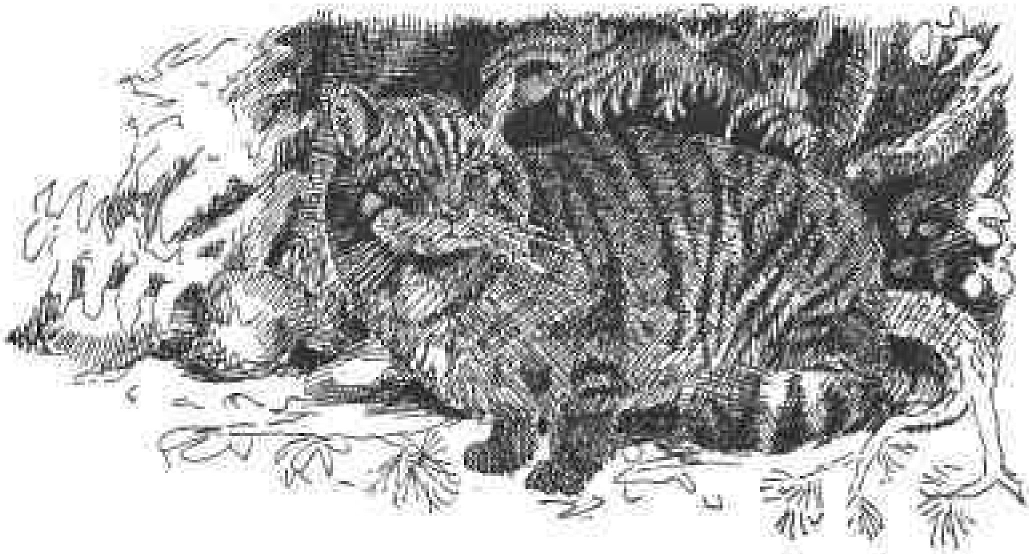
The carnivores most familiar to us are the domesticated dog, descended from the wolf, and the cat, descended from the African wild cat. These two animals were tamed in ancient times. In the cat the senses of sight and hearing are especially well developed. Its long whiskers and eye 'brows' give further indication of its delicate sensitivity. The dog, on the other hand, has developed one of the duller senses, that of smell. The cat's sensitive constitution is also revealed in its paws, whose claws are retractile, in contrast with the dog, whose limbs have become tools for running, with immovable claws. The dog is not even strictly carnivorous; it finds a mixed diet most acceptable. If given only meat, it sometimes buries the bones in order to obtain a food that has decomposed and become rich in bacteria. The wolf, too, tends to eat carrion, and both wolves and foxes occasionally eat berries, in order to supplement their all-meat diet.

All this is disdained by the cat. With the exception of milk, its taste runs to pure meat, rich in blood. Even its method of obtaining food is in keeping with its strongly developed sense organization: it prowls stealthily, then crouches motionless, with all its senses alert, and finally pounces with lightning speed. The wolves, on the other hand, as well as their descendants, the dogs, hunt by pursuit. Tirelessly they drive their victim until it is exhausted and must surrender. The cat hunts primarily with its senses, thus avoiding great physical exertion; the dog hunts with its limbs, powerfully activating its metabolism. Thus the dog and cat have developed polaric differences within the basic behavior of 'attack' typical of all carnivores.

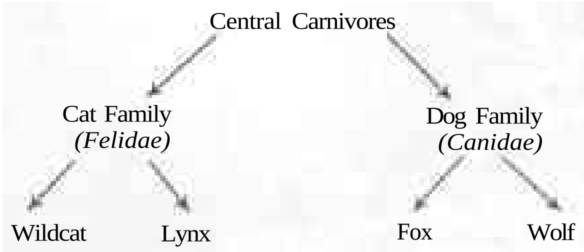
Tamed no earlier than about 1500 B.C., the cat remains an 'individualist,' a loner whose attachment to the house is often greater than its attachment to man. The dog is the more dependent of the two, more 'loyal' and good-natured, and is often kept by lonely people as a substitute for a lost relative. The dog inherits this instinct for life-long attachment precisely from its ancestor the wolf, who lives in the strong community of the pack. Thus the dog is able to direct this instinct towards man, while the cat, having inherited no comparable instinct, is unable to do so. Anyone who has owned both these animals can easily recognize the constitutional difference between them. The cat manifests primarily the nerve-sense organization; the dog, metabolic-limb processes. And yet in their supple agility, well-proportioned form, and moderate size, both are typical carnivores, shaped primarily by the rhythmic system.

In addition to the wild cat, we also find in Europe the lynx, a large animal with brushlike, elongated hairs on the tips of its ears, whiskers, a rather short tail, and long, powerful limbs. Often, it covers great distances in a short time, and it also makes use of its limbs when capturing prey. In this animal the feline type slightly approaches the canine. Among the dogs, on the other hand, we find the small fox, with its short legs and long tail; this animal generally stalks its prey or lies in wait for it, thus representing a rather sense oriented member of the canine group. Thus the basic contrast we have discovered between the sense-active cats and the metabolically oriented dogs also exists within each of these groups. The fox, compared with other European canines, has rather feline characteristics, while the lynx is almost dog-like among the cats. Even so, however, the lynx, Europe's largest cat,

4. European wildcat (1/7 X) and wolf (1/13 X).

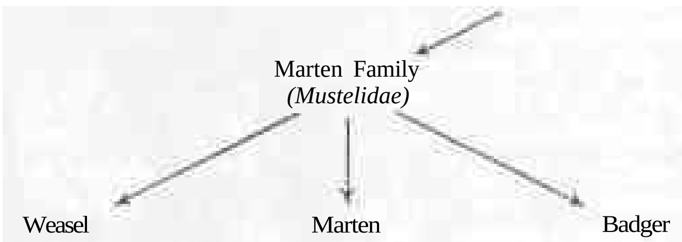


remains smaller than the wolf. Correspondingly, the fox, the smallest of the canines, is larger than the wildcat. This fact is quite significant for the biology of form, for as we have seen, size is dependent upon the relationship between the sense and metabolic systems. Thus the very size of the different animals is indicative of the order inherent within the multiplicity of nature.



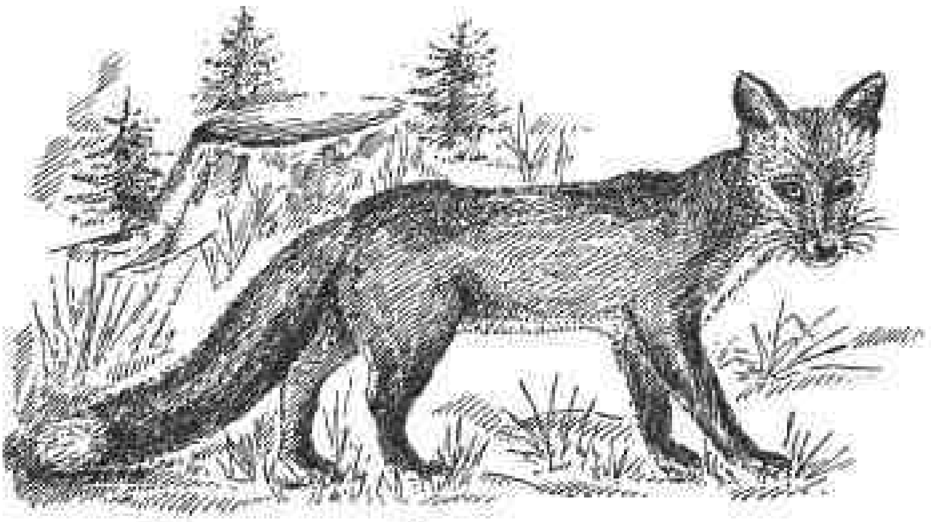
We turn now to the smallest European carnivores, the martens and weasels. As we might expect from their size, these carnivores are very sense-active, nervous and restless. Such unrest so pervades the nature of the common weasel that this animal requires constant freedom of movement and adjusts to captivity only with extreme difficulty. Its diet is significant; for the weasel is not satisfied with meat alone, but prefers a kind of nourishment still richer in energy and easier to digest than meat: the blood of its victims. It is well known that the beech marten, when it invades a chicken coop, does not appease its hunger with one chicken but satiates itself with the blood of them all. Only when there is no more blood and the brain has been devoured does the marten settle for meat.

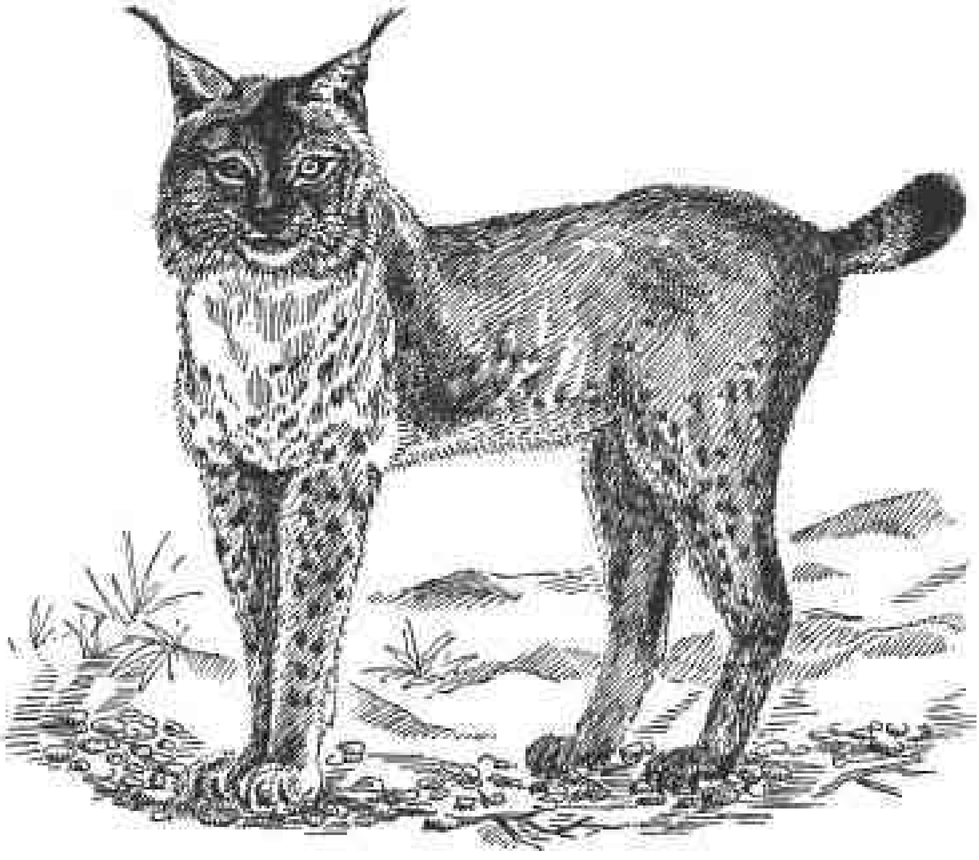
The European marten family is itself divided into three groups: the extremely sense oriented species, such as the weasels; the central animals, such as the martens; and species such as the badger, which, despite its membership in the most sense oriented group of carnivores, is strongly influenced by the metabolism.



There are, of course, several species of weasels and martens in Europe: for example, the polecat, ermine, dwarf weasel, mink, pine marten, and so forth.

5. The red fox, *above*, and the lynx (each 1/9 X).





How can we find order in such variety? It is relatively easy to find the extremes. The smallest of the weasels, the common and dwarf weasels, **are** extraordinarily aggressive, even wildly so (Herter). They often take on much stronger opponents, such as the buzzard or the owl, if these have mistaken them for mice. The stronger opponent, of course, is usually victorious. These small weasels are so erascible because in them a vivid life of the senses is strongly bound up with the aggressive nature of the carnivore. Normally, these animals prey upon mice. They are able to make themselves nearly as slender as their victim and to follow it into every mouse hole, from which it cannot hope to escape.

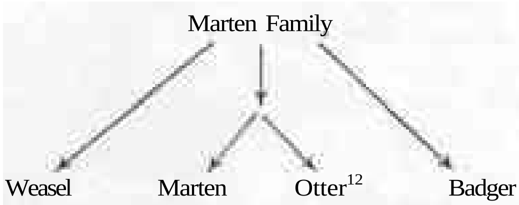
The badger is the largest European member of the marten family. During the night this animal ambles along the damp forest floor, enjoying its search for snails, earthworms, beetles, roots and berries, snapping up a warm-blooded mouse only when one happens to cross its path. Thus the badger's metabolic system is so strong as to make this animal almost vegetarian! Because of the diminished activity of its physically debilitating sense system, the badger is able to build up immense fat deposits and to feed upon these during hibernation. One must see a sleeping badger in order to have some idea of its almost passionate turning inward towards its own metabolism: snuffling deeply, it lies curled up, its nose buried in the fur of its belly.

How do the other members of the marten family fit in between the dwarf weasel and the badger? At this point we must make ourselves consciously aware of a difficulty that may arise. For the rest of the mustelids do not arrange themselves neatly in linear sequence between the sense-active dwarf weasel and the metabolically dominated badger. The living variety of these animals cannot be reduced to a graduated scale on which each species could be ranked according to the degree in which one tendency predominates in it over the polar opposite; for the two tendencies do not simply stand opposed in ways that would cancel each other. They actively organize themselves in relation to one another. And they are not mere concepts but actually existing capacities within the animals. It is because of these real capacities that a middle ground invariably exists, representing *par excellence* the ability of an organism to coordinate within itself opposing tendencies. For this reason, in the final analysis, nature is not dualistic but triadic, or threefold.

Among the mustelids, the martens themselves most strongly possess these actively mediating processes. The pine and beech martens, as well as the otter, as members of the central group within this family, form its harmonious, basic type. The pine marten is the best example of this middle group; a small, muscular athlete, it scampers with agility and admirable strength through the treetops. The larger otter, by contrast, slightly accentuates the metabolism. Still, it does not resemble the shuffling badger but gives the

6. *From the top down,* pine marten, beach marten, otter (1/5.5 X, 1/5.5 X, 1/7 X).

impression of strength and energy combined with wary repose. This slight accentuation of the metabolism also becomes evident in the kind of food the otter eats: the flesh of crustaceans and fish is more alien and dissimilar to the protein of its own body than is the meat of warm-blooded animals. In size the otter surpasses the martens significantly, if not by very much. It is noteworthy, too, that the otter, although undoubtedly descended from land animals, secondarily chooses the water as its life-element (Plate 109). This fact will prove quite basic to the otter's position within the whole of the marten family, for we shall find in the course of our study many **other** examples of this secondary adaptation to an aquatic way of life.

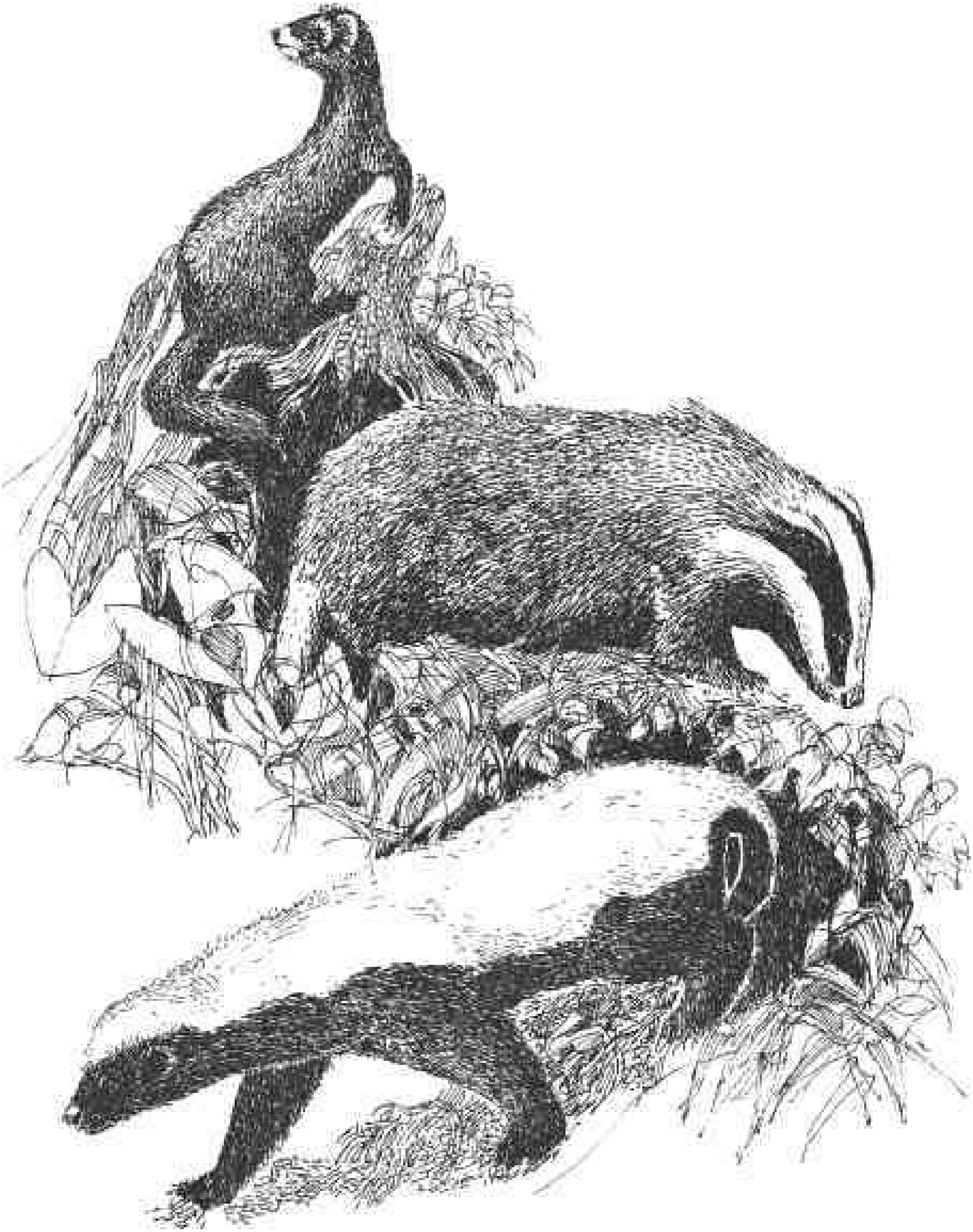


We have already mentioned the relationship between the size of an animal and the organic system dominant within it. In the observations that follow the validity of this motif will be borne out again and again. We may therefore consider at the same time another motif, the outward coloring of the animal's form: its coloration. Here we touch upon a much-discussed complex of questions that is only now beginning to be understood. Portmann (1957) has concluded that coloring shows too many 'accessory' characteristics to be explained causally on the basis of mutation and selection. On the other hand, it has too many 'unaddressed' characteristics to be considered purely functional (protective, warning or attractive). The meaning of coloration, according to Portmann, is to a great extent to be found in the 'self-expression' of the particular species. This concept of Portmann's has either been rejected without understanding, or accepted as a complete explanation that renders any further questioning unnecessary. Neither approach has proved helpful. In what follows we shall try to understand the *way* in which the organization of a particular species is expressed in its coloration.

We may begin by observing that, in general, sense oriented forms have sharply contrasting, dark dorsal and light ventral sides, while metabolically oriented species tend toward a uniformly dark coloration. The reasons behind this basic distinction, as well as its complexities, will become clear in the discussion that follows.

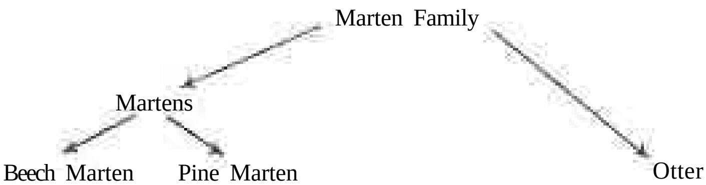
When, for example, we compare the beech marten with the otter, we observe that both have a dark upper side and a light-colored throat and chest. In the otter the dark color merges gradually with the light. In **the**

7. *Above,* Eurasian polecat and badger (1/6 X), *below,* the honey badger of Africa and India (1/4 X).



beech marten the two colors are sharply set off from one another; the white of the throat is clearer than that of the otter and extends over the front of the chest to the axillae of the forelegs. These fine distinctions cannot be taken seriously enough. The beech marten, more sensitive and open to the surrounding world, sharply contrasts the colors of its upper and lower sides, while the otter, with its stronger metabolism, tends toward a homogeneous coloring. Here again, we must remind ourselves of the fact that every detail in an organism is a reflection of its basic organization.

The pine marten, closely related to the beech marten, is somewhat larger and more powerful than the latter. The spot on its throat is of a less contrasting, even yellow, color, and is confined to the throat alone. In the pine marten, then, the markings typical of the beech marten are slightly less accentuated. The pine marten really is the 'prince of martens' (German *Edelmarder* or 'noble marten'), with an organization as finely balanced as is possible within the marten family.

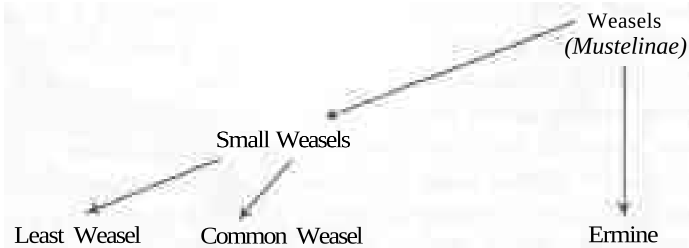


In observing the weasels, we see at once that their color pattern is characteristically more extreme than the beech marten's. As the most sense-active members of the marten family, they have a light brown dorsal side and a sharply defined white coloring that extends over the entire ventral side. The least, or pygmy, weasel, as the smallest member of the group, shows this white coloring even on its paws. In the common weasel, which is only slightly larger, it is the brown color that has become dominant on the limbs! Even the irregular borderline between the two colors shows how the common weasel manages to avoid the extreme color pattern shown by its smaller cousin.

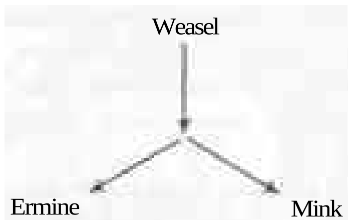
The stoat, or ermine, indicates in its larger size an even further retreat from one-sidedness. Its coloration is remarkably well correlated with this tendency towards balance: the brown of its upper side is darker than that of either weasel, and the tip of its tail is even black. The influence of the sense organization is again expressed in the straight-lined color division between upper and lower sides, even as an inclination towards the metabolic system is announced by the black tail tip. In the ermine, both tendencies within the

8. *Above left,* least weasel, *right,* common weasel, *below left,* ermine, *right,* European mink (each 1/3 X).

weasel type are brought together. Though more balanced in form than the small weasels, which can almost be mistaken for mice, this animal is still obviously a weasel. We may thus extend our survey as follows:



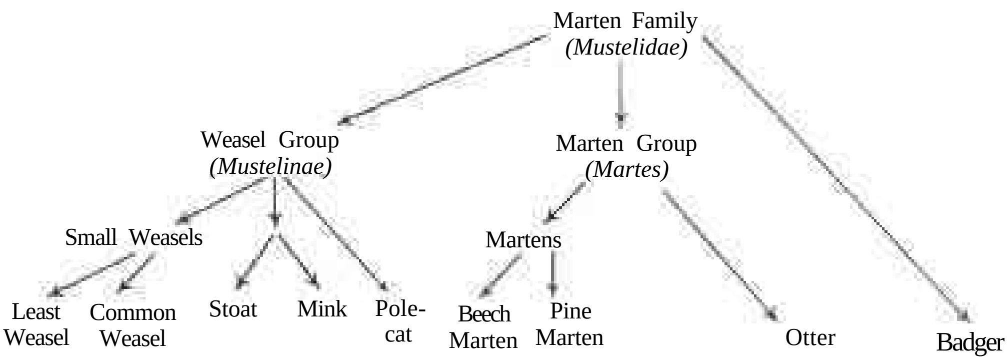
There remain two additional members of the European marten family, the mink and the polecat. Both are so closely related to the weasels that they are designated by the same generic name, *Mustela.* But the coloring of the mink is quite different: uniformly dark brown. The white color of the underside has receded to the head, where it appears only in small spots on the lower jaw and upper lip. It is as though the black tip of the ermine's tail had taken possession of the entire animal from behind. Only at the foremost point of the head, at the sense pole, does a last vestige of the white underside remain. This almost completely homogeneous coloring is an indication of the mink's strong metabolism. This animal feeds chiefly upon cold-blooded frogs and fish. It lives just as well in water as on land and has rudimentary webs between its toes. In addition, it is still larger than the ermine. Yet it is such a balanced mustelid that it represents, in fact, the metabolically oriented counterpart of the ermine[13].



The polecat, the largest member of the European weasel family, 'metabolizes' even further. Frogs are its favorite food. Yet its diet also ranges from the occupants of hen houses and rabbit hutches to rats, mice, snakes, fish, snails, earthworms and beetles, and even fruit and honey. If these omnivorous eating habits seem unusual in a member of the weasel family, its coloring is just as strange. The basic color of its fur is brownish-black. On the ventral side this color has intensified to a deep black. The dorsal side, on the other hand, is lighter, in parts even yellowish-brown! The dark upper side and light lower side typical of most sense oriented animals are here reversed. (In the discussion that follows we shall refer to this pattern as 'inverted coloration.') But what has happened to the white color? It has moved up to the head. The tip of the snout, the temples, and the edges of the ears are brilliant white, contrasting with the deep brown-black to create a conspicuous facial design (Plate 108). Inverted coloration and sharply contrasting patterns on the head are characteristic of the polecat. Can this be connected with the fact that the polecat has the strongest metabolism of any member of its sense oriented group?

The contrast we have found between the colorations of the ermine and mink is even further intensified by the small weasels and the polecat. The greatest degree of contrast within this family is found between the dwarf weasel and the badger. The badger's underside and limbs are pure black, its upper side, whitish gray. Its head has sharply contrasting black and white stripes that make it even more striking than that of the polecat. As a representative of the metabolic system within a group generally dominated by the sense organization, the badger shows the strongest color inversion and head markings of the European animal world. The North American badger shows a similar color inversion, with small differences. The median white line of the head is narrower than that of the European badger and extends down along the back; the cheeks are white, and there is a strongly contrasting black spot in front of each ear.

On the basis of the above observations, the European carnivores of the marten family may be arranged in the following order:



This systematic arrangement not only takes into account the variety of this group, but at the same time it provides an ordered structure that is in harmony with the threefold concept. Each characteristic is of basic significance, and this significance is there for all to see.

We can also observe certain basic tendencies in each species' choice of habitat. Within any of the middle groups, for example, those animals with strong metabolic systems particularly love the water and are adapted to life in rivers, lakes, brooks or ponds. This tendency is more pronounced, the more strongly the middle system predominates, as it does in the mink and especially in the otter (Plate 109). The sea otter even lives in the ocean, along the North Pacific coasts. The sense oriented representatives of the middle group, on the other hand, seek out a different habitat, namely, that of the trees. The pine marten, for example, is an excellent tree-climber.

The most sense-active animals typically choose a habitat in which the animal can instantly hide and just as suddenly reappear: grass thickets, rubble, dead leaves, dense underbrush, fallen tree trunks, low shrubbery, broken walls—in short, wherever it is able both to move about in continuous contact with solid ground and to hide quickly. Here the nervous constitution is given full rein. The dwarf weasel, for example, creeps on its short legs so close to the ground that one might almost mistake it for a large caterpillar. Suddenly, however, the little creature sits up on its haunches and for a moment lifts its head above the level of the grass, only to go undulating off again in some other direction. The beech marten, the most sensitive member of the marten group, also lives on ground level but is not so rigidly bound to it, for it can jump, climb, swim and dig equally well.

Metabolically oriented members of primarily sense-active groups typically dig and occupy deep burrows. This is true of the polecat and particularly of the badger. Both animals require periods of undisturbed peace; far from the events taking place on the earth's surface, they can give themselves over to their own digestion and to the sleep they so profoundly enjoy.

Coloration, as we have seen, is also basic; and it has a special relationship not only to the animal's own organization, but also to its behavior within the environment. The coloring of the nerve-sense oriented forms, with their dark upper and light lower sides, is clearly protective. Within their own environment, these animals are equally inconspicuous whether seen from above or below; for when looking down, we tend to see darkness rather than light and when looking up, primarily light; these animals therefore contrast but little with their background. Such coloration also diminishes the natural brightness from above and the shadowing of the underside, so that, for the observer, the animal loses in spatial depth and is hardly noticeable. In appearance, then, the sense-active constitution blends with its environment, contrasts with it but little, and is little noticed (cryptic coloration).

The badger, on the other hand, has a conspicuous (semantic) coloration. This animal's inverted coloring makes it quite visible, and the strongly contrasting pattern of its head attracts additional attention. Because this member of a sense oriented group is secondarily dominated by the metabolism, it really belongs to a separate group of its own; and it is this quality of uniqueness that it expresses so strikingly in its coloration.

This tendency toward semantic coloration is first seen in the polecat and reaches its peak in the honey badger of Africa and southern Asia. This animal's entire underside is dark, while its upper side is pure white. Spreading out from the head, the light coloring has here taken over the entire upper side of the body and has come to fullest expression[14].

But why should the otter's coloring be so unexpressive? The answer lies in the fact that this animal belongs to a group that is at least partially dominated by the middle system. For if we look at the polar opposites within this middle group (the beech marten and the otter), we see in their coloration only hints of the differences found between the sense oriented and metabolically dominated extremes. And even within the sense oriented weasel group itself, the polarically opposite species (the dwarf weasel and the polecat) show greatly contrasting colorations. Apparently, such contrasts develop more readily in one-sided groups than in central ones. In such extreme groups, the equalizing central possibilities are lacking; thus, the difference in coloring between the ermine and the mink is quite pronounced. Within groups whose basic characteristic is a mediating ability, the resulting harmony is shown also in the individual forms' relatively small deviation from the basic type. Thus the sable of Eastern Europe and Asia[15] and the mighty sea otter of the North Pacific have a uniformly dark coloring. Despite the relatively well developed metabolic systems of these animals, the underside conforms in color with the upper side; color inversions and head patterns are absent. Extreme colorations are avoided.

Yet another motif is revealed through close observation of the European marten family: most species (five) are sense oriented, while only three belong to the middle group, and there is only one metabolically oriented species, the badger. Animals with strongly developed senses are evidently more apt to divide into different species than other groups are. The formative possibilities are directed not so much towards developing a common type as towards producing many small forms whose bodily growth comes quickly to an end. As numerous in species as they are, members of the weasel group are all similar in shape. In the genus *Mustela* there are 13 species, in the subfamily of the weasels *(Mustelinae)* there are 24, and in the entire marten family *(Mustelidae)*, 65. The badger, on the other hand, is the only species in its genus; and in its subfamily there are a total of only 7 species, which are divided among 5 genera (Haltenorth, 1953-55). Here, in almost every case, the species stands on the level of the genus, so that each species forms its own genus. The differentiation into species is here restrained in favor of developing a powerful common type, making it possible for large animals with a strong metabolism to appear. Thus in the faunal balance, the badger species is equal in weight to the multiplicity of different weasel species; it is, so to speak, its own entire family.

The single metabolic form and the grouping of many related sense oriented forms stand in a complementary relationship that is also apparent in a survey of the major groups of mammals. Thus, if 100 % represents the total number of living mammal species, the rodents comprise 46.4 %, the carnivores and whales 14.3 % and the ungulates 10.4 %; the additional 28.9 % includes all other mammals (calculated according to Krummbiegel, 1953/55). The most sense oriented group, the rodents, has been most active in splitting off into many, relatively similar species. In this tendency the marten family among the carnivores resembles the rodents. "Indeed, the mustelids are almost rodent-like in their extreme polyphyly and convergences and offer taxonomic difficulties like those of the *Rodentia* on a smaller scale" (Simpson).

Let us also compare the more limited circle of relationships of the feline and canine groups. Both families are well balanced, central carnivores; their species number 35 and 32, respectively, and differ from one another but little. Yet here again, the sense oriented cats have the greater number of species. The same holds true within each family. The wild cat is one of 22 species of the subfamily of small cats; the subfamily of the lynx, on the other hand, has only 5 species in the world. The wolf is the only species in the genus *Canis;* the genus *Vulpes* of the fox, however, has divided into a total of 11 species (Haltenorth, 1953-55). Exactly how this differentiation of species relates to the living constitution of each animal remains to be examined more closely.

How different from the weasels, cats and dogs are the seals! Mighty animals up to 17 feet (5 meters) in length (elephant seal), having stout bodies with thick layers of fat beneath the skin, they wallow along in the sand of the seashore or glide gracefully under the water. Yet despite their size, they are genuine carnivores. They are exclusively carnivorous; their teeth are dominated by the canines; the three wrist bones (the scaphoid, lunate, and capitate bones), like those of terrestrial carnivores, are fused; the placentas of these animals are also similar to theirs (see Chapter X). Names like sea dog (harbor seal), leopard seal, sea lion, and sea bear (fur seal) attest to their carnivorous nature. What then is the basis for their separation from land carnivores? Why is it that precisely these carnivores have become aquatic?

Evidently, their aquatic way of life is connected with the fact that, as carnivores, they are dominated by the middle system, while they are secondarily influenced by a strong metabolism. Evidence of the latter comes to light in their massive bodies, their long intestines, and, as we shall see, in the reduction in the number of their incisors. Beyond all these details, of course, it is their overall appearance that gives strongest evidence of this metabolic influence. These animals demonstrate on a large scale tendencies we have already discovered in the mink and otter among the marten family. For the seals, too, are certainly descended from land animals; their choice of the watery element as a habitat must surely be associated with the fact that they

9. Harbor seal (1/13 X).

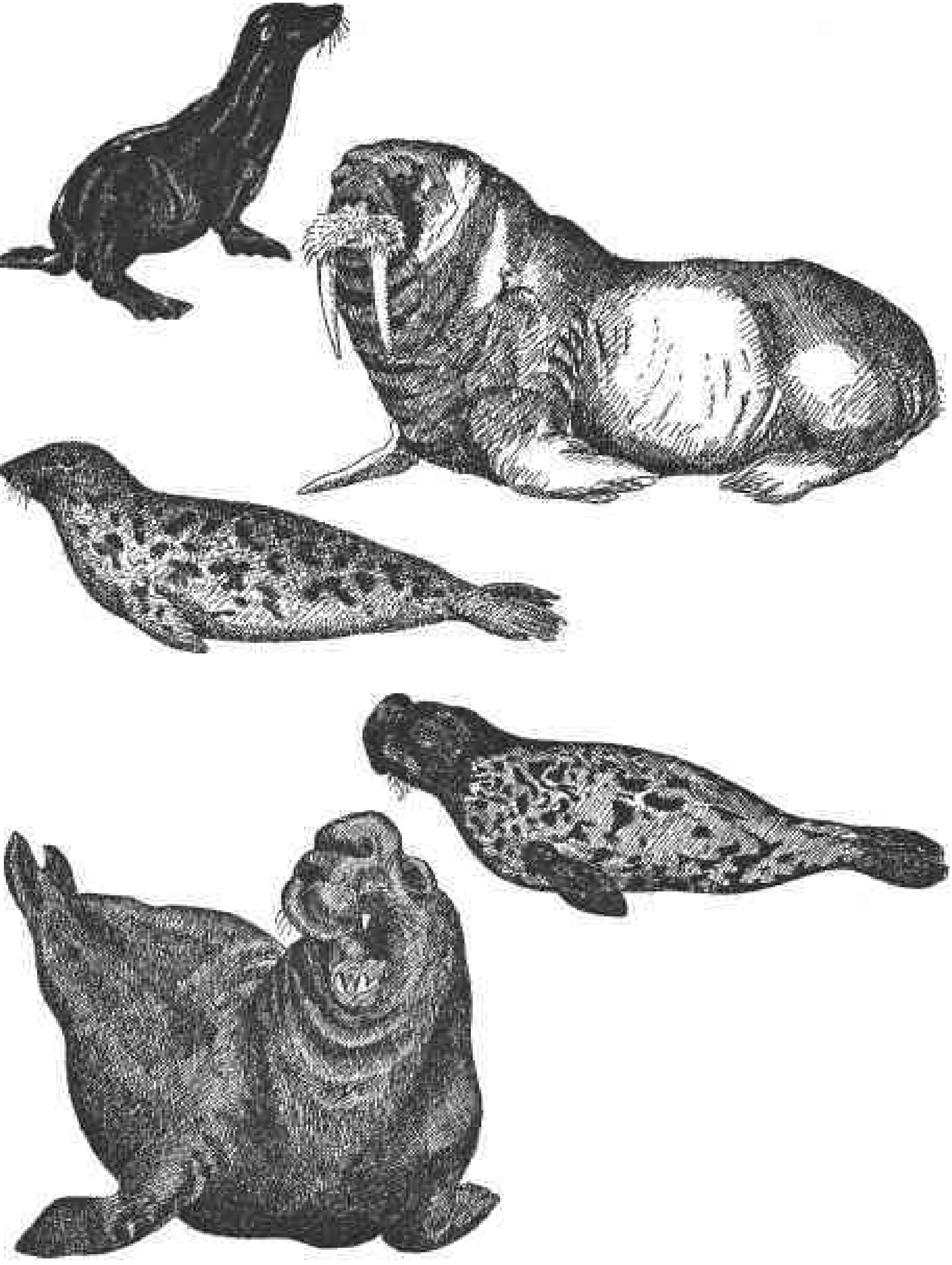
are middle forms that have developed an intensified metabolism. The carnivores are after all the central group of mammals, and their metabolically oriented subgroup is the seals. What we have found, in the mink and the otter, as limited tendencies toward large size and a preference for life in the water, comes to full expressions in the seals.

As clumsy as the seals appear on land, they move in the water with incomparable grace. In harmonious curves they virtually fly through their element, surfacing now and again to breathe, and always engaged in play with their own kind and with the water. For months at a time they live, eat, play and sleep on the high seas, covering vast distances in this way during their migrations. Some of the species that live near the coast, such as the harbor seal, still return to land regularly for short intervals to sun themselves, but most do so only in order to mate and give birth. Their shape and particularly their limbs are even more strongly transformed for life in the water than are those of the otter. The forelimbs have become effective paddles; the hind legs in their most highly developed form have fused so completely that they can no longer be turned forward but, like the tail fins of a fish, are directed backward to serve the motion of swimming. The more complete the adaptation to water in each species, the smaller its external ears. The muscles used by land mammals to move the auricles are transformed into sphincter muscles that close off the auditory canal under water. The nostrils, too, are closed under water and must be actively opened for breathing. All these organ transformations are a necessary part of the process, so extraordinary in a lung-breathing animal, of making possible its life in the water.

What follows is intended as an introduction to the great variety of forms to be found in the seal family. In sequence from the eared seals (otariids) to the *Cystophorinae,* we see an increasing perfection of the ability to live in water. The *Cystophorinae*—including the eleven-foot-long (three meter) hooded seal, at home among the drift ice north of Iceland, and the elephant seal of the North Pacific and the Antarctic—are the most representative members of this group. The elephant seal is the largest of the seals. The males of this species grow to be powerful animals measuring as much as 18 feet (or 5.40 meters) in length and weighing up to about four tons (or 3.65 metric tons). (The heaviest terrestrial carnivore, the Kodiak bear, weighs 'only' 0.85 tons or 0.77 metric tons.) The nose that gives this animal its name has two massive inflatable sacs that can be arched forward to form a trunk 10 inches (25 centimeters) in length.

The configuration of the teeth in these animals is very instructive. All land carnivores have three incisors in each ramus of the upper and lower jaws. In the seals, with the growing dominance of the metabolism, these teeth decrease

10. *From the top down,* sea lion, walrus, grey seal, hooded seal, elephant seal (each 1/33 X).



Family:	*Otariidae*	*Odobenidae*	*Phocidae*		
	Eared Seals	Walrus	*Phocinae*	*Monachinae* and *Lobodontinae*	*Cystophorinae*
Number of incisors in each ramus	$\frac{3}{2}$	$\frac{3}{0}$	$\frac{3}{2}$	$\frac{2}{2}$	$\frac{2}{1}$

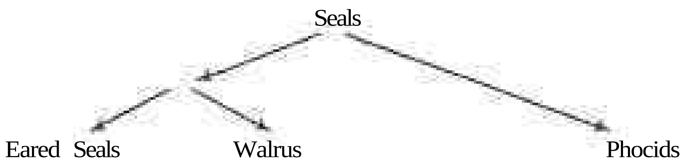
It is quite significant that in all seals the first set of teeth, the milk teeth, scarcely makes an appearance. These teeth are still to be seen in newborn eared seals, but are replaced by the permanent teeth that follow close behind. In the harbor seals this change of teeth is accomplished even before birth; and in the elephant seal the milk teeth never even penetrate the gums, but are reabsorbed within the mother's body. This animal is born with a complete set of permanent teeth.

It is equally noteworthy that the number of teeth not only varies from one species to another, but is more variable than usual even within a given species. Thus on occasion walruses have been found to have not just one canine in each half of the upper jaw, as do all other mammals, but three (Scheffer). The number of molars in particular is quite variable. Occasionally a few are missing; more frequently, however, extra ones appear (Weber).

Polarically opposite the elephant seals are the more sense oriented eared seals, which, unlike all other seals, have outwardly visible external ears (Plate 112). These animals can leap high out of the water; in the circus we admire the unexpected artistry of their agile performance, and in the zoo, their great speed and jumping capacity. The anterior and posterior limbs have not grown so deeply into the body as those of the elephant seals, so that these animals are still able to use their limbs to raise their torsos off the ground; they can also still turn their hind limbs forward under their bodies; and the soles of their feet are hairless.

The walrus has the same mobility of the hind limbs the eared seals have, but it no longer has external ears. More metabolic in orientation than the eared seals, this animal grows to massive size. It also lacks the wonderful pelt grown by many eared seals and coarsens its entire head organization by transforming the canines into powerful tusks that protrude far out of the mouth, and by adorning its muzzle with a stiff-bristled beard. These tusks help the animal to dislodge shellfish, its principal food, from the ocean floor in coastal waters. While eared seals feed on the fish they catch in the open sea, the walrus grazes on submerged 'meadows' of shellfish. This primitive food is chewed up and swallowed together with the shells.

The group of seals most thoroughly adapted to water, the phocids, or true seals, lack external ears, and on land they can no longer turn their hind limbs forward. In them, the requirements of the aquatic life wholly predominate.



The seaworthiness of the seals is surpassed only by that of the whales. In them the highest degree of mammalian adaptation to water is attained. The hind limbs in particular have degenerated almost completely, while the forelimbs are restricted to finlike appendages. Even mating and birth take place in the water. Aristotle recognized the whales as mammals, but men of late antiquity, the Middle Ages, and the Renaissance believed them to be fishes. In 1693 it became apparent to John Ray that whales have warm blood, breathe by means of lungs, and bear fully gestated young, which they suckle with milk. From that time on the whales have been regarded as one of the most astonishing riddles of the mammalian world.

The vast majority of whales live in the open seas; only a few small species live in fresh water (the Ganges, Amazon, and La Plata dolphins, as well as the white flag dolphin of China). Usually they avoid coastal waters, for to be washed up on the sand means certain death for the great whales. When they are deprived of the water's buoyancy, the mass of their own bodies prevents them from breathing and eventually suffocates them. In the water, however, they seem to weigh far less, since their own weight is diminished by the mass of the water they displace. Surfacing and diving through great walls of waves, these animals move in herds through the breadth of the ocean, the larger species sailing peacefully and majestically, the smaller ones, such as porpoises and dolphins, in narrow circles, jumping and playing with one another. Into the endless seascape of the ocean, with its jellyfish, crustaceans, fish, and sea turtles, an animal life that seems rigid and cold, these animals bring their warm-hearted friendliness. Thor Heyerdahl gives the following account of his voyage across the Pacific on the raft Kon-Tiki:

... We started when suddenly something behind us blew hard like a swimming horse and a big whale came up and stared at us, so close that we saw a shine like a polished shoe down through its blowhole. It was so unusual to hear real breathing out at sea,

> where all living creatures wriggle silently about without lungs and quiver their gills, that we really had a warm family feeling for our old distant cousin the whale, who like us had strayed so far out to sea. … Here we had a visit from something which recalled a well-fed jovial hippopotamus in a zoological garden and which actually breathed—that made a most pleasant impression on me—before it sank into the sea again and disappeared.

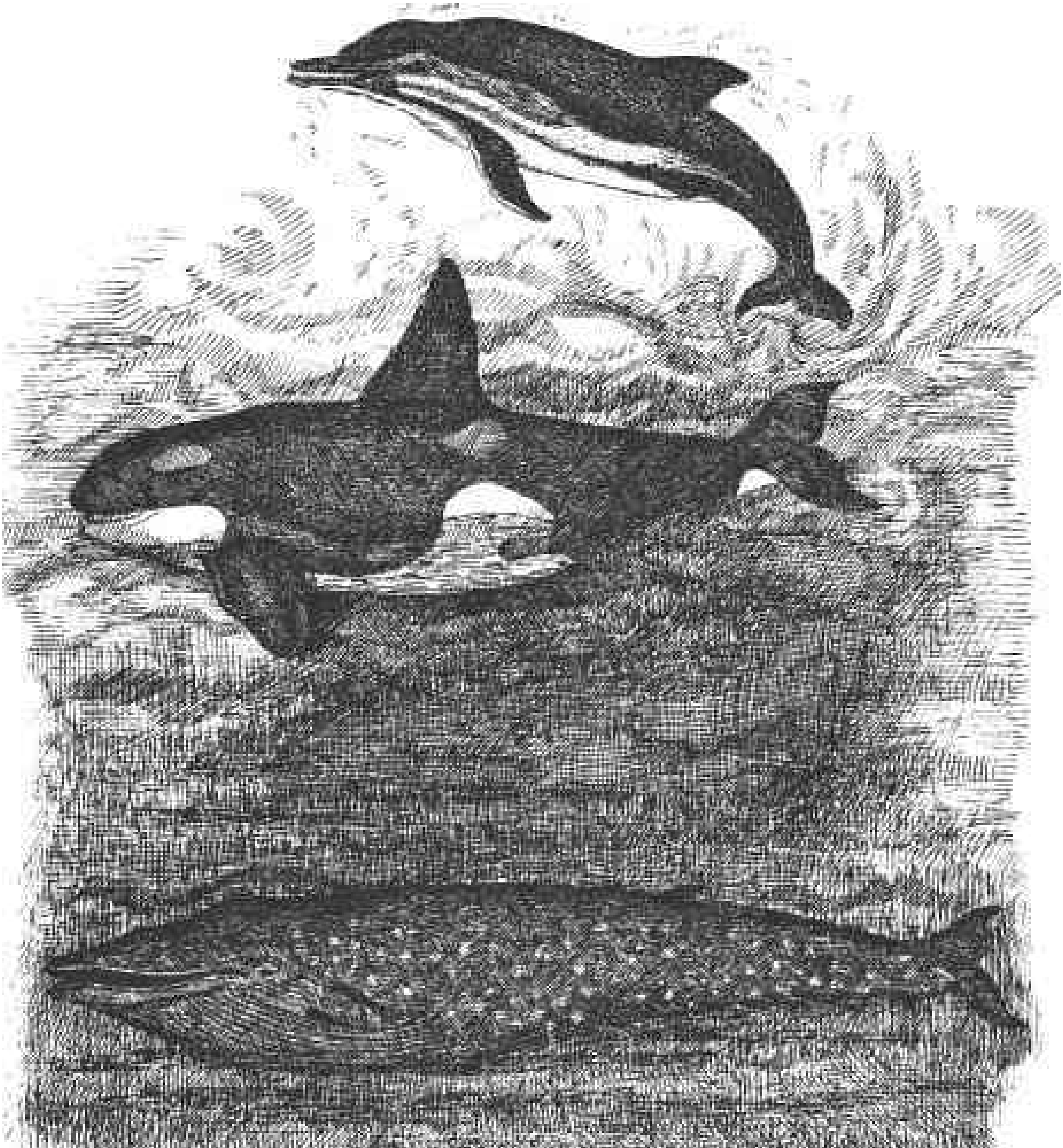
Many ancient tales of the helpfulness of dolphins and their friendship with man have been confirmed today, since in recent decades zoologists have begun to study them more closely (Alpers). They are most playful and teachable animals whose ability to learn surpasses the accomplishments of even the anthropoid apes.

Among the giant whales, this highly developed soul life seems to be locked away deep within the body. Male sperm whales, which can attain a length of about 75 feet (or 5 meters) (Plate 118), dive in only 40 minutes to a depth of about 3000 feet (1000 meters); they have been found entangled in underwater cables at this depth. There they search for the giant squid, their principal food. Upon surfacing, they exhale steam-saturated air as a pale cloud 20-25 feet (5-8 meters) high and inhale about 500 gallons (or 2000 liters) of new air; if necessary, one or two seconds suffice to let this mass of air pass twice through the blowhole. Even as these animals sink into the depths of the sea, so also do they sink into their own bodies. This tendency holds true especially for the baleen whales, including the blue whale; with a length of about 100 feet (or 30 meters), it is the largest animal known to man.

While the sperm whale prefers tropical waters, the baleen whales bring life to the icy waters of the Arctic and Antarctic regions. There, strangely enough, the seas are filled with a very rich fauna of microorganisms, particularly the plankton that form the principal food of the baleen whales. The huge mouth sifts myriads of these tiny crustaceans out of the upper layers of the water, using as a sieve the baleen (fimbriated horny plates) that it has instead of teeth; the excess water is pressed out of the mouth and a mass of small crustaceans remains behind to be swallowed. As though in a sea meadow, the baleen whales graze on this 'flora' of tiny organisms and build from it gigantic bodies that carry their warmth-filled life unscathed into the icy cold of the polar regions. The enormity of the whales' metabolism can be comprehended from the milk production of the nursing whale cow: the blue whale calf daily adds about 220 pounds to its weight (Mohr).

The killer whale develops a strong rhythmic organization. Like a sword, its 4 foot (1.5 meter) long, vertical dorsal fin juts out of the water. Nothing is safe from the killer whale: every fish, every water bird, and every seal that it can lay hold of, it devours. Its mouth is studded with numerous cone-shaped teeth. It is truly the most voracious predator on earth. Many books on whales

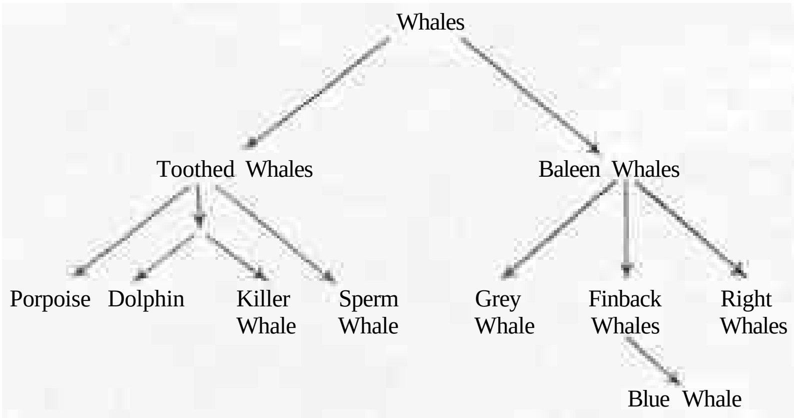
11. *From the top down,* a dolphin leaping (1/25 X), the voracious killer whale (1/80 X), the giant blue whale (1/200 X).



mention the discovery of 13 intact porpoises and 14 seals in the omasum of a 25 foot (7.5 meter) long killer whale that had been killed, while a fifteenth seal was still lodged in its throat. In another, 32 full-grown seals were found (Slijper, 1962). In packs, they assail even the giant whales, tearing at their enormous lips and tongues until they bleed to death. This whale can attain a length of up to 30 feet (or 9 meters); it is found in all oceans. The false killer whale (up to 18 feet, or 5 meters, in length) is closely related to it.

The dolphins and porpoises are the most sense-active representatives of the whale group and therefore have a dark upper side and white underside. Sperm whales and blue whales, on the other hand, are more or less uniformly dark in color. In the white area that extends up along the sides of its body and the white spot behind each eye, the killer whale shows an interpenetration of dorsal and ventral coloring that is unique; by bringing the two colors together in his fashion, the killer whale avoids either extreme in coloration.

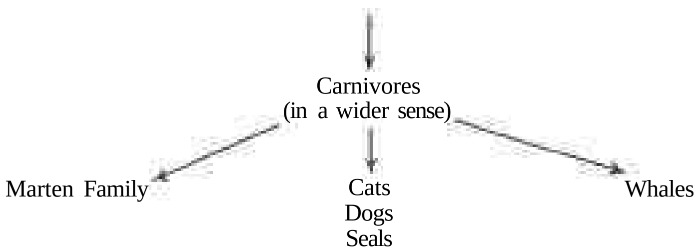
The following survey represents a first, as yet incomplete, threefold survey of the whales:



We have cited here only a few characteristic whale species. Even in these few, the threefold processes are active in determining both shape and organization. But which of these three processes provides the formative principle basic to the entire group? Which organic system constitutes, by its dominance, the characteristic quality of the whales? Without doubt we are dealing here, to an even greater extent than in the seals, with the dominance of the metabolic system. Enormous masses of fat envelop these animals, and processes that build up the body outweigh those that deplete its strength.

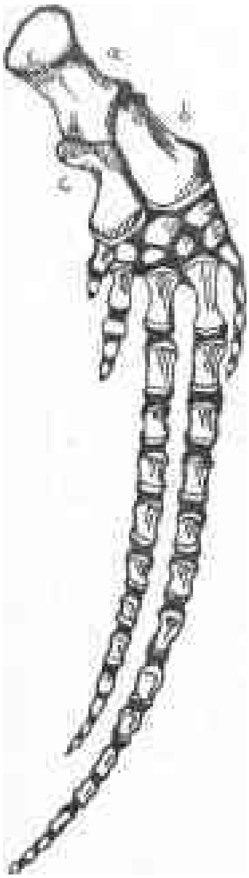
The forepart of the head in particular is packed with great masses of fat and oil. The life of the senses is greatly reduced: smell and taste are almost entirely lacking; the eyes are little developed. (The blue whale can no longer see even its own flukes; the Ganges whale is completely blind.) Only the sense of touch, and especially that of hearing, are distinctly present, so that whaling boats must creep up on their prey by rowing softly, with motors turned off. Embryonic development leads to fully mobile newborn animals that are, as it were, 'complete'; the placentation is similar to that of horses and pigs; the blood serum, to that of camels and cattle. All these characteristics that emphasize the strong metabolism of the whales have led many systematists (see Slijper, 1936, and Thenius-Hofer, 1960) to assume a close relationship between the whales and the ungulates.

At the same time, however, whales have many traits in common with the carnivores. (The multichambered stomach, for instance, cannot be derived from the stomach of the ruminants but only from that of the carnivores; the tendinous plate of the diaphragm also is similar to that of the carnivores; and the Atlantic right whale has a penis bone like that of many carnivores.) In the Tertiary strata some transitional forms between the whales and the prototypes of carnivores *(Creodontia)* have been found: the *Archaeoceti*. Especially the Middle-Eocene *Protocetus octavus* of Egypt shows, in its dentition, the distal position of its nose, the construction of its vertebrae, as well as indications of a functional pelvis, obvious connections with modern terrestrial carnivores. Thus Abel (1914), Slijper (1936), Starck (1955), and Thenius (1969), for example, have advocated the theory of a relationship between whales and carnivores. The biology of form also lends support to this theory. For the tendencies demonstrated by the otters and seals are even more clearly shown by the whales, which may be seen as the members of the middle group of mammals, the carnivores, whose metabolic capacity is most strongly developed. Mink, otter, seal, and whale do not constitute a linear sequence of related forms. But what the mink represents among the weasels, the otter among the martens, and the seals among the central carnivores, the whales represent within the group of carnivores as a whole. Thus we have broadened the usual concept of carnivores by adding the whales. As we have seen, it is characteristic of animal groups dominated by the middle system that their metabolically oriented representatives secondarily choose the water as a habitat. Only by connecting the whales with the carnivores can we fully understand this characteristic trait[16].



We have yet to mention the special characteristics of the whales' dentition. All whales grow a set of teeth, at least in the embryonic stage. In the large whales, however, these develop only partly (in the sperm whale, in the lower jaw) or not at all (all baleen whales are toothless). The small whales have teeth in great number. In dolphins and porpoises the teeth have been simplified to pointed cones. Incisors, canines and molars can no longer be distinguished from one another, and it is as yet unknown whether these are milk or permanent teeth, since no change of teeth has ever been observed in whales. Most likely they are permanent teeth, since we have already seen in the seals the gradual disappearance of the milk teeth.

Along the German North Sea coast the whale most frequently found is the porpoise (Plate 115). Six feet (or two meters) long at most, it is the smallest of the whales, a playful fellow that hunts only in the upper layers of the water. Apparently we may also consider it to be the whale that is most receptive to the surrounding world. Its coloring, dark on the upper side and light on the lower, supports this idea, as do its teeth: this animal has about 100 teeth, which, unlike those of all other toothed whales, are not pointed, but flattened like spatulas (Plate 116/117). While all the teeth of dolphins and killer whales resemble canines, the porpoise has an entire set of 'incisors,' though the teeth set farthest back and hidden in the gum have crowns that are somewhat broadened. These spatula-like teeth are, for the most part, probably not homologous with real incisors, but their shape is similar and corresponds with the sense-active character of this smallest of the whales.



It is also worthwhile to consider the peculiarities of the whale's teeth in general. Kipp (1952) has already delineated in Goethean terms the connection between the teeth and the limbs, in calling attention to the fact that the stunted growth of the whale's teeth corresponds to that of the limbs. The whale's main organ of propulsion is the posterior vertebral column, the tail, which has at its end finlike, boneless projections (the flukes), carried in a horizontal position (the tail fins of all fish are vertical). The fingers of the forelimbs have fused to form paddles, and the posterior limbs appear only in the embryo when it is about 2 centimeters long. By the time the body has reached a length of about 3 centimeters, the leg rudiments have already atrophied. In newborn whales, tiny vestiges of the pelvis, femur and tibia are found, without any connection with the spinal column and hidden deep within the root of the tail. This atrophy of the limbs corresponds to the lack of teeth in the baleen whales.

The relationship described by Kipp has even greater implications. For the seal's curious tendency to increase its number of teeth has progressed even further in the small whales. Instead of a few many-faceted teeth, they have many, each with only one cusp. A dolphin may have as many as 67 teeth in each ramus of both the upper and lower jaws, or a total of about 270 teeth. This increase appears again in another form in the forelimbs, where in an entirely unique development, each of the fingers, having fused, nevertheless

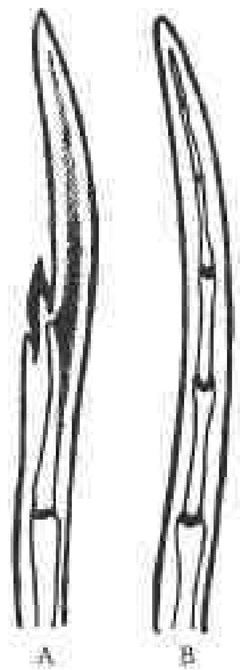
12. Forearm skeleton of the pilot whale: a) upper arm, b) radius, c) ulna and the 5 fingers, with 4, 14, 11, 3, and 1 finger bones (after Flower/Weber).

grows more than the usual three finger bones. As many as fourteen such bones may be contained in a single whale finger. This is especially true of the toothed whales, but not at all of the baleen whales, whose teeth have completely degenerated. These elongated whale fingers have been explained from the standpoint of expediency, as an adaptation for the paddling function of the anterior limbs. Yet it is difficult to understand why nature in this case alone should deviate from an otherwise strictly observed pattern, according to which most fingers have three bones. A similar lengthening of the surface of the forelimbs is accomplished in the eared seals by the addition of boneless cartilage to the fingers at a point beyond the roots of the nails (Plate 113). In the same way, the whale's dorsal fin, and indeed even its fluke, the principal organ of locomotion in swimming, lack bones. So lengthening the jaws by increasing the number of teeth and lengthening the forelimbs by increasing the number of bones are correlated—a concrete example of the close connection between the jaws and limbs[17].

In concluding this chapter on carnivores, let us turn once again to a terrestrial species, the bears. We have chosen to deal with them only at this point because their peculiarities must be considered carefully and accurately in light of the threefold concept. (See Plate 119.)

Bears are the largest land carnivores alive today. The brown bear still lives wild in the southern Alps (Krott, Lechner), the Pyrenees, the Balkans, and in Scandinavia (Pedersen), and is also found in Asia and North America; in Kamchatka and on the Kodiak Islands it reaches an enormous size. This animal can subsist on a completely vegetarian diet. Fruits and roots, grass and herbs, berries and honey are its favorite foods. It preys upon animals only when non-animal food is scarce, as for example in spring at the time of the salmon migration. It is a carnivore with a particularly well-developed metabolism and its basic characteristics have been strongly influenced by the digestive system.

Contrary to our expectations, however, bears, with the single exception of the polar bears, do not choose the water as a habitat. We believe that this surprising choice of habitat is connected with the fact that the bears are related less to the cats, dogs, or even seals, than to the marten family! This remarkable connection becomes obvious when we examine the special characteristics of the bears, and it sheds light upon many riddles posed by their biology. Based on the following evidence they appear to be close, yet metabolically oriented, relatives of the marten family. Like the martens, they have relatively unspecialized limbs that cause the large bears, in particular, to appear clumsy. Anterior and posterior limbs are short, hands and feet are also rather primitive. So the bear, like many small carnivores,



13. Sketch of the forefin of an eared seal (A) and a whale (B). A) shows 2 of a total of 3 finger bones, as well as the nail and the elongated fin tissue, while B) shows 6 of a total of 7 finger bones (after Leboucq/Weber).

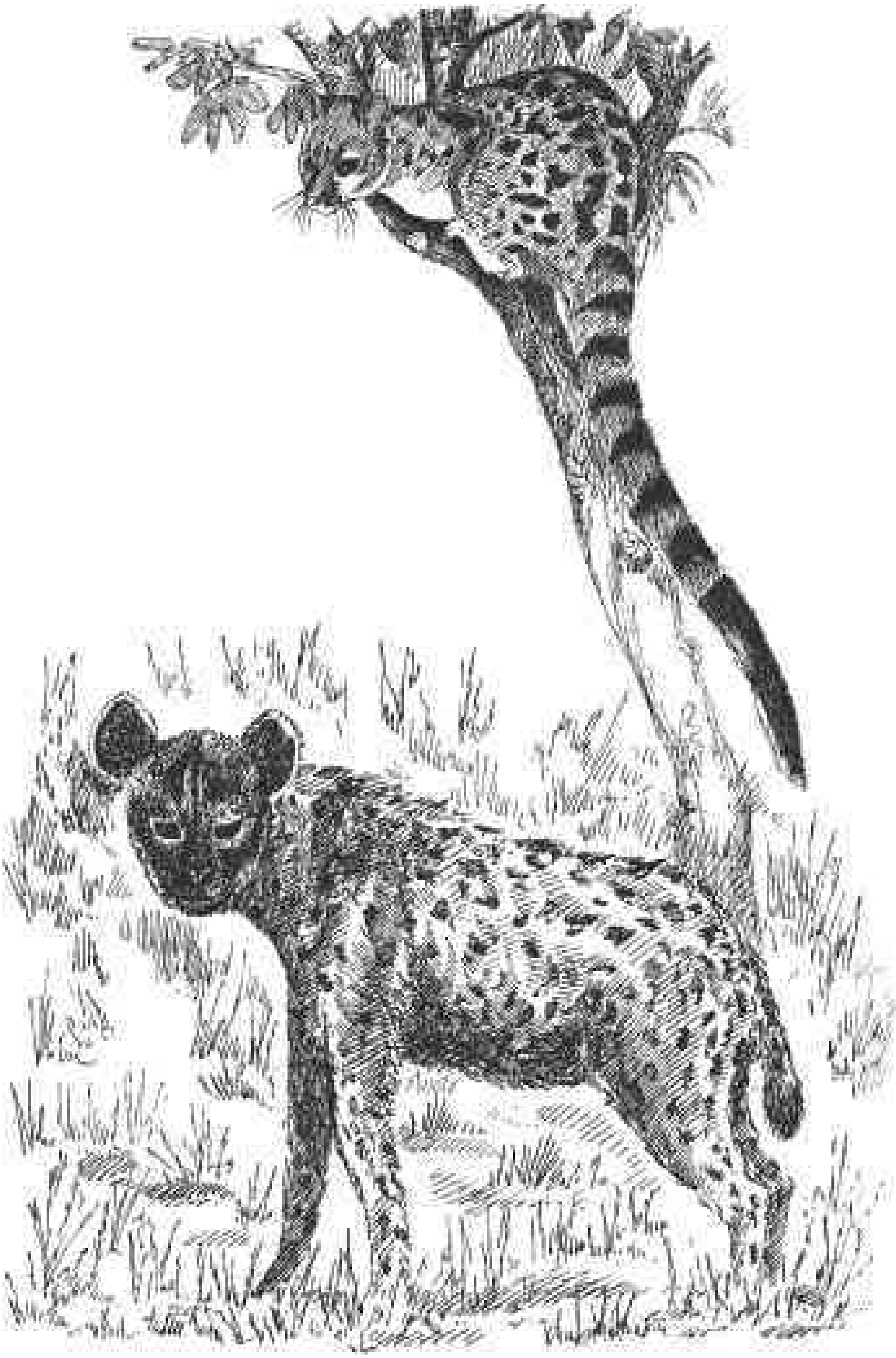
runs on the flat soles of its feet. Like those of the martens, the bone sutures of its cranium are fused. In particular, however, it is the bear's conditions of propagation that can be explained only by a close relationship with the small carnivores. (The following remarks are based on statements made by Starck, 1956 a; Mohr, 1958; and Slijper, 1960.)

Bears bring into the world rat-sized, almost completely naked young weighing little more than a thousandth part of the mother. For such large mammals, this is most unusual. How do these young compare with those of other carnivores? Newborn seals and whales have almost finished their development and live, from the first day of their lives, like complete, small replicas of the adults. At birth they have already opened their eyes, are covered with fur (with the exception of the whales, which remain hairless throughout life), are able to regulate their own body heat, are already quite capable of coordinated movement, and have almost completed the convolutions of the brain. All these developments are still lacking in the young of weasels and martens when they enter the world. Immature, indeed in an embryonic state, hairless and still completely dependent, they lie in the nest for several weeks, until at last they reach a degree of maturity comparable to that of newborn seals. The balanced, central carnivores, such as cats, dogs, and their closest relatives, are born in a median stage of maturity. At first, their eyes are shut, although their fur has already grown; mobility and the regulation of warmth mature after a short time.

Small, newborn bears, however, are definitely of the unfinished, embryonic type. The cerebrum is as yet unconvoluted, their eyes open only after thirty days, and only after eight weeks do they appear to be able to hear; for a long time their ability to maintain bodily warmth remains dependent on the mother. All this is even more astonishing when we consider that the brown bears give birth to these helpless cubs during the coldest time of year, in the middle of winter, when food is scarce. Without leaving the winter den, the mother warms the young for months in the fur of her belly and suckles them until they grow large, without taking food herself. The embryonic period is thus continued outside the body of the mother, until the young reach the degree of maturity appropriate to such large mammals. Only in the spring, when the young animals come forth into the sunlight, having become physically self-sufficient at last, does the actual 'birth,' take place.

The inadequacy of trying to explain the bear's biology of propagation as an expedient adaptation is shown dramatically by the polar bears. Mating takes place towards the end of the polar night, at the end of March or beginning of April. The development of the embryo, however, is arrested at an early stage until the end of October. This 'pre-gestation period' is also known to occur in many members of the marten family (such as the common

14. *Above*, the genet, an African civet that has spread through Spain into France (1/7.5 X), *below*, the spotted hyena, native only to Africa (1/12.5 X).

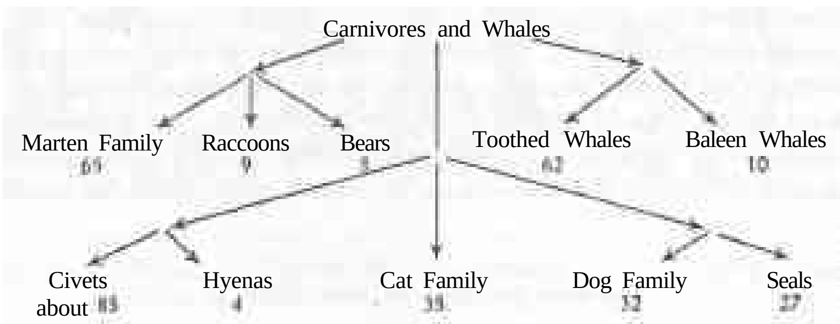


weasel, ermine, beech marten, pine marten, otter, and badger). Among these small carnivores the short gestation period which follows mating in the fall is thus arranged so that the young are born only in the warmth of spring; yet the opposite is true of the bears. Just at the onset of winter embryonic development resumes; in the midst of the most extreme cold, in January, deep within the snow caves over which arctic storms are raging, the tiny, naked, warmth-requiring young enter the world, almost as embryos. Here, causal and teleological explanations break down. But the essential character of the bears is expressed all the more clearly in the very circumstances of their birth; these clearly indicate a close relationship between the bears and the small carnivores of the marten family. Yet, that they are born enclosed within dens at midwinter also expresses the complete independence of their strongly metabolic nature. In space as in time, these large carnivores withdraw from a surrounding world and time of year that are better suited to sense-active species, surviving purely on the strength of their metabolism.

The entire nature of the bear is based on the fact that it is, in a sense, a small carnivore that has grown large. The bear is like a giant baby, large-headed and relatively short-legged, which never achieves the specialization of the cats, dogs, seals, or whales. In its basic characteristics it most nearly resembles the badger, the metabolically oriented counterpart of the weasel. It is true that the large bears are for the most part uniform in color; but when young, the brown bear has around its neck a broad, light ring that calls to mind the bright patterns of the badger (Plate 119).

Between the martens and the bears there is outside Europe an intermediate family of carnivores, the raccoons *(Procyonidae).* The North American raccoon belongs to this group, as does the Chinese panda. Together, these three species form that group of carnivores whose organization is primarily directed towards the surrounding world.

In the following chart all groups of carnivores and whales are brought together, and thus a preliminary attempt to clarify their threefold relationship is made. In the interest of completeness, the civets and hyenas, related to one another through the aardwolf (Plate 120), have also been included. The placement of the dogs will be mentioned again the ninth chapter. The numbers indicate the existing species.



V The Rodents

When I consider the rodents, . . . I realize that they are inwardly determined generically, and held within strict bounds; outwardly, however, they have undergone limitless transformations and have been altered in the most diverse ways. . . .

[We observe] in the rodents the acute but limited ability to grasp objects, the hasty appeasement of hunger, followed by repeated gnawing of objects. This continuous, almost convulsively passionate, unintentionally destructive gnawing, however, directly serves the goal of building and furnishing shelters and burrows, thus proving once again that in organic life even the useless, indeed, even the injurious, are within the necessary circle of existence and work within the whole as an essential and living means of binding together its disparate individual parts.

In general, the rodents have a well-proportioned basic design; the extent to which they vary from it is not too great; yet the entire organization is open to impressions of all kinds and is predisposed to a versatility that leads in all directions. . . .

The organ of grasping, the two incisors in the upper and lower jaws, has already claimed our attention: these teeth are adept at nibbling anything and everything; . . . this gnawing should be regarded as a kind of snuffling pre-tasting that has, in addition to the appeasement of hunger, many other purposes. It promotes a superfluous intake of food for the purpose of materially filling the stomach and might also be regarded as continuous excercise, a restless urge to be occupied that may ultimately lead to destructive fighting.

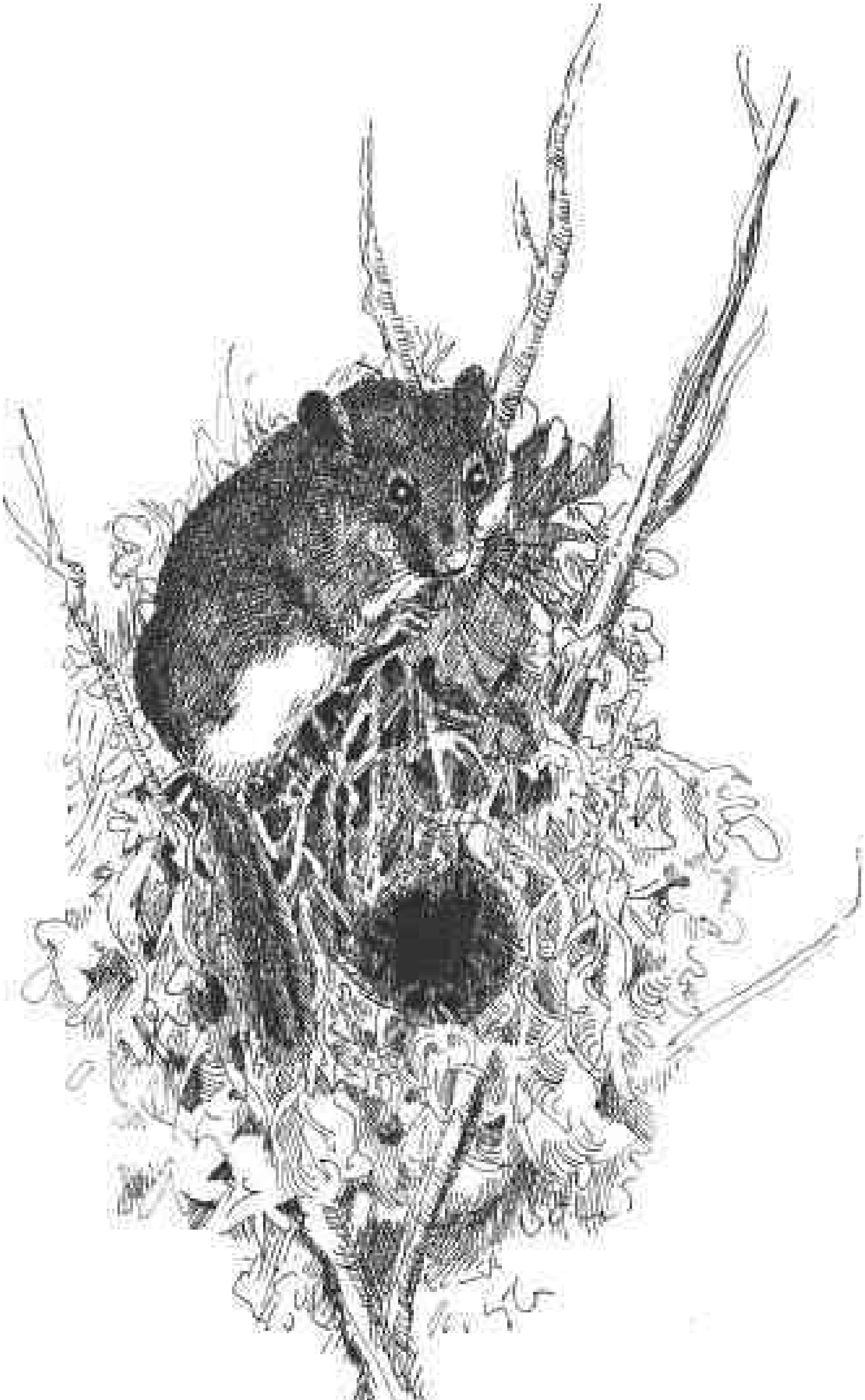
In these words of Goethe (1824), much of the rodent's nature is revealed to us at once. For just as the nerve-sense processes work within the individual organism to debilitate it biologically, so too do these nervous mammals work destructively in the world that surrounds them. A cow, it is true, pulls up grass for her nourishment, but what fertility is returned to the soil in her dung! The hasty digestive processes of the mice, however, so greedily consume nourishing substances while they are still in the digestive tract that only desiccated, mineralized residue remains. At the same time, Goethe emphasizes that even the most destructive activities of the rodents have meaning within the totality of nature's workings.

If we study comparatively the physical attributes of these animals, we see that in almost all cases they are remarkably small. The trunk and limbs in particular have extraordinarily basic, unspecialized forms. The hands and feet have five fingers and toes, the claws remain small, and the skeletal structure of arms and legs is virtually unmodified. These small animals are still genuine plantigrades, since their heels touch the ground. The stomach and intestine of typical species are simple, that is, formed without additional chambers. The two uterine tubes have not fused with one another; the mammary glands are still divided into two rows along the embryonic mammary ridge and extend over the entire length of the body's ventral side. In marked contrast, however, the head is highly specialized. All canines are missing, and in many species the molars have become strange, rootless prisms, reduced in number. The incisors are so well developed that they dominate both upper and lower jaws, and their roots extend far back within the bone structure of the mouth. One studying only the bodily skeleton of a rodent would scarcely believe that he had before him a highly developed animal. "The rodent's head is quite highly specialized, but its body generally is not" (Landry). In this animal it is the nerve-sense pole whose development takes precedence over that of the rest of the body; in both size and formation, the latter remains almost embryonically primitive.

What cannot be developed physically by such an unfinished organization is often supplied by outer activity and craftsmanship. Thus the rodents supplement their minimal bodily covering by eagerly and painstakingly constructing their nests, adding from without what their limited physical development no longer supplies. The nests of mice, squirrels, dormice, marmots, beavers, and other rodents may therefore be considered bodily sheaths, which are formed not through the unconscious growth processes of embryonic development, but through the aid of the waking nerve-sense system, which instinctively gathers these protective coverings and adds them from without to the fully grown body. Thus, through conscious activity in the outer world the rodents compensate for a physical development that has been cut short by the early beginning of the nerve-sense processes. And it is these supplementary bodily coverings that enable the rodents to exist and to withstand the onslaught of sense impressions that would otherwise overwhelm them.

This external compensation for undeveloped physical capacities is carried also into the rodent's method of obtaining food. The ungulate, when it ruminates, first allows its food to slide down into the omasum, regurgitating it once again for thorough chewing. Similarly, the hamsters and squirrels first stuff food into their cheek pouches and then gather it into the 'extra-bodily' chambers of their underground storage places before taking it into their mouths a second time. The food supply that the bears, whales, wild boars, and cattle are able to store internally as fat deposits is accumulated by many

15. Common dormouse on its carefully woven nest (natural size).



rodents, especially those that hibernate, in the form of kernels, nuts and roots that they pile up next to them in their burrows (Plate 121). It is true, of course, that some rodent species do become obese, especially at the beginning of hibernation; yet even these, as we shall discover, are able to do so only to the extent that the metabolic system secondarily predominates in them. In most rodents, instinctive behavior in the outside world must replace what can no longer be accomplished by the creative life processes of bodily growth[18].

Among European mammals the long-tailed mice *(Muridae)* are undoubtedly the typical rodents. One of Europe's smallest mice, the harvest mouse, is a charming, incredibly skillful little animal. Of all the mice, it builds the most elegant and artistic nests, which hang suspended in the underbrush and, like those of birds, are painstakingly woven from blades of grass. This animal is a light orange-brown on top and a sharply contrasting white beneath. Its close relatives, only slightly larger, have basically the same coloration, although in most cases the dorsal sides are darker and tend toward the brown and grey-brown tones. This is the case in the wood mouse (Plate 121), the yellow-necked field mouse (Plate 166), and the house mouse (Plate 122). In these animals large, protruding eyes, long, almost hairless ears, a slender, long-whiskered snout, and a conspicuously long, sparsely covered tail are signatures of an overly sensitive nature. The striped field mouse, less abundant than these other species, is closely related to them; it slightly de-emphasizes in its own organization their extreme accentuation of the nerve-sense processes. Less frisky and nimble than the wood mouse, quieter in its behavior, it digs hiding places in the earth, where it lays up small stores of provisions. It has smaller eyes and ears, a somewhat shorter tail, and a significantly altered coloration: its ventral side is whitish-grey, and on its reddish-brown dorsal side, along the center of its back, runs a dark stripe that is particularly well defined in young animals—a first suggestion of contrasting patterns on the dorsal side!

The black and brown rats also belong to the group of long-tailed rodents. Which of the three organic systems do they represent within this group? In comparing the two rats with one another, we find that the black rat, with its longer tail, larger ears, and somewhat smaller size, represents the more sense oriented species, while the heavier brown rat, with its blunt snout, is the more metabolically oriented of the two. The preferred habitats of these animals also differ. Both species follow human civilization. (The brown rat, following the shipping traffic of the seventeenth and eighteenth centuries, spread from Asia to all continents of the world.) The black rat (or 'roof rat') lives primarily in haylofts and attics, preferring, in most cases, the upper stories. The brown rat, on the other hand, prefers cellars, sewers and stables, particularly pig pens, and always selects damp, dank surroundings. These

16. *From the top down*, harvest mouse on its nest, wood mouse, and the rare striped field mouse (natural size).

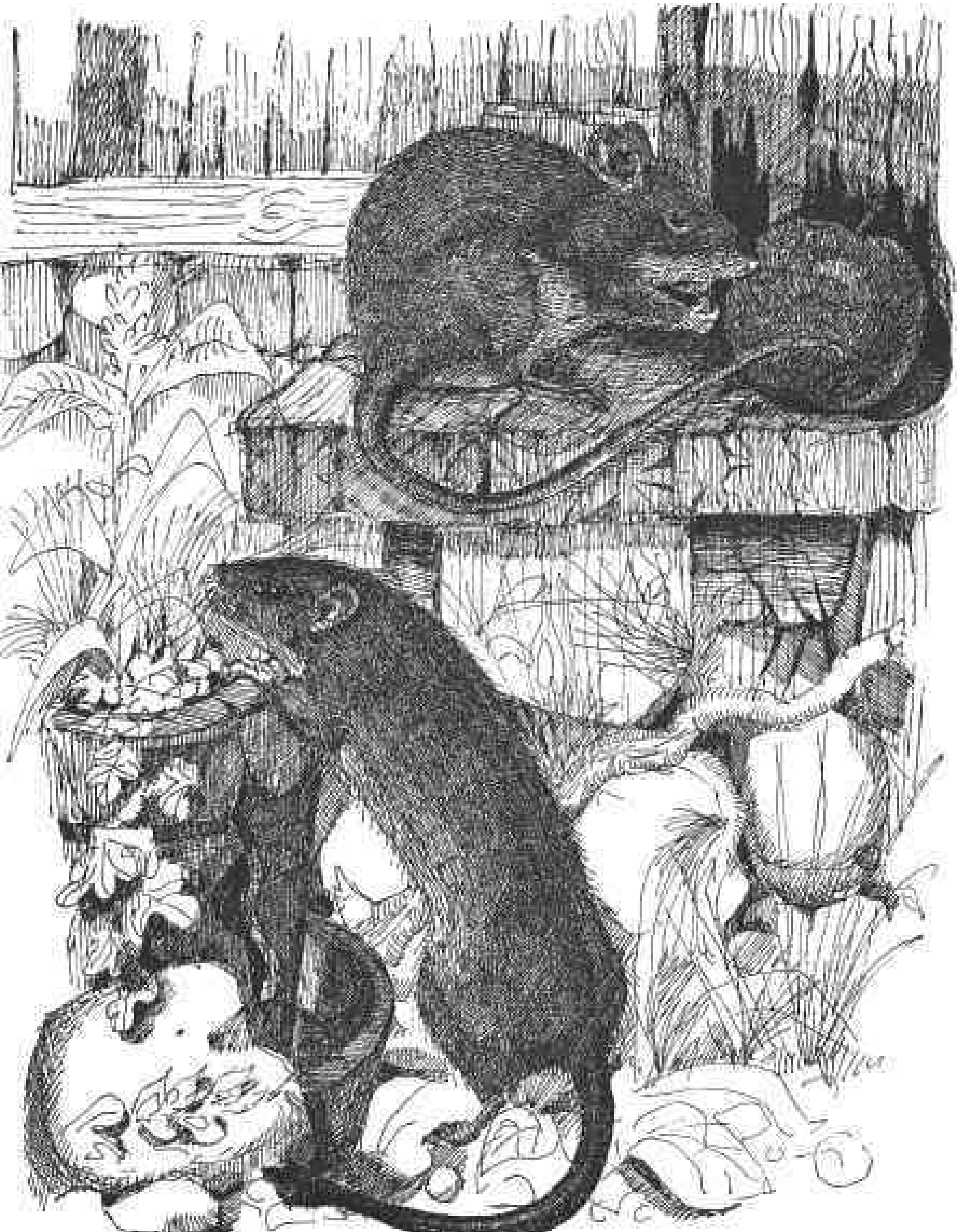
tendencies are reminiscent of the 'pine marten motif and the 'otter motif,' which we have discovered in our study of the marten family. Both rats thus demonstrate that they belong to a middle, or rhythmically oriented, group. Much that is directly observable—for example, the fact that they are carnivorous to the point of cannibalism when they encounter rats from different nesting communities—confirms this classification. The frantic, compulsive restlessness they experience as members of the most sense oriented of the rodent groups is combined in them with a predatory ferocity; it is precisely this combination that makes them rats[19].

What then must be the external appearance of the metabolically oriented members of this group of long-tailed rodents? As members of an extremely sense oriented group, they might be expected to show an exaggerated 'badger motif: large size, color inversion and contrasting patterns, the inclination to dig burrows, and perhaps a shortened tail, or a reduction in the number of species.

The animal that fits this description is the common hamster. Its color inversion is classic, and contrasting spots extend down along the sides of its chest. Whatever it cannot manage to accumulate as fat deposits within its body it stores in the larder of its burrow. (Thirty-five pounds of potatoes were once discovered in a single hamster burrow [Ognew].) In Europe the common hamster is the sole representative of its genus. Its closest relatives are the Near Eastern golden and grey hamsters, which range as far into Europe as the southern Ukraine and eastern Greece. In size, coloring and behavior, these two animals show a progressive loss of the metabolic capacities demonstrated by their larger cousin. And even this animal, despite its relatively well-developed metabolic capacity, shows strong evidence of a close connection with the nervous murids. An ill-tempered loner, the common hamster is active by day and loves the sunlight, despite the fact that it digs burrows. At the slightest disturbance it flies into a boundless rage, defending itself vehemently. This animal's strengthened metabolism scarcely conceals a life as frantic, as exaggerated and rash in its reactions, as that of any murid. The hamster's intimate connection with the murids is demonstrated not only in such aggressively nervous behavior, but even in the structure of its molars, which is basically quite similar to theis (see page 82-84).

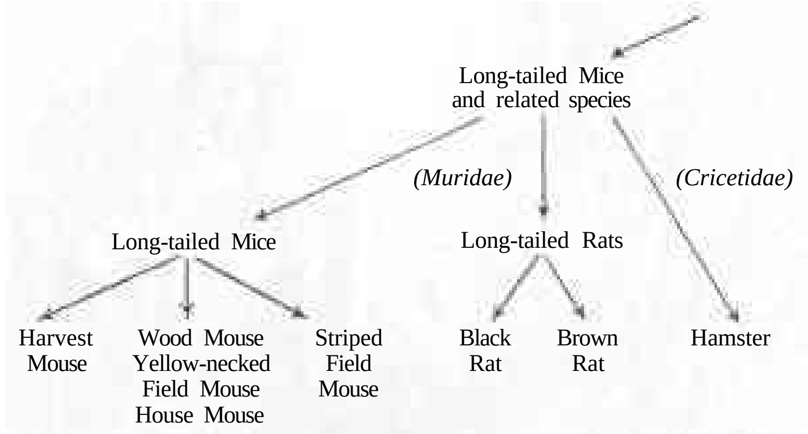
In North and South America the hamster family has split into numerous small species, which seem to replace in the faunal balance the Old World long-tailed mice that are not indigenous to these continents. Even the New World harvest mice, so similar in form to the Old World murids, are actually members of the hamster group *(Cricetidae)*.

17. Black rat, *above,* and brown rat (each 1/2.5 X).

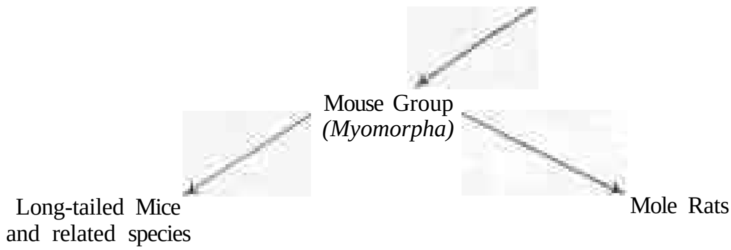


18. *From the top down,* grey hamster, golden hamster, and common hamster, showing increasing degrees of color inversion (1/3 X, 1/2.5 X, 1/3 X).

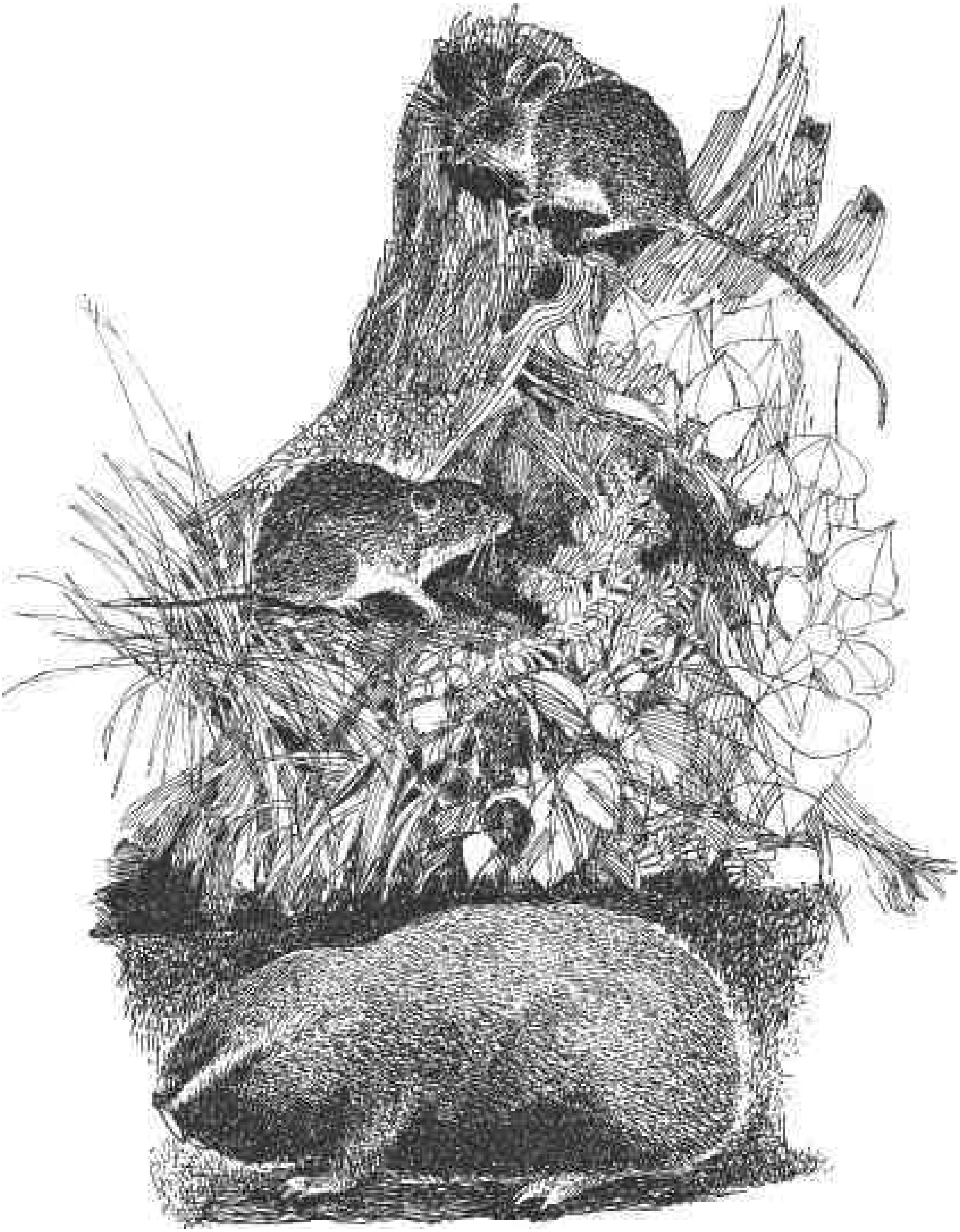
19. Enraged common hamster (1/2 X).



Fewer in species and even larger and more metabolically oriented than the hamsters are the mole rats. In the steppes of the Balkans and of Eastern Europe live two of the eight genera that make up this family. They live primarily underground, where they construct complicated systems of burrows ten to twelve feet in length and depth (Ognew); there, they feed on roots, which they consume in great quantity. Unlike the moles these animals dig less with their limbs, which are quite weakly developed, than with their large, protruding incisors. In these animals the head has become a real tool for digging and to some extent has even given up its sensory functions. Thus the eyes have shrunk to tiny vestiges the size of poppy seeds and are scarcely visible beneath the animal's fur. Both European mole rat species have a deep black coloring on the ventral side, while the dorsal side of the lesser mole rat is light brown, and that of the greater mole rat is quite dark, so that its coloration is virtually uniform. The heads of both animals, however, are masked with bright white areas and stripes. Relatively large animals, divided into few species, the mole rats are also members of the mouse group *(Myomorpha);* yet to an even greater extent than the hamsters, they are opposite the sense-active mice.

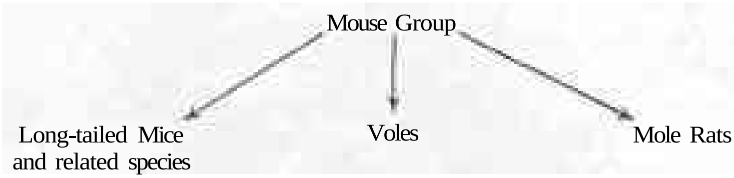


20. *From the top down,* wood mouse, common vole (both natural size) and lesser mole rat (1/3 X).



There is also in Europe a central family of mouse-like rodents. These animals choose a habitat that lies between those of the murids and the mole rats: while the long-tailed harvest, field, and wood mice live either on the surface of the ground or just above it, and the mole rats live deep underground, these central animals burrow just below the surface. These animals are the voles. In most cases their dorsal sides are of a greyish-brown color that merges gradually with the greyish-white, dull coloring of the underside.

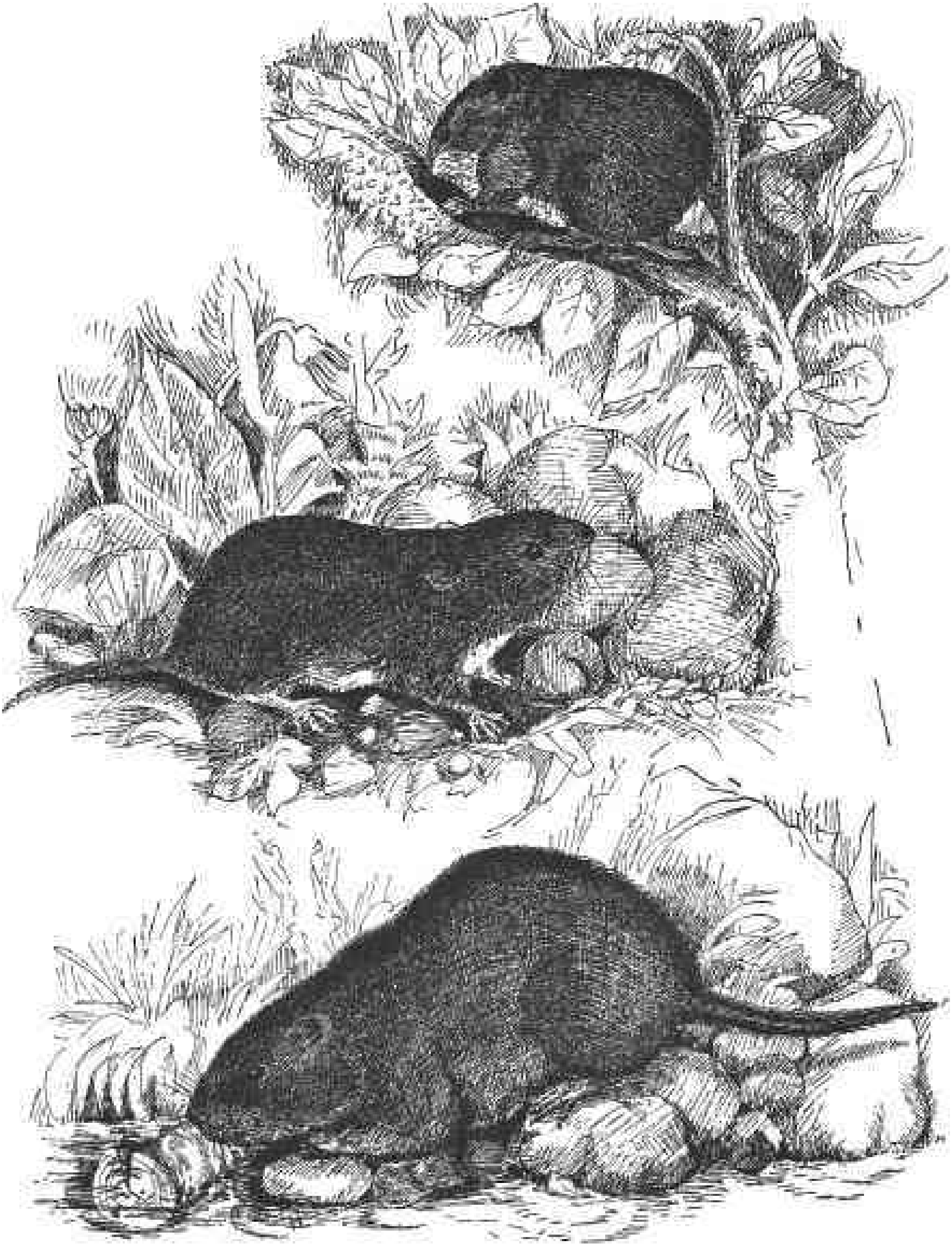
While the hamster has a relatively short tail and the mole rat has none at all, the vole's tail is of medium length and somewhat more heavily covered with hair than those of the long-tailed mice. The ears, barely visible above the fur, the blunt snout with its very short whiskers, and the scarcely protruding, tiny eyes are all indications of a nature that is not very open to the outside world.



The centrality of the voles becomes even more obvious when we examine closely the range of species that make up this group. Typical are the voles that live in open fields, avoiding forests as well as houses and barns. Nevertheless, there is one member of this group that prefers woodlands and parks: the bank vole, a rather slender animal with a warm red coloring and the largest ears of any member of the vole group (Plate 123). It scarcely burrows at all, but for the most part lives above ground, even climbing into trees and bushes in order to eat tender young bark (Wrangel). It sometimes eats even insects and young birds (Weber). Thus in diet, as well as habitat, this animal shows tendencies typical of members of central groups.

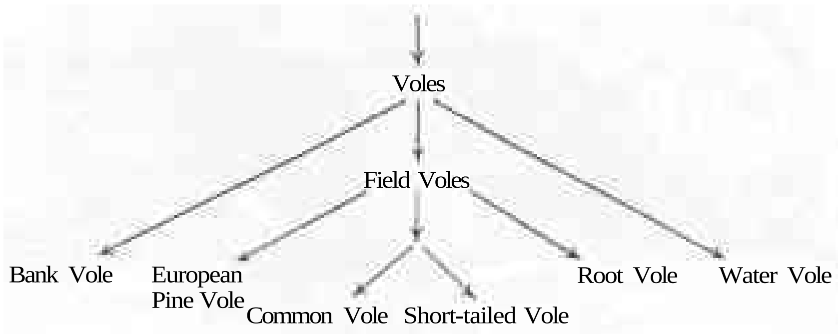
In direct contrast to this sense oriented member of a central group is the largest of the European voles, the water vole. A burrowing animal, the water vole also indicates in its coloration the relative strength of its metabolism; this animal is dark brown on its upper side and grey underneath. Its choice of habitat is also striking: it likes the water and often lives near it, without being firmly bound to it. Thus, in these two animals, the metabolically oriented water vole and the sense-active bank vole, we find once again the 'otter motif' and 'pine marten motif' discovered in our study of the martens. These motifs, as we recall, indicate that these animals belong to a group that is strongly influenced by central, rhythmic processes. The feral muskrat

21. Bank vole, common vole, and water vole (each 1/1.5 X).



(introduced into Europe from America) is also a member of this central group and is quite well adapted to water. This large rodent has even developed webs between its toes and has a laterally compressed, paddle-like tail.

To a lesser degree the smaller field voles demonstrate similar tendencies: the pine vole shows a slight inclination towards life in the forest, while the root vole shows a preference for very wet, marshy areas. Indeed, the most numerous and characteristic European members of this family, the wide-spread common and short-tailed voles, are so similar that they can scarcely be distinguished from one another. Still, the common vole is a little smaller than the short-tailed vole, and its coloring is somewhat paler. The former prefers dry fields and meadows, the latter, a damp environment with denser vegetation, such as may be found in fallow ground, pastures, and forest clearings. In these animals polaric tendencies have reached the greatest possible degree of closeness. Even so, to careful observation they too reveal characteristics that give a true picture of the objective processes of life itself.



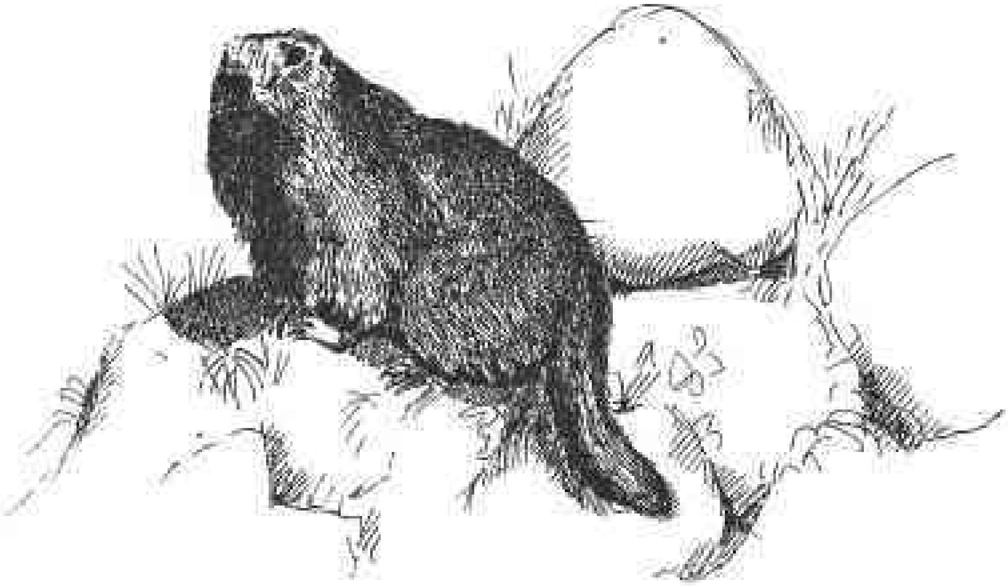
With the help of the owls, we can easily study the dentition of these small rodents. We need only search in some ancient church spire or hay loft for owl pellets, the undigested remnants (the hair and bones) of their prey, which the owls regurgitate as little balls that pile up beneath their roosting places. When we carefully dissect these pellets, we often find fully preserved rodent skulls, cleaned of all flesh by the strongly acidic digestive juices of these nocturnal birds. Primarily, these are vole skulls, which can be recognized by their prism-shaped, rootless molars. Mouse skulls, too, are frequently found, with rooted molars. These are the skulls of the long-tailed mice, particularly the wood mice. The entire group of long-tailed mice, rats, and hamsters has such many faceted, short-crowned, rooted molars. The field voles, on the other hand, as well as water voles, muskrats, and mole rats, have rootless, prism-shaped molars. In these animals the root canal never closes to form a root, but remains open so that the tooth continues to grow throughout the animal's life. What is worn off at the top of the tooth through chewing is replaced from below.

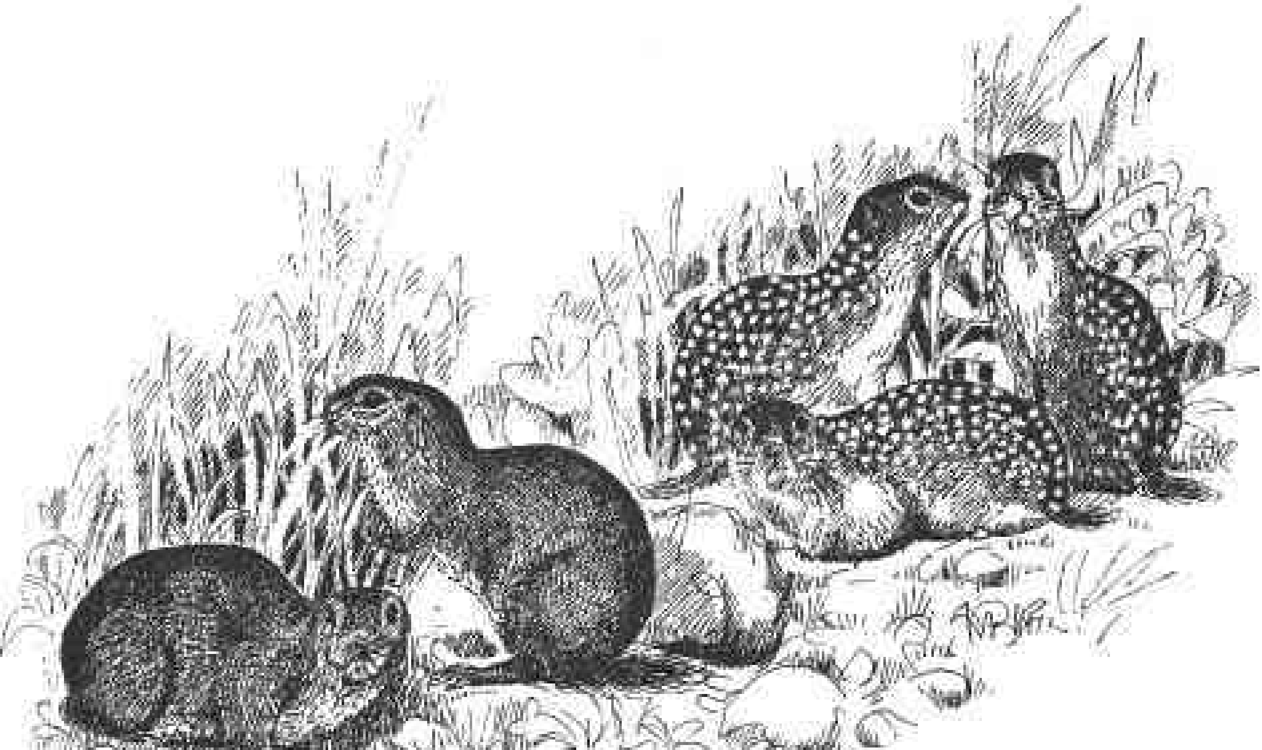
The rooted molars of the long-tailed mice, rats, and hamsters also wear quite well. Their durability, however, is not the result of uninterrupted growth processes but comes about because the porcelain-like enamel (formed from the embryonic ectoderm) that covers the surface of the teeth is so hard that the teeth suffer little wear. Thus, as we might expect, the sense oriented species achieve through a *hardening* of the enamel that covers the teeth the durability that metabolically oriented species accomplish through the continuous *nourishment* and *growth* of the teeth themselves. An exceptional case supports this rule, for the bank vole first develops molars of the rootless variety typical of all voles; yet, as the most sense oriented member of this group, it closes off the roots of its molars at the end of six months! In this sense oriented vole the processes of growth thus gradually come to an end in the head. All this information (as well as similar data to be found in the skulls of shrews, and occasionally of moles and small weasels) can easily be obtained from the pellets of owls.

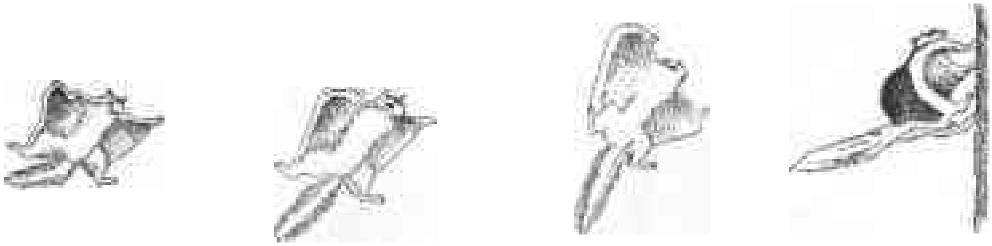
How different from these sensitive rodents is the squirrel! If, indeed, many people regard mice and rats with a certain reserve, the squirrel, with its refreshing appearance, is pleasing to everyone. (Almost all picture books for children contain at least one picture of a squirrel.) In its own way this animal manages to overcome the dark, fearful character of the mice and rats. It is true, of course, that the squirrel is also a nervous rodent: it twitches constantly and its movements are jerky and abrupt; its coloration, too, is typically sense oriented, with reddish dorsal and white ventral sides. But its entire form is harmoniously organized. Its long-haired, bushy tail, unlike the naked tails of mice and rats, in no way stands out from the basic shape of the rest of its body. And how strong and agile this animal is! Active from early morning, full of daring and joyous playfulness, it scampers boldly through the branches of trees. Conifer seeds, nuts, and fruits are its favorite foods; yet in summer it also eats caterpillars and even snatches eggs and young birds from their nests. There is a small carnivore hidden within every squirrel! When we watch a squirrel in life and understand the significance of these characteristics, it becomes clear to us that the life pattern of the squirrel must rest upon strong rhythmic processes, which have completely permeated its basic rodent form. The squirrels, together with other rodents closely related to them, such as the dormice, susliks, marmots, and beavers, thus form a second large group next to the group of mice (myomorphs): the squirrel-like rodents. These are the genuine central rodents.

Next two pages:

22. *From the top down,* two flying squirrels at play, European red squirrel (each 1/3.5 X), and Asian chipmunk (1/2 X).
23. *From the top down,* Alpine marmot (1/7 X), spotted suslik of the Ukraine, and European suslik (both 1/3 X).







24. Flying squirrel landing (after Bourlière).

In the northern regions of Eastern Europe, Asia, and North America, lives a small, sense oriented member of this central group, the flying squirrel. This animal surpasses even the squirrel in its ability to climb and jump; it can sail through the air or even actively flutter (Lorenz, 1963) with the aid of a membrane that can be spread out between its anterior and posterior limbs. This animal is especially well equipped for a life high in the branches of trees.

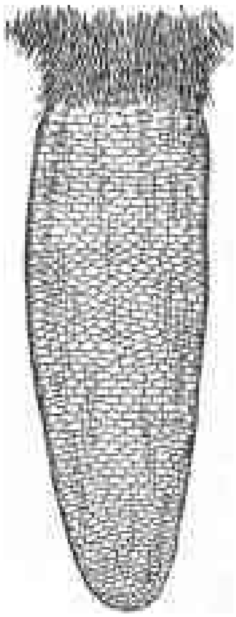
At the other extreme, the susliks and marmots, as the metabolically oriented members of this central group, have become ground-dwellers. In their coloration the white of the ventral side has disappeared and been supplanted by the brownish-yellow shade of the dorsal side. For the most part they eat foods composed chiefly of cellulose, although the suslik still eats seeds, as well as the flesh of animals (insects, young mice, and the young of birds that nest on the ground).

In the Alpine marmot the metabolically oriented members of the central squirrel group have completed their transition to vegetable food. Relatively sedate in comparison with the squirrel, even this large rodent remains dexterous and playful. In stony rubble it scrapes out deep burrows, filling them with the life of its large colonies. Outside in the sun, whether the marmots are feeding or at play, one member of the colony must always stand guard for all the rest. On hikes through the mountains we are often aware of the presence of these animals only because we hear in the distance a sharp warning whistle. Only by patiently and quietly waiting can we ever hope to see them[20].

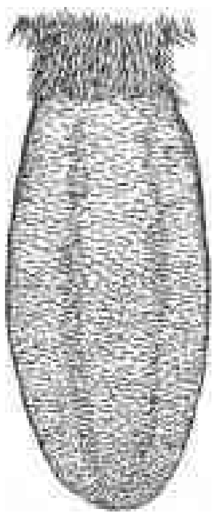
The largest of the European rodents is the beaver. It is the only species in its family and can attain a weight of 75 pounds (35 kilograms) and a length of 4 1/2 feet (1.3 meters). It is not, however, a burrowing animal and displays neither color inversion nor head patterns. Its fur is a completely uniform dark brown; its body, despite its large size, seems less fat or ungainly than compact and muscular. Its tail has become a broad, horny plate, covered with scales. Twigs and bark serve as its principal food. Furthermore, this

25. The beaver, second largest living rodent, requires a fresh water habitat (1/5 X).

metabolically oriented representative of the central rodent family is also this group's most thoroughly adapted aquatic animal.



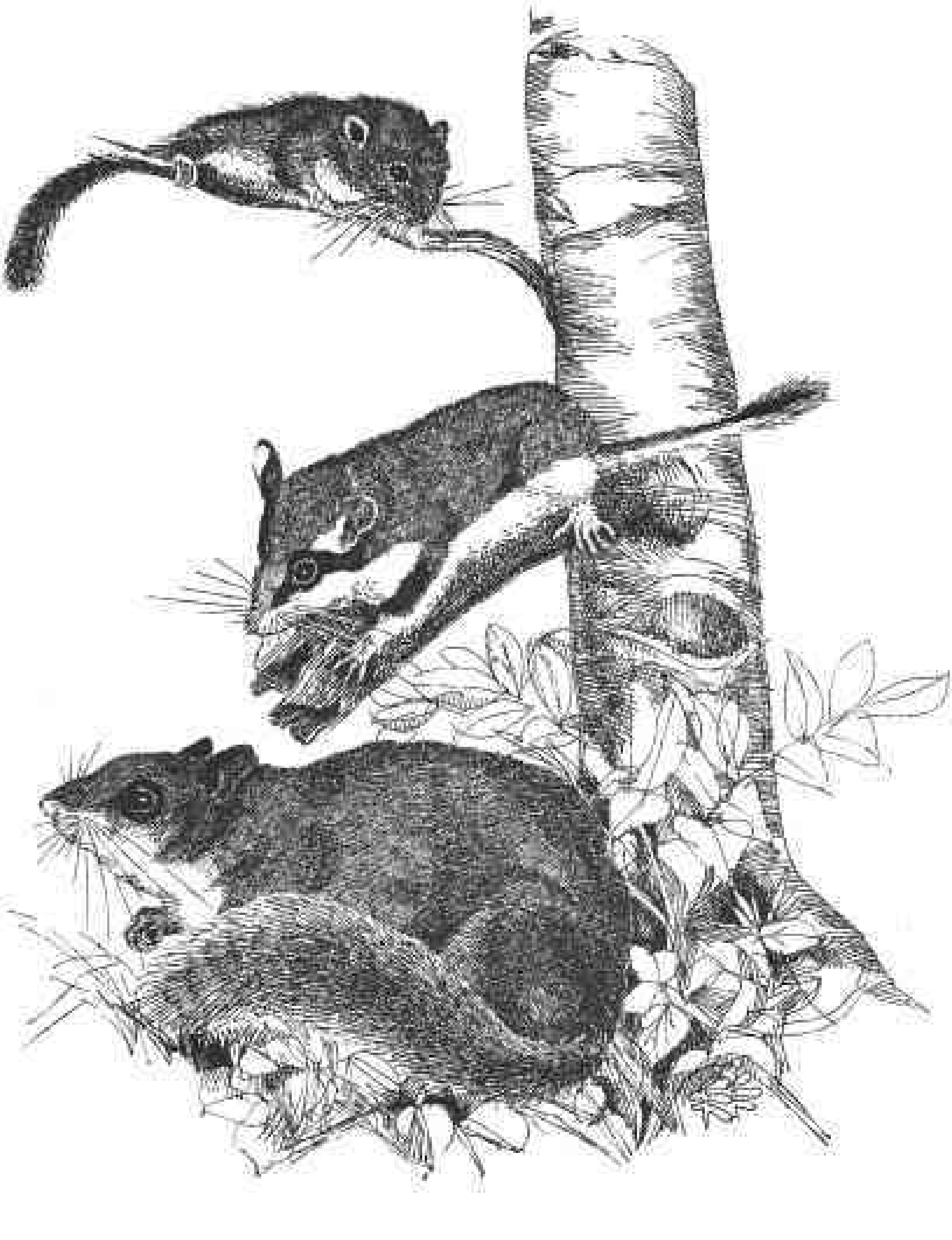
It is amazing what an orderly synopsis is made possible when we survey these basic correlative relationships. For a wealth of phenomena is revealed through the direct, careful observation of nature, and the order underlying these phenomena becomes clear when we study them according to the threefold principle. The beaver, for example, is a living manifestation of the motif demonstrated by the otters, seals, and whales. And it is hardly surprising that the same motif should recur, for when we describe in the form of ideas relations that actually exist in nature, we take an active part in processes at work in the world of living beings that surrounds us. What light is shed upon the beaver when we regard it as the most metabolically oriented rodent of the middle, or rhythmic, group! As a rodent, it is still subject to the influences of the surrounding world, yet at the same time its metabolic strength enables it to exert a regulatory influence upon its own aquatic environment. For the building of dams when water reserves are low and the digging of canals in swampy areas, as well as the constant regulation and control of these structures, are not only advantageous to the beaver, but are also necessary to the health of the ecosystem as a whole, as has been rediscovered in recent studies of the Canadian beavers (Pilleri, 1962)[21].



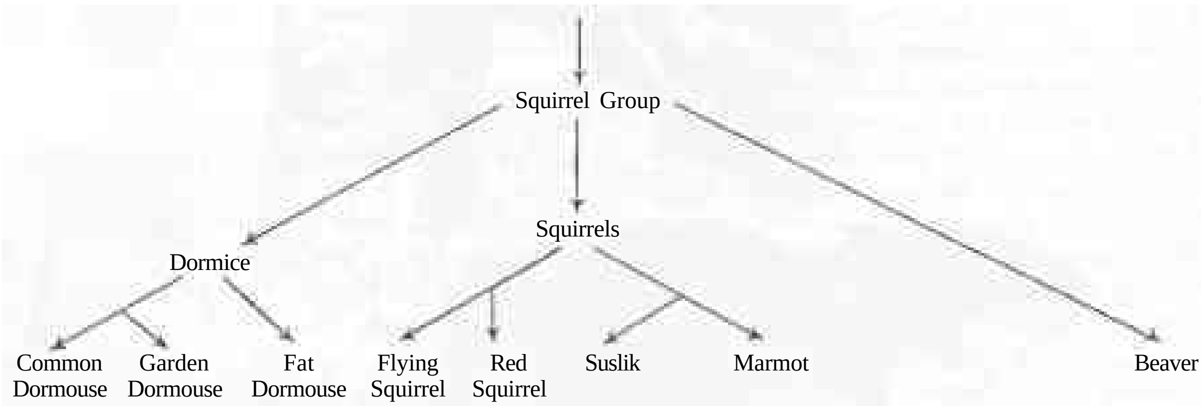
Within this central rodent group the animals polarically opposite the beavers are the dormice. These animals are nocturnal, and, with the aid of their long whiskers, large protruding eyes, hairless ears, and sensitive hands and feet, they keenly take in all their sense impressions. They are not at all rare in Europe, yet since they flit through the trees only at night, their presence is usually not even suspected. The largest of the dormice, the fat, or edible, dormouse, is smaller than the squirrel, though its body is similar in shape, and it has a long, bushy tail. Yet its upper side is a light bluish-grey, while the ventral side is, predictably, white. The edible dormouse is an unapproachable loner, snappish and quarrelsome, and never becomes quite tame when caged. In addition to eating fruits and nuts, it plunders birds' nests, consumes insect larvae and young mice, and even devours its own kind when the first members of a sleeping colony wake from hibernation. It prefers animal food to any other. This animal combines a nervous sensitivity with the 'carnivorous element' basic to the squirrel group, and the result is a rat-like, aggressive constitution. To understand that this is true one need only hear the unpleasant staccato snarl this animal emits when disturbed in its burrow. In Germany it is called the *Siebenschläfer* ('seven months sleeper') because its underground winter sleep lasts for seven months. At all other times it is definitely arboreal and often usurps the houses intended for birds.

26. The male beaver's tail *(below)* is shorter than the female's *(above)* (1/6 X, Gaffrey).

27. European dormice. *From the top down,* common dormouse, garden dormouse, and fat (or edible) dormouse (1/2 X, 1/2.5 X, 1/2 X).



In regions where fruit is abundant the smaller garden dormouse is found. This animal is more delicate in build than the edible dormouse: its nose is more pointed, its tail is brushlike rather than bushy, the white of its underside extends higher. Seen together with the black stripe above its eyes, however, its face shows at least a partial mask-like design, so that we may expect to find an even more sense oriented, smaller species. This animal is the common dormouse. As the smallest, most sense oriented of the dormice, it takes on many mouse-like characteristics. In doubtful cases, however, it can always be identified as a dormouse because of its tail, which is thickly covered with short hairs. Also, unlike the true mice, it has a genuine period of winter hibernation. There is nothing violent or irritable about this animal. In hazel and blackberry bushes the common dormouse, like the harvest mouse, builds an ingeniously woven ball-shaped summer nest with side entrances (Plate 15). Playful and easily tamed, it lives in harmony with the life of its surroundings. The yellowish-red of its dorsal side is the color of an animal open to the world. Thus the common dormouse and the beaver define the outer limits of this central, squirrel-like group of rodents.



The threefold concept also sheds light on the formation of the central rodents' teeth. While the dormice and squirrels have rooted molars, the molars of the beavers remain rootless, and grow throughout the animal's life, in the prismatic form typical of all metabolically active rodents. The central character of the squirrels is revealed in the fact that they are the only rodents to have canines; even in these central animals, however, the canines appear only before birth, in the set of milk teeth (Freund). Despite such striking correlations, it remains unclear why animals as small as the moles have developed prism-shaped molars, while the large marmots still have rooted ones. Obviously, there is still much to be learned about these complex relationships.

As our understanding of the unique and contrasting characteristics of the mice and squirrels deepens, we must ask whether there is a third large group of rodents, in which the rodent organization is thoroughly transformed by the metabolism. Between this group and the mice the centrality of the squirrels would become even more evident, for it would be possible for us to see the two groups between which these animals mediate. Rodents so strongly dominated by the metabolism would necessarily be large and would divide into comparatively few species. Could these animals possibly be the hares and rabbits, which have not yet been mentioned?

If we study the hares and rabbits according to our threefold method, we shall find that there is much evidence against such an assumption. If they were in fact rodents influenced by the metabolism, the rabbits would show a color inversion still greater than that of the hamsters and mole rats. Yet, their underside is white! Further evidence of their sense-active nature is found in their large eyes, long ears and whiskers, as well as their ability to evade pursuers. Their elongated posterior limbs, too (as we shall discover by comparing their form with that of the cattle discussed in the next chapter), are indications of a sense oriented constitution.

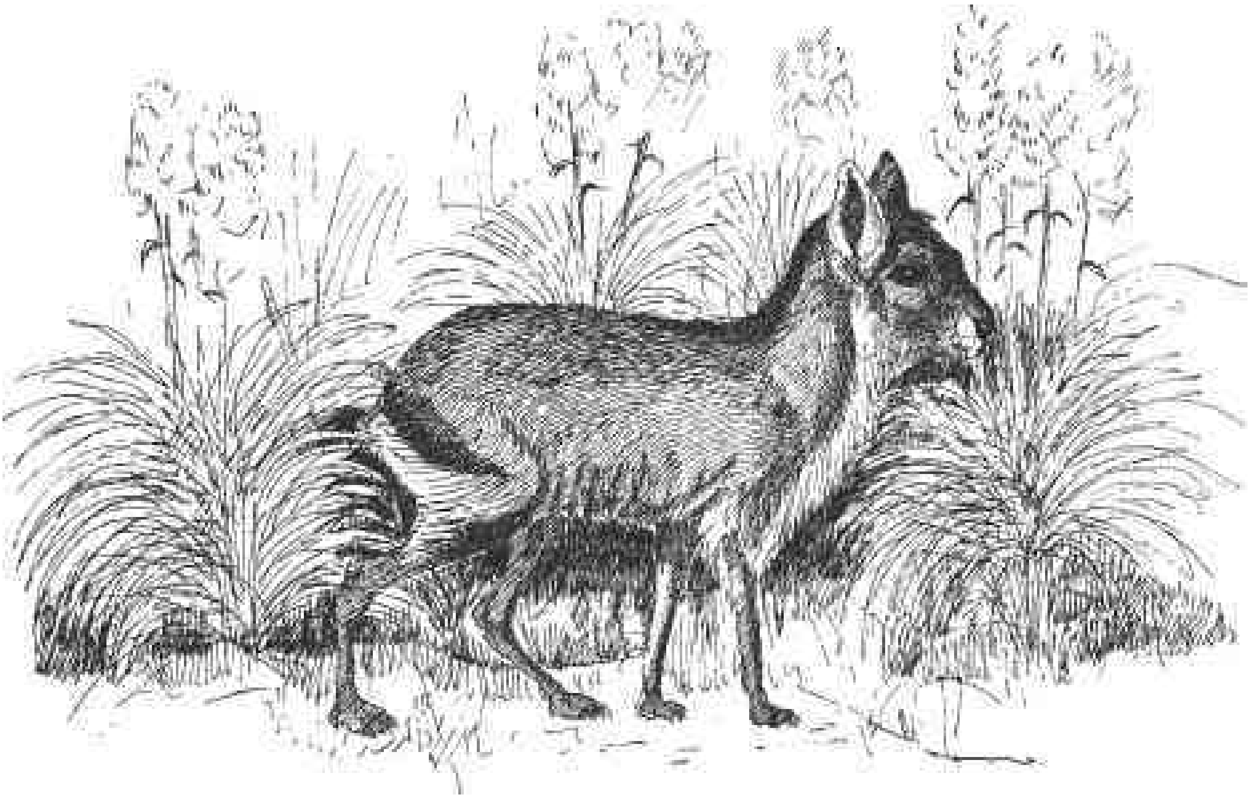
Yet the hares are much too large to be grouped with the sense oriented mice and rats. Instead, they form a remarkable, separate group of mammals, closely related to the rodents. This close relationship is apparent in the structure of their teeth: incisors predominate, canines are absent, and molars remain rootless. Yet behind each of the two upper gnawing teeth there is a small, pointed, additional incisor that no genuine rodent has! (For a more complete explanation of this phenomenon, see Chapter XIII.) In addition these animals appear to be more reserved, more self-sufficient, and stronger than the genuine rodents are. The many characteristics found in the hares but not in the genuine rodents have led taxonomists since Gidley (1912) to separate the hares and their closest relatives (the pikas and the rabbits) from the true rodents and to place them in a separate group; for despite their many similarities with these animals, the hares are really quite distinct from the true rodents.

The one genuine rodent completely ruled by the metabolism is the porcupine. What a remarkable animal! Large, clumsy, and so ponderous that it almost has the bearing of a pig, it is a solitary, cantankerous, and on the whole rather unpleasant animal that digs deep burrows and hides in the earth. It dramatically contrasts the dark coloring of its ventral side with its light-colored head and back. Extending over forehead, neck and back is a crest of long, white hairs that have hardened to form tough bristles that can be raised. At the posterior end of the back, these hair-like structures have undergone further hardening to form still thicker and longer quills, each one banded with brilliantly contrasting black and white stripes. The underside and tail have somewhat shorter quills. All that we have learned to recognize as characteristic of color inversion here undergoes its greatest exaggeration.

28. Crested porcupine of Africa and the southern regions of Europe and Asia (1/8 X).

This coloration is not only conspicuous, it is defensive. In direct contrast to the cryptically colored, highly sense oriented animals, which seek to hide in an environment that threatens to overwhelm them, the porcupine shows in its coloration absolutely no desire to blend in with its surroundings. Instead, in the formation of quills, it gives bodily expression to an utter rejection of the surrounding world. With the porcupine as an obstinately self-determined form, our picture of the rodents is complete.

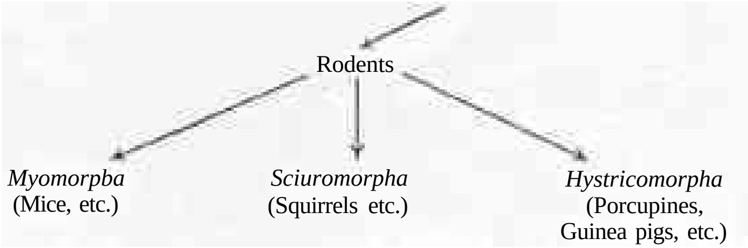
The metabolic character of these animals is also revealed in the fact that only three different species are found in all Europe, Asia, and Africa. The North African porcupine has also spread to southern Europe (central Italy, Albania, and northern Greece), to the island of Elba, and to the Roman Campagna, where it leads a completely nocturnal life.



29. The mara, of the Argentine pampas, is slightly larger than a hare (1/5 X).

The porcupines' more distant relatives, such as the American tree porcupines, as well as carpinchos ('water hogs'), maras and agoutis, pacas and pacaranas, live primarily in South America, although some of these have moved up into North America (Thenius, 1972). Better known in Europe are the guinea pig and the chinchilla. The former is a peaceful little animal that acquired its dappled coloration when it was domesticated in ancient times by the Incas. Snuffling quietly, it reconciles without difficulty the basic rodent nature and a strong metabolism. As valuable fur bearing animals the chinchillas are raised in captivity. With their silver-grey backs, white undersides, and large, funnel-shaped ears, they are the sense oriented representatives of the porcupine group. They look like overgrown mice and thus have acquired the German name *Hasenmaus* ('hare mouse'). They are strangely quiet little animals, yet their breathing and movements are quite jerky; they appear to be animals in which sense processes and metabolic strength exist side by side without any central organization to mediate between them. They seem torn between the two extremes. Active only at night, and lying semi-conscious in their burrows by day, they are pulled between the two extremes whether caged or in their natural environment, the heights of the Bolivian Andes.

In reviewing this chapter we find that many of the characteristics of form already discovered in the carnivores are also encountered among the rodents; in this group, however, those characteristics that are primarily associated with the sense organization are revealed with even greater clarity and distinctness. But the rodents are also a true reflection of the whole, since they, too, have divided into three different groups of related animals, each of which brings to expression one of the three main organic systems[22].

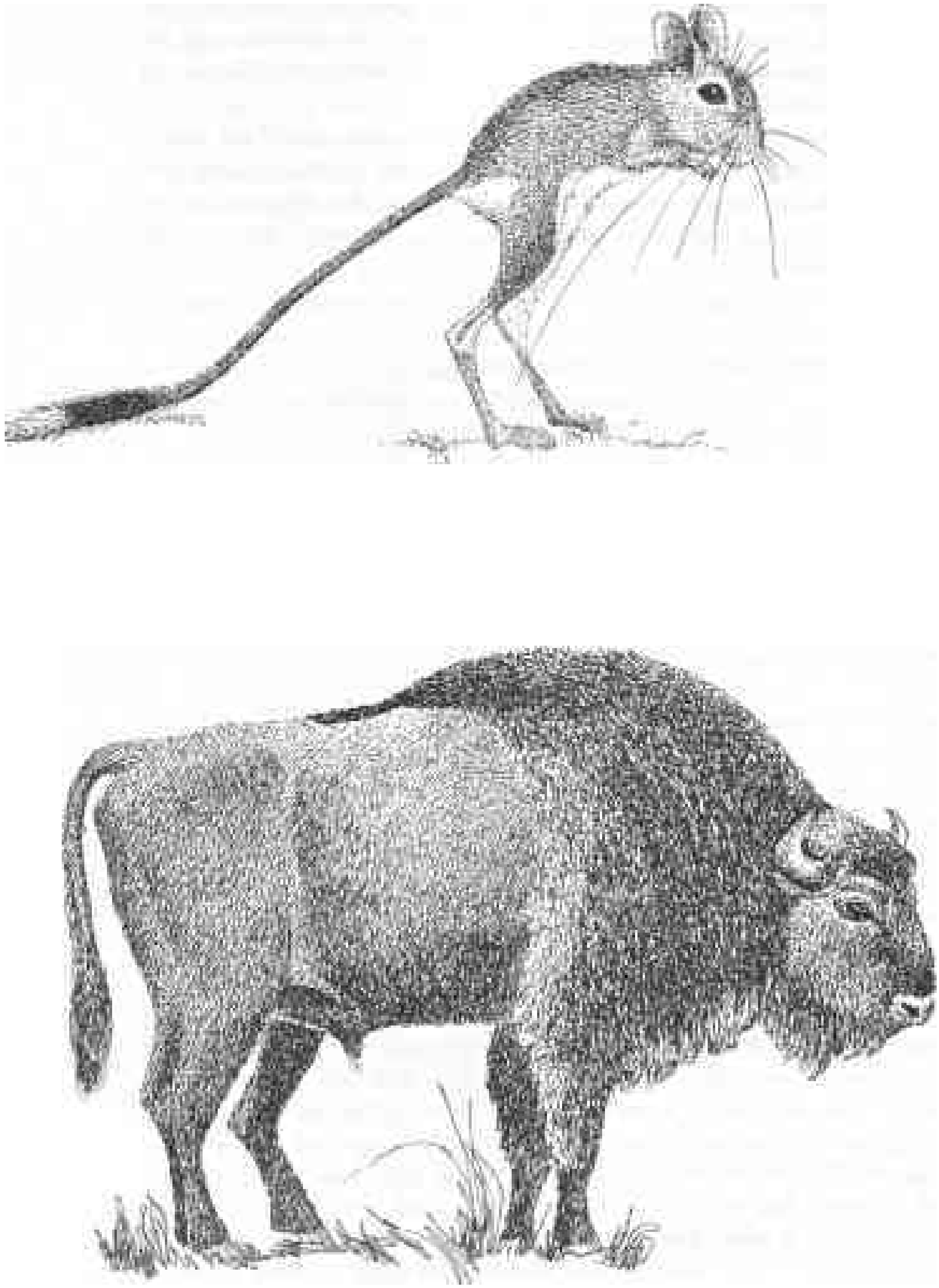


If the rodents are the nerve-sense oriented mammals, we may ask which of them are the more 'sense oriented' and which are the more 'nerve oriented.' If we recall the difference between the sense organs, so open to the outside world, and the brain, strictly closed off from its surroundings, we might expect to find the more sense oriented forms among the mice and the higher development of the brain among the porcupines.

Pilleri (1959, 1960) discovered that the brains of the mouse group are, in fact, little developed, that is, unconvoluted; both cerebellum and cortex show this limited degree of development. Many members of the squirrel group, too, have unconvoluted brains; yet, significantly, those of the marmots and beavers are convoluted. Most of the porcupine group have convoluted brains; only a few, such as the North American porcupine, have brains without convolutions. Particularly well-developed and numerous convolutions are found in the brains of the Old World porcupine and the carpincho, viscacha, and mara—that is, in the largest of the rodents. Pilleri also compared the different parts of the brain in these groups and found, as did Portmann (1962) and Wirz (1950), that the squirrel group is to be ranked below the porcupine group but above the group of mice.

Thus it is apparent that the development of the brain is closely connected with the formation of a strong metabolism. Ungulates have convoluted brains. Among the carnivores, the mustelids have only slightly convoluted brains, while those of seals and particularly of whales (Pilleri, 1962 a) are quite convoluted. As early as 1920, Rudolf Steiner made reference to the fact that there is a connection between the development of the cerebrum and the metabolic organization; he also attributed the extraordinary capacities of the human brain to the fact that it is so well nourished (1919 a).

The rodents, which have differentiated into so many specialized forms, may be regarded as an expanded spectrum of the many processes that constitute the nerve-sense system. The entire range of this spectrum can, of course, be revealed only when all the rodents of the world are carefully studied.

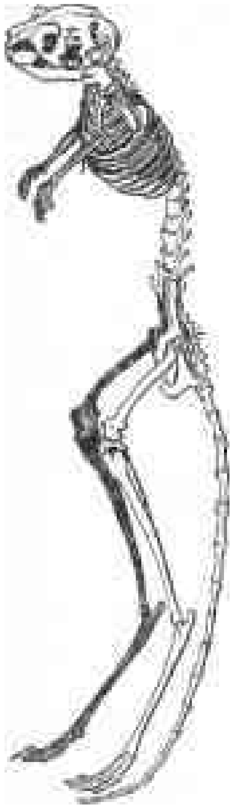


30. The jerboa of Egypt exaggerates the posterior pole of the body as much as the European bison emphasizes its anterior pole (1/3 X, 1/25 X).

VI The Ungulates

The ungulate group is characterized by its intensification, throughout the entire organism, of metabolic-limb processes. The large size of these animals is significantly connected with this strengthened metabolic capacity. In our study of the rodents and carnivores we have established already the relationships between the basic organization of an animal and its size and coloration. Since these same relationships hold true in the ungulates, we may now consider a third aspect of appearance: the outer form in its narrowest sense, the body's shape in space. The ungulates in particular demand such a consideration since most of them have on their heads some kind of protuberances, such as the antlers of deer and the horns of cattle, rhinoceroses, chamois, rams and others. Here we are interested primarily in the way these protuberances vary among the different ungulate groups and in discovering the ordered relationship that prevails between each of these variations and the physical organization as a whole. An examination of these relationships would reveal that such outgrowths of form are by no means arbitrary, but that their occurrence, their shape, their very placement on the head, follow strict and understandable rules. On the basis of this understanding such outgrowths emerge from the context of the particular species under consideration and are revealed as something true and comprehensible in themselves. We do not claim the ability to answer every question that may arise, but such an analysis would explain much that is not to be understood through causal or teleological theories.

Let us first consider the shape of two typical ruminants, the domesticated bull and the bison. Even if we ignore the head appendages, we see that the front part of the animal's body is strongly accentuated: in the bull, by the long dewlaps and powerful neck; in the bison, by the high withers and long, shaggy hair that covers the chest. The hind quarters, by contrast, are quite slender. The front pole of the body, then, is over-accentuated in shape, and the animal's physical center of gravity is also located here. This fact is strikingly illustrated in the way the bull or the bison stands up: first it straightens its less heavily burdened hind legs; only then does it raise the heavier, front part of its body. It lies down, too, in a way that is strange to us; first, it bends its front legs, laying the main burden of its body down upon the ground; then the back part follows effortlessly.



Animals whose basic organization is polaric to that of the ruminants are opposite in shape, as well. In the mouse, for example, the posterior limbs and the tail are over-accentuated in form. The entire front part of its body, including the forelegs, is less heavily burdened than the ruminant's, Quite the opposite of the buffalo, whose head is bowed down by heaviness, are all the sensitive rodents, which are able to sit up on their haunches and raise their heads. The European wood mouse can jump on its hind legs several times in succession, without once resting its forelegs on the ground. The jerboa of the Sahara, which shows the most extreme developement of this form, has such elongated hind legs that its forepaws rarely touch the ground. In addition, it has whiskers as long as its body and a tail twice its length. The rare European jumping mice, the so-called birch mice, are less characteristic of this family; their back legs are not so over-developed but the exceedingly long tail, nearly twice the length of the body, still marks them as members of this group. Smaller than the harvest mouse, these are the tiniest of the rodents found in Europe. In North America only the silky pocket mouse and some of its relatives are smaller.

31. Skeleton of the northern three-toed jerboa, of southern Russia. Note the elongated bones of the lower legs and the feet (1/2 X, after Brehm).

32. The birch mouse may be recognized by its very long tail, the dark stripe down its back, and its rooted molars, of which 4 are found in the upper, and 3 in the lower jaw (natural size).

In studying the rodents we must pay special attention to the posterior pole of the body. A long tail is evidently correlated with an exaggerated sense orientation. The voles, as we have mentioned, have tails of medium length, and the tails of hamsters are shorter yet. Similarly, the tails of the metabolically oriented suslik, marmot, beaver, and porcupine are relatively short in comparison with those of the dormice and squirrels. As the metabolic organization increases in strength, the body's accentuation of its posterior part and tail is reduced. A similar development may be observed among the carnivores when we compare the weasel with the badger, the wild cat with the lynx, the raccoons with the bears, and the dogs with the seals. The most metabolically active animals, such as whales and cattle, once again have rather long tails. These, however, unlike the sense-active tails of the rodents, tend to take on limb functions and have well-developed motor faculties. Furthermore, these tails by no means balance the accentuated anterior body of a whale or a bull.

This polarity between the sense oriented and metabolically strong animals seems quite natural to us. Yet closer examination reveals it as a remarkable phenomenon, for the physical and physiological-functional centers of gravity do not coincide but are inversely related to one another. In cattle the physiological emphasis is on the posterior part of the body, the metabolic realm, while the physical center of gravity is located in the front part, the area of the nerve-sense system. The rodents' physiological center, the nerve-sense system, is in the head, while the physical center of gravity is located at the body's posterior end.

In the central group of mammals, the carnivores, we find the jaguar and leopard, whose bodily shapes are in perfect balance. No one part of the body is accentuated beyond any other; every aspect is permeated with controlled strength and suppleness. The physical and physiological centers coincide in space and are functionally reconciled in all the rhythmic processes—especially in the heartbeat and breathing of the central, chest region. In the carnivores, as we recall, the rhythmic processes dominate those of any other organic system.

In order to avoid stereotyped thinking we must also keep before us a clear picture of the carnivore's great diversity of form. In so doing we shall at the same time bring further evidence in support of the foregoing argument. The balanced form of the carnivore is altered in the smaller, more sense oriented species. The shape of the house cat, for example, in comparison with that of the large cats or the dogs, shows a slight posterior accentuation. This posterior emphasis is even more pronounced in the weasel, with its characteristically arched back. Of course it would be easy to say, "The animal is better able to jump from this position, and therefore …" But the animal shows an ability to jump precisely because its hind quarters have developed such strength and the front part of its body has remained so light.

The lion is a carnivore strongly influenced by the metabolism; in it the accentuation of the body's anterior pole is revealed in the formation of a mane. Lions jump but little, hunt in groups, and rarely climb trees. These animals, particularly the males, are the most indolent of cats. They sleep most of the time, utterly overwhelmed by an irresistible somnolence, and may take as many as two or three days to digest a single massive meal. The European lynx and Asiatic tiger, slightly smaller than the lion, still have a fringe of whiskers around the face. In the most metabolically active of the carnivores, the seals and whales, the anterior portion of the body is most strongly accentuated. Their form has long been regarded in a narrow technical sense, merely as 'drop-shaped,' so as to offer the least resistance to water. But these animals are able to take on such a shape precisely because of their exaggerated metabolic capacity. Developments made necessary by an animal's intrinsic organization and those necessitated by the physical requirements of the environment are by no means mutually exclusive, but the shape of an animal cannot be predicted on the basis of external requirements alone. Conversely, characteristics of form that seem superfluous when seen only from a technical point of view become understandable when considered in light of the animal's basic organization. For example, the development of 'manes' in sea lions and fur seals, the enormous tusks that develop from the upper canines of the walrus, and the inflatable nasal sacs of the hooded seals and sea elephant are absolutely consistent with the metabolic orientation of these carnivores. The massive size of the giant whale's head thus appears in a new light, as appropriate to an organization dominated by the processes of metabolism.

In the ungulates, whose whole form is basically determined by the influence of the digestion, the front part of the body takes on such predominance that the most varied kinds of processes, such as warts, antlers, or horns, may appear. In these animals even the nerve-sense pole shows the influence of metabolism; here additional organs are formed and protrude beyond the basic shape of the head. Through their placement at the anterior pole of the body, these processes reveal the metabolic character of these animals.

Turning now to the ungulates themselves, let us first consider those that are indigenous to Europe. During the course of their long association with man, these animals have experienced a fate quite different from that of the rodents. A biological equilibrium once existed between the harmoniously balanced plant and animal worlds. But wherever human settlements sprang up, this equilibrium was disturbed, for monoculture replaced the natural balance of the plant world. Refuse and garbage accumulated too rapidly to be taken up into the natural cycle of growth and decay, and mice and rats, attracted by the ready source of food, proliferated. The settlements of man have always attracted rodents; indeed, he has always had to fend them off. His relationship with the indigenous hoofed animals has been entirely different, however: they retreat before him. He has hunted them and driven a considerable number of them (such as the European bison, elk, and ibex) away from cultivated areas. Many of them (such as the European wild horse and the aurochs) he has brought to extinction. Some, however (such as cattle, horses, pigs, sheep, goats, and donkeys), he has captured, tamed, and brought back to his stables, where they have become his most important domestic animals and for millenia have played a vital role in his existence. The rodents intrude upon man's domain and do him harm; the ungulates avoid his realm, yet he needs them. (Among the birds a similar situation exists. Man needs geese, ducks and chickens, yet he cannot rid himself of sparrows.)

Ungulates still found wild in Europe are the roe deer, red deer, elk, wild boar, chamois, and Alpine ibex. The wild sheep (mouflon) and the fallow deer, originally from the Mediterranean area, have adapted well to Middle Europe and have lived there since before the last Ice Age.

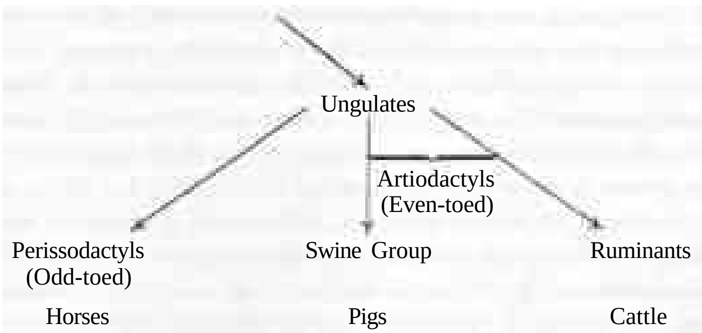
Those ungulates whose digestive system is highly specialized chew their food a second time and also grow either horns (bison, cattle, sheep, goats, and chamois) or antlers (roe deer, red deer, and elk). Non-ruminant ungulates (horses and pigs) have no such appendages! Instead, the horses develop a highly specialized limb organization. While the ruminants, as well as the pigs, have two main hooves and two lateral hooves ('dew claws') on each foot, the horse holds back the development of all toes save one, the third toe. The nail of this one toe has thickened to form a strong hoof. The horse, then, is odd-toed, in contrast with the other, even-toed, ungulates. Its single hoof, in avoiding any lateral appendages, appears to be oriented solely towards forward movement. This accentuation of the limbs enables the horse to be entirely open to the surrounding world; thus, herds of wild horses gallop through the steppes, their eyes and ears remaining active and alert.

This sense-active character of the horse should be apparent to anyone familiar with both horses and cattle. Of the two, the horse is the more easily frightened. Its metabolism, too, is much weaker than the cow's: it must be fed more frequently than a cow and requires more nourishing food. Yet its digestive system is never able to transform all the food for its use (there is always something left for the sparrows). This animal is also quite susceptible to disease; sterile procedure must be observed far more strictly in an operation involving a horse than in one involving a cow. On electric fences a horse can be killed by a current of only 40 volts, while pigs and cattle can easily withstand up to 120 (Cohrs and Köhler). The face itself, both in the structure of the nose and mouth and in the alertness of the eyes, reveals the sense-active character of the horse. For in contrast with the moist, hairless muzzle of the cow, the horse has a dry, velvety upper lip, dexterous and mobile, and trimmed with delicate whiskers. The cow, on the other hand, has the more agile tongue! Moreover, the horse has the largest eyes of any land animal except the giraffe and is able to see quite well even in the dark (Milne).

What, then, is the basic characteristic of the horse? As we have seen, this large, powerful animal is a member of the ungulate group and is therefore dominated primarily by the forces of metabolism. But it is, after all, the delicate, sense-active, limb-oriented character of this animal that marks it as a horse. Its shape is absolutely consistent with this sense-active nature: humped withers, dewlap, head protuberances, indeed, any exaggeration of the anterior body, are entirely absent. Unlike the cow, with its heavy anterior body, the horse is able to stand by straightening its front legs first, and it is well able to jump. Any outgrowths from the head would be inconsistent with the horse's nature since its entire organization, in comparison with that of the ruminants, is quite open to the surrounding world (Plate 124).

The pig, too, has neither horns nor antlers, and has in common with the horse a simple digestive tract. Its stomach has only one chamber, its intestines are relatively short, and it does not ruminate. It is, however, even-toed, and thus it is closely linked with the ruminants. The pig, like the horse, retains the digestive tract in its original form, while, like the ruminants, it retains the original limb formation. The pig, then, is not so specialized as either the horse or the cow, but has an organization more basic than either of theirs.

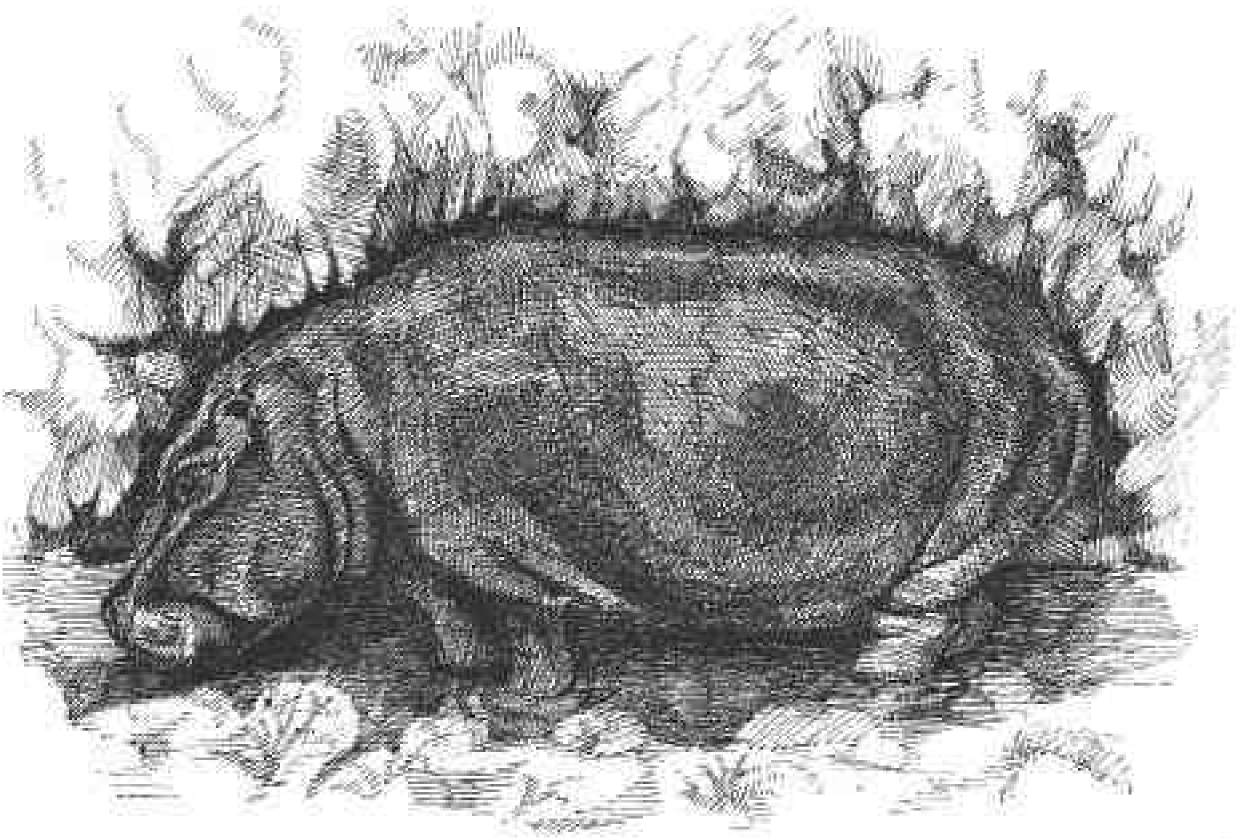
This lack of specialization is revealed in many other features of the pig's organization, as well. Its dentition, for example, includes all three kinds of teeth, the molars remaining unspecialized and having high, conical cusps. Litters are quite large (as many as twelve); the udder has many teats and extends along the entire mammary ridge. Within the otherwise highly specialized ungulate group, this rather primitive organization allows the pig to mediate between the two extremes.



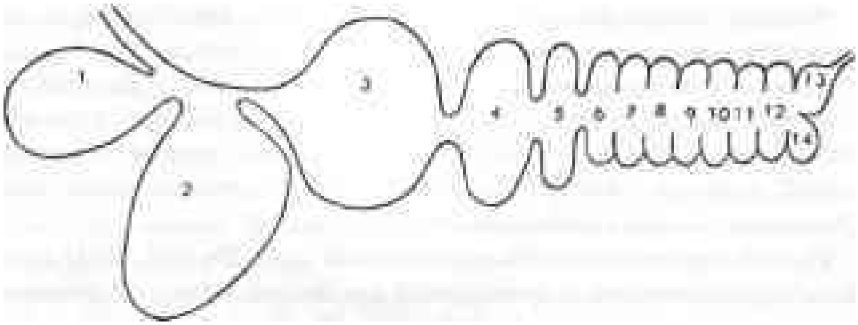
As central, rhythmic ungulates, the swine take on some carnivorous traits. Though primarily herbivorous, they also eat meat, strange as this seems for a hoofed animal. Wild boars root for earth worms, grubs, and even mice, and whenever they can find them, they devour the eggs and young of birds nesting on the ground. Domesticated pigs even hunt the rats that infest their pens. Thus, they are omnivorous, but for reasons quite opposite those of the badger or the bear. For the latter are metabolically oriented carnivores; the former, carnivorous ungulates.

Moreover, because the swine, as central ungulates, retain such a basic, unspecialized shape, they are noticeably smaller than either cattle or horses. The growth processes governing ungulates, then, are evidently quite different from those that shape the rodents or carnivores. In the following pages we shall observe repeatedly the conspicuously small size attained by many central ungulates; then, having become better acquainted with this phenomenon, we shall examine it in detail in Chapter IX.

The swine group is also differentiated within itself. The Old World pigs, including all domesticated breeds, which are descended from the Eurasian wild boar, represent the actual middle group. The South American peccaries (Plate 127) are more slender than these central swine, and the African hippopotami are more massive. The peccaries have a belligerent, aggressive nature, while the hippopotamus is completely herbivorous and has a specialized, multi-chambered stomach. The first section of this animal's small intestine has developed numerous sacs similar to those found in the colon, and serves as an additional fermentation chamber for chyme. Despite these specialized developments, however, the stomach is not that of a genuine ruminant, and the food is not chewed a second time.



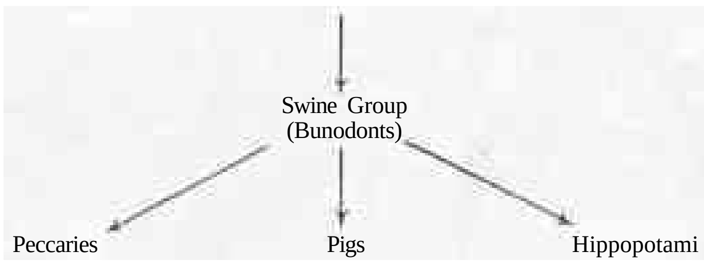
33. Hippopotamus (1/28 X).



34. The stomach of the hippopotamus has fourteen chambers (Verheyen).

Our assumption that the swine are the central ungulates is well supported by a study of the hippopotami. As metabolically oriented relatives of the pigs, these animals are the ungulates best adapted to aquatic life. The aquatic tendency of metabolically oriented members of central groups thus applies not only to the seals and whales among the carnivores, and to the beavers among the squirrel-like animals, but to the central hoofed animals, as well.

Of the two living hippopotamus species, the common hippopotamus, as the larger form, is the more closely bound to the water. There it takes refuge in time of danger, and there it even mates and gives birth to its young. The pygmy hippopotamus of Liberia, however, in both behavior and organization, is more open to its environment. This rather small animal moves freely between water and land, flees from the water when in danger, and gives birth on land, as well. This animal does not possess the enormous mass of the common hippopotamus.



Further confirmation of our proposed threefold division of the ungulates is found in the formation of their teeth. The rodents accentuate the incisors; the carnivores, the canines; and the ungulates, the molars. Thus the formation of the teeth in any particular species reflects the relationship between its nerve-sense, rhythmic, and metabolic systems. Within the ungulate group itself, despite its accentuation of the molars, a similar modification of the teeth takes place.

35. A male wart hog (1/17 X).

In the horse group (horses, donkeys and zebras), for example, the molars are broad and square. In the wide gap between the large molars and the incisors of the males, small canines are found. In front, however, strong upper and lower incisors appear; these are directed almost vertically toward one another, enabling the horse to use its front teeth to bite off food. Here the front part of the ungulate dentition has metamorphosed into a form slightly reminiscent of the rodents' teeth (Plate 124).

As we have mentioned, the swine's set of teeth is complete and has no gaps. In each half of the jaw there are three incisors, one canine, four premolars, and three molars. The incisors are directed sharply forward and can be used like small spades for digging. The molars are unspecialized in form and equipped with cone shaped cusps that have given the entire swine group the name *Bunodonta* (Gr. *bounos*, 'hillock'). The largest of these teeth are the canines, which project as tusks beyond the wild boar's snout (Plate 125). This development, too, indicates that these central ungulates approach the carnivore in type. Despite this accentuation of the canines, however, the pig's dentition is by no means that of a carnivore; for the canines of all swine remain rootless, grow continuously, and grind against one another in order to maintain their sharp edges. In addition, these tusks, together with the heavily built withers, give increased mass to the anterior pole of the pig's body. This formative function of the canines reaches its extreme in the South Asian babirusa. In this animal both upper and lower canines grow straight up; the upper ones even grow through the top of the animal's nose and then curve back towards the eyes, thus forming the primitive 'antlers' that have given this animal the German name 'deer hog' *(Hirscheber)* (Plate 161, 162).

The structure of the African wart hog's teeth is equally consistent with its overall constitution. The massive chest and neck region of this metabolic animal is covered with a shaggy mane and stands in sharp contrast to its relatively weak hind quarters. Projecting sideways from its enormous head are canine tusks up to 10 inches (25 centimeters) in length, and along the cheeks and lower jaw are conspicuously long, wart-like outgrowths. The wart hog has become practically herbivorous, and in the structure of its teeth it shows the influence of a strong metabolism. Even in young animals the upper incisors are incomplete; both upper and lower incisors are soon shed, so that except for the enormous tusks, only the molars are left.

The peccaries, on the other hand, show a complete set of teeth, with moderately long, rather pointed canines and a full complement of incisors. These incisors meet and are therefore able to bite off food, so that they functionally recall those of the rodents.

The molars of the *ruminant ungulates* are strongly modified. In typical cases they continue to grow for a long time, are incompletely rooted, and always have crowns with folds shaped like half moons. As selenodonts (ungulates having molars with crescent shaped ridges) all ruminants are to be differentiated from the bunodonts. In the upper jaws of most ruminants, the canines and incisors have disappeared—a reflection of the fact that both the rhythmic and nerve-sense systems have receded in these animals. The premaxillary bone of the jaw is covered not with teeth, but with a horny plate originating from the mucous membrane of the mouth. The lower jaw contains both incisors and canines, which are almost identical in shape and have broadened to form a single flat, shovel-like plate. When grazing, the ruminant holds the grass with its tongue, pressing it with the lower teeth against the horny plate of the upper jaw. Then, the animal does not bite off its food, but jerking its head forward, tears it off with great relish. Between the highly modified incisors and molars of the lower jaw there is a wide gap, indicating the deficiency of rhythmic processes in these extremely metabolic animals.

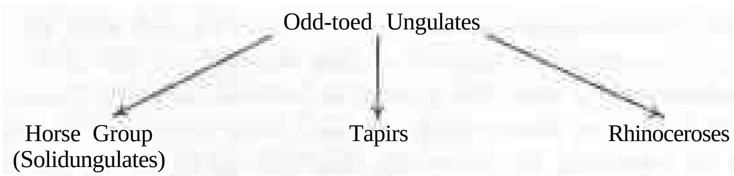
So the teeth, regarded from the viewpoint of the threefold idea, truly reflect the way in which an organism's three great life systems have developed. The phenomena speak for themselves. Cuvier was one of the first to recognize the great value of the teeth for the classification of mammals, when he said, "Montrez moi vos dents et je vous dirai qui vous êtes (Show me your teeth and I'll tell you who you are)." Since his time paleontologists have been able to make fairly accurate reconstructions of entire animals from their sets of fossil teeth. Yet even today's scientists are as unaware as Cuvier was of the fact that the formation of the teeth is not merely a key to correct classification, but also the precise expression of a threefold organization in the mammals.

We turn once again to the principal theme of this chapter, the head processes. These are quite consistent with the animal's overall form, since they develop in metabolically oriented animals that already add mass to the forequarters and the head. The stronger an animal's metabolic capacity, the more likely it is to develop head processes. These are found, therefore, in almost all ruminants, but conversely, they are lacking among the central ungulates (the pigs), as well as those most sensitive to the environment (the horses). All members of the horse group, such as donkeys, mules, and zebras, are without horns or antlers.

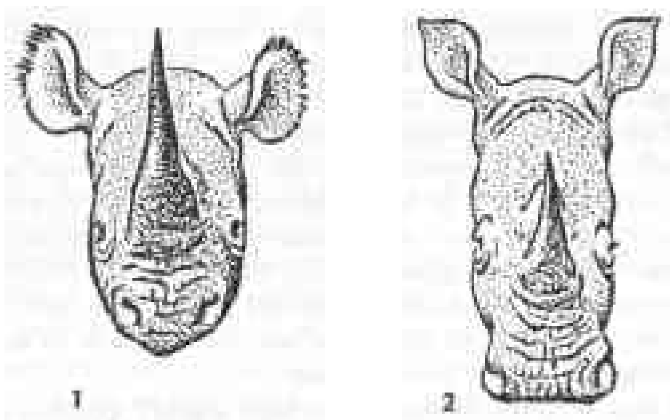
Closely related to the horses are the tapirs. Although they, too, are odd-toed, their overall appearance is quite different from that of the horses, whose joy is in running. They more closely resemble large pigs, and their life in the marshy swamps of tropical southern Asia and South America is also similar to theirs. Their limbs have retained several toes, but the fact that the third toe is always dominant provides additional proof of their kinship with the horses. Predictably, these animals lack head processes of any kind. Their dentition (Plate 128) shows accentuated canines. Within this odd-toed ungulate group, the tapirs, in contrast to the horses, may be regarded as the family dominated by the rhythmic system. This dominance of the middle system also explains the tapirs' similarity to the primarily rhythmic ungulates, the pigs. Occasionally, they even eat animal food (Grzimek, 1968).

We shall fully understand the implied connection between metabolic strength and the formation of head processes, however, only if we take the exceptions into account. For this purpose we must broaden our field of observation to include ungulates outside Europe. Specifically, we must investigate both odd-toed ungulates with head protuberances and ruminants without them. For just these exceptional cases will enable us to understand the typical horn- and antler-bearing animals.

Let us begin with the rhinoceros. This huge, ungainly animal is odd-toed and must therefore be closely related to the graceful horse. A paradox? Hardly: for it, too, is a magnificent animal, cast in a grand mold. What, then, is the constitution of this animal? The relationship of the rhinoceros to the tapir and the horse is shown in the simple construction of its stomach, the presence of incisors in its upper jaw (at least in young animals) and, as we have mentioned, in its odd-toed limbs. Each limb has a large main hoof and two slightly smaller lateral hooves. In its basic nature and behavior, however, the rhinoceros is by no means as agile or sensitive as the horse, but rather dull-witted and completely occupied with its own powerful metabolism. It is given to brooding and likes nothing better than peace and quiet. A solitary animal, it seeks to avoid any creature, including man, that might disturb it. Through the Asian jungles and the savannahs of Africa, the rhinoceros stumps along, the virtual embodiment of concentrated dullness: an odd-toed ungulate that has yielded to the influence of the metabolism and whose organization is therefore polaric to that of the horse.



In addition, the rhinoceros' body is enormous and is covered with a tough, leathery hide. Consistent with these developments is the accentuation of its head, which is massive and usually bowed down under its own weight, with horns along its snout. When these are paired they do not stand side by side, but one behind the other along the median line of the head. In the dentition, molars and incisors are present in both upper and lower jaws; canines are absent. Like horses, the relatively sense oriented rhinos of Asia (ranging from India to Indonesia) use their incisors to bite off food; only rarely do they use their horns defensively. While most Asian species have only one horn (Plate

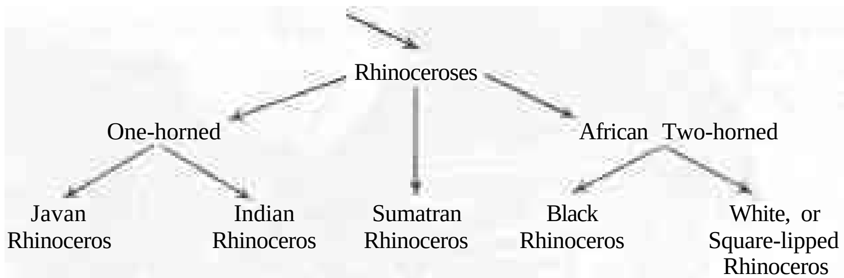


36. Frontal view of the heads of (1) the black and (2) the white rhinoceros of Africa (Dorst and Dandelot).

37. Malayan tapir; between the ages of 2 and 5 months the young lose their stripes and spots, adopting the coloration of the adults (1/17 X).

130), the strongly metabolic African rhinos (Plate 131) have two. The increased metabolic capacity of these African species is further indicated by the fact that they lose all their incisors at an early age, and unlike their Asian cousins, they fight almost exclusively with their horns (Spinage)! The black rhino of East Africa has even been observed chewing food for the second time, in an act that could almost be considered rumination—though in this case it is not the animal's own partially digested food that is 'ruminated,' but that of the droppings of the gnu (Grzimek). An intermediate position is occupied by the Asiatic two-horned rhinoceros of Sumatra (Plate 129), a relatively small animal, primitive in its organization. Its skin is quite hairy, and it has incisors as well as two small horns.

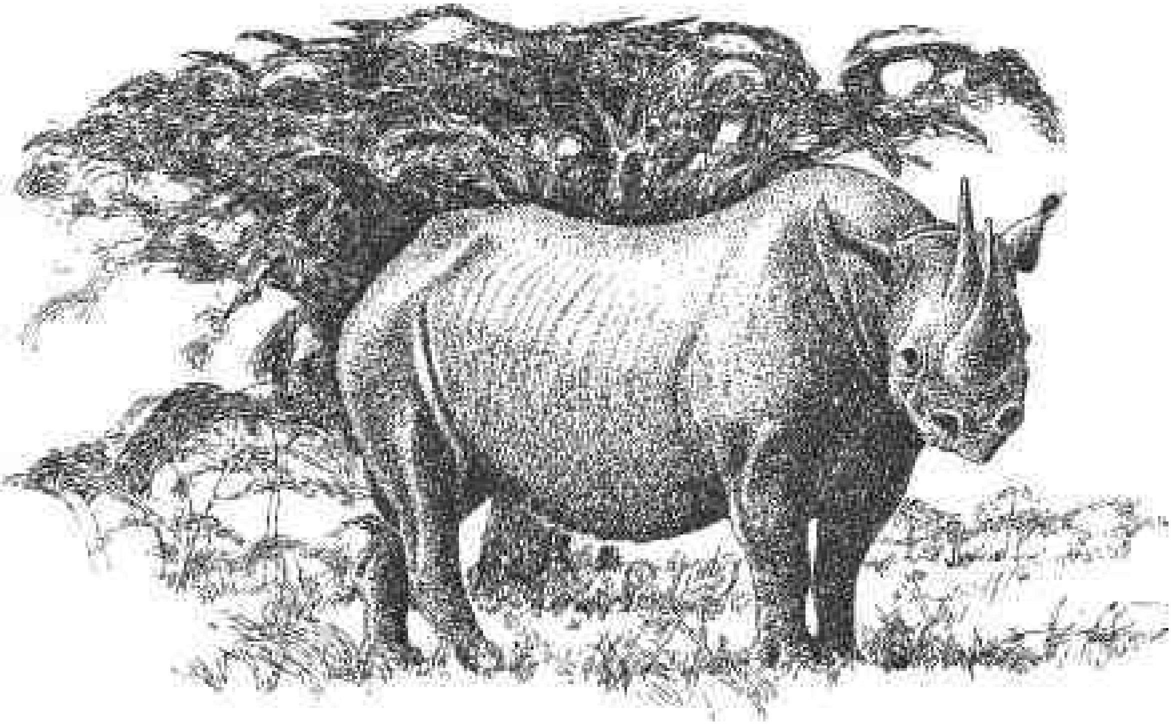
The so-called white, or square-lipped, rhinoceros is the largest of its group. It lives wild only in two strictly protected African preserves. Its head is huge and takes up nearly a third of its enormous body length, and the horns alone can attain a length of 5 feet (1.5 meters). The mobile, prehensile upper lip of other rhinos has broadened in this animal to form a 'square lip.' All incisors are shed soon after birth. With a length of 15 feet (4.5 meters), a height of about 6 feet (2 meters) at the shoulder and a weight of 4 1/2 tons, this animal (with the exception of the elephant and the hippopotamus) is the heaviest land mammal alive today. As the most metabolically oriented of all rhinoceroses, it represents an extreme development among today's ungulates. The five living rhinoceros species, then, may be grouped as follows:

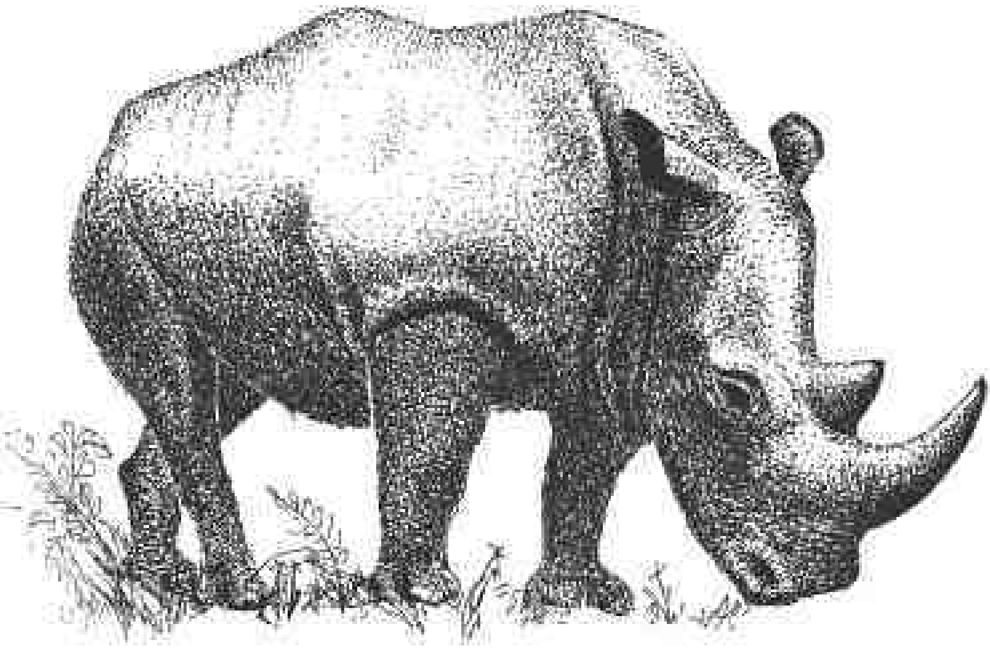


From cave paintings we know that in prehistoric times man was contemporaneous with the rhinoceros even in Europe. During the postglacial period the woolly rhinoceros was quite common. It, too, was square-lipped and had large, double horns, and it was far more metabolic in orientation than any of its descendants are. On its withers was a fatty hump, and its entire body was covered with long, thick hair. In this animal even the normally cartilaginous nasal septum became massive and bony—another indication of its extreme emphasis of the head (Plate 132).

38. The black rhinoceros of Africa feeds on leaves and twigs (1/28 X).

39. The white, or square-lipped, rhinoceros of Africa feeds only on grass (1/30 X).



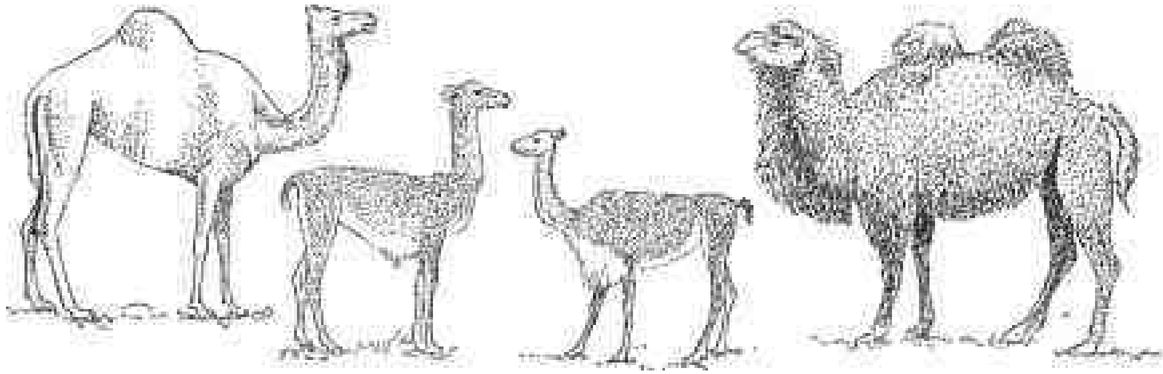


Which of the ruminants are without head processes? The best examples are the camels. Members of this group have the same crescent-shaped molars as the cattle, they ruminate, and they have a multi-chambered stomach. Yet this stomach is not of the fully developed, four-chambered type found in cattle, for the omasum merges into the rennet stomach (Plate 47)[23]. Though this system is adapted to rumination, it remains the most primitive of all ruminant digestive tracts. The camels' lack of the head appendages so characteristic of all other ruminants is correlated with this primitive metabolic system. Within the ruminant group, then, the camels show a one-sidedness approaching that of the horses.

In such a 'hybrid' creature, existing between the cow and the horse, we might expect to find a set of teeth in which the molars are slightly emphasized, but in which upper incisors are still present. This is, in fact, the case. In addition to the canines, the upper jaw also contains all six incisors in the set of milk teeth, and two of these remain in the permanent teeth. The lower incisors are of the same shape and vertical orientation as those of the horses. The molars close off their roots early and therefore stop growing sooner than those of cattle. In the formation of its limbs, the camel, like the cow, is even-toed; like the horse, however, it has no lateral hooves. It is noteworthy, too, that this animal, unlike the horse, does not walk on modified claws, but on the calloused, thickened pads of its toes. The entire group of camels is therefore designated taxonomically as the *Tylopoda*.

The archetypal form of the camel family, however, is neither the well known dromedary nor the Bactrian camel, but their humpless South American relatives. In these animals the camel family's development of the system open to the outside world is most clearly expressed. This nerve-sense orientation is especially apparent in the wild forms, particularly the guanaco. Its form is quite graceful. Its flanks are drawn in, thus separating the thighs from the belly, and the hind quarters are in no way accentuated. At the same time, however, the neck has become neither short nor thick but remains slender and quite long, carrying the tiny, small-muzzled head high above the region of the trunk. Its strikingly large, long-lashed eyes show a strange mixture of dreaminess and attention as they gaze out upon the world. The ears, nervously attentive to sounds from all directions, are long and pointed. The elongated upper lip is split and, together with the lower one, droops slightly. The guanaco's well known 'haughty' expression is a result of this almost grotesque mixture of dullness and wakefulness.

A similarly grotesque mixture is shown by the rhinoceros, as the most strongly metabolic member of the sense-active horse group; yet the result is entirely different. Both the outer form and the inner nature of the guanaco and other camels are expressions of a constitution diametrically opposed to that of the rhinoceros. For the latter is a member of a group predisposed to wakefulness in the outer world; yet it sinks deep into the dullness of its own massive body. In the camel, by contrast, the nerve-sense pole rises high above



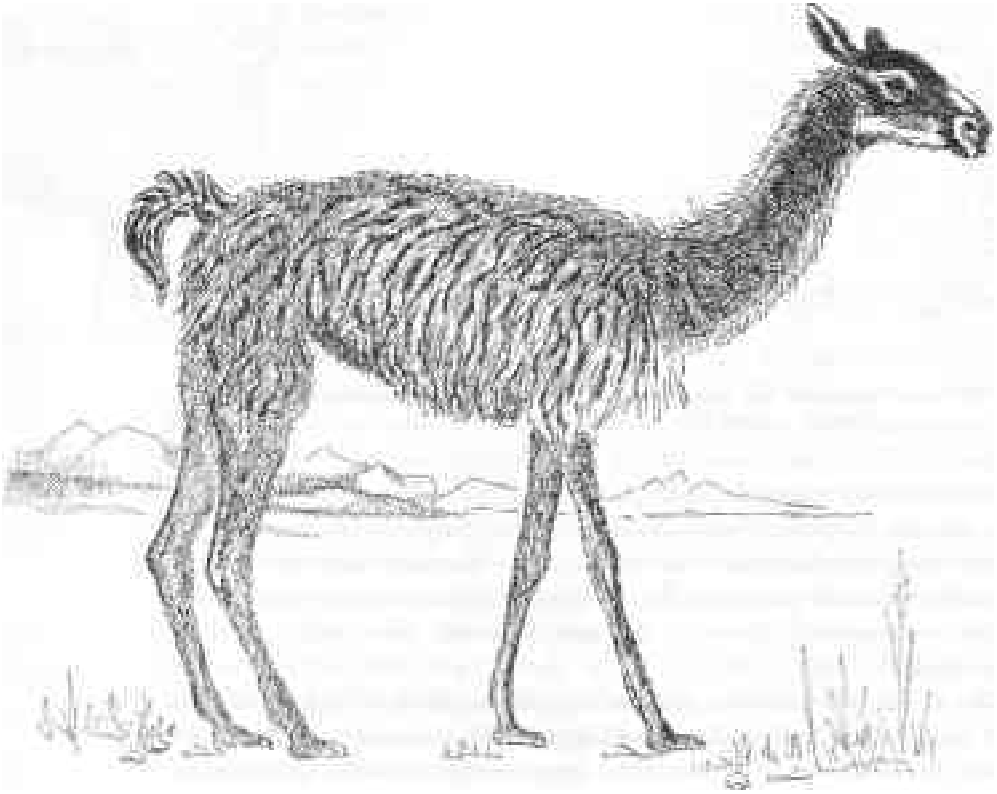
40. The four species of the camel family. *From left to right,* dromedary, guanaco, vicuna, and Bactrian camel (1/50 X).

the metabolically oriented trunk. The entire shape of the rhinoceros spreads out into the horizontal, while the camel's form lengthens into the vertical. Thus, the rhinoceros, an odd-toed ungulate that atypically stresses the metabolism, is able to develop head processes; and conversely, the camel, a ruminant atypically open to the outside world, must lack any such appendages.

The vicuna, the guanaco's even smaller relative, also lives in herds high in the Andes. The chest of this appealing animal is covered with a delicate mane. Its lower incisors have even become small-crowned, prism-shaped 'rodent teeth' that grow continuously through open roots (Weber)! This animal is so sensitive that it cannot adjust to any environment outside its ancestral home (Krummbiegel, 1952). From one of these two species or from both (research on this question has not been conclusive), the native Indian population has bred two domesticated animals: the llama as a beast of burden and the alpaca as a supplier of wool.

Larger than these South American animals are the camels of the Old World. The dromedary was originally native to the Middle East, and it was only at the beginning of the Christian Era that this animal was introduced into North Africa. It is no longer known in the wild state. Its tough, life-sustaining metabolism, which is held within strict bounds, enables this animal to cross deserts and semi-arid lands. Yet, though its patience and tenacity, its very capacity for endurance, are important for this ability, its senses are even more so. For its gaze reaches far over the endless, flat expanse of the desert, and with straining senses, it finds, in time of need, the way to shelter, food and water. Thus until quite recently, man's existence in the desert was literally made possible by the camels.

The dromedary's form gives visible expression to this combination of metabolic strength and well-developed senses. Even its size indicates that it is more metabolic in orientation than either of its South American cousins. Yet the increased bodily mass that accompanies this larger size does not extend to



41. Guanaco, a small wild camel of South America (1/15 X).

the head; instead it is confined to the region of the trunk, where it forms a hump in the middle of the back. It is in this formation that the camels' 'hybrid' character becomes apparent. For the trunk is obviously dominated by the metabolism. Yet the sense-active head is able to rise high *above* the sphere of the trunk, since the neck, though it begins low on the body, nevertheless towers above it in an S-shaped curve.

This paradox becomes even more evident in the Bactrian camel of Central Asia. The most strongly metabolic of the camels, it is the largest form, has two humps instead of one, drapes the front of its body with a thick neck-mane, and has hairy tassels on its forelegs. In this way its anterior body is slightly accentuated, but this accentuation still does not lead to the development of head appendages—the animal's entire nature is far too sense oriented for that.

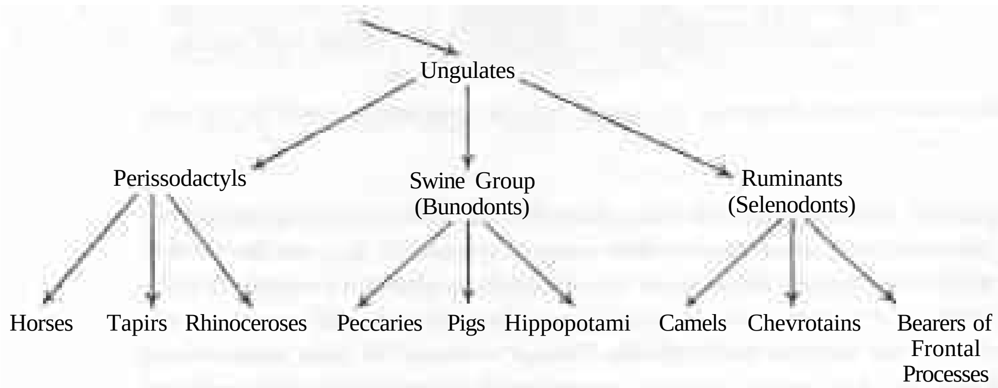
Like the camels, the ruminant chevrotains *(Tragulidae)* have no head processes. These tiny forest dwellers are no larger than hares and live in tropical Africa and Asia. Singly or in pairs, they slip through the underbrush near rivers and streams, leading a completely hidden existence. In Asia this

42. African water chevrotain. The female lacks the long canines found in the male (1/6 X).

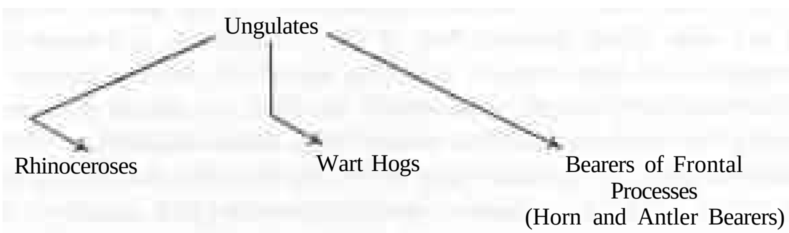
group is represented by the mouse deer (or true chevrotains); in Africa, by the water chevrotain. Because their outward appearance is so similar to that of the Himalayan musk deer, the chevrotains have often been considered close relatives of this animal; this classification is erroneous, however, since the chevrotains have no musk glands. Further evidence of their independence from the deer group is their incomplete development of the ruminant digestive system; in them the omasum (see Plate 47) has not developed fully. Consistent with this incomplete digestive system is the fact that chevrotains have no head appendages. They differ from the camels, on the other hand, in the formation of their limbs. Each limb has the typical even-toed arrangement of main and lateral hooves, a total of four on each foot. Thus, the limbs of the chevrotains avoid the one-sided specialization of the camel's two-toed foot and more closely resemble those of the four-toed deer and cattle. The chevrotains avoid both extremes, the highly specialized ruminant stomach of the deer and cattle, as well as the equally one-sided structure of the camels' limbs. In both metabolic and limb systems rather primitive conditions prevail in these animals. This primitive level of development is so far-reaching that the ulna and radius remain separate, and the second and fifth metacarpal and metatarsal bones are distinctly retained. In the water chevrotain even the third and fourth metacarpals, unlike those of all other ruminants, remain unfused.

In reviewing these characteristics we see that the chevrotain's mediating position within the ruminant group is similar to that occupied by the swine between the odd-toed ungulates and the ruminants. And, in a development consistent with this middle position, the male chevrotains have upper canines that protrude down from the mouth and attain a remarkable length. Upper incisors are lacking. In addition to its naturally preferred vegetable diet, the African water chevrotain also eats insects, small crustaceans, fish, small mammals, and carrion (Grzimek, 1968).

All other ruminants have the four-part stomach typical of this group and therefore represent the genuine metabolic mammals. In apparent connection with their completely metabolic nature, nearly all of them have a pair of bony projections attached to the frontal bone[24]. In contrast with the camels and the chevrotains, these animals have been called *Pecora* (cattle). We shall refer to this group as the bearers of frontal processes. We are now able to set forth a ninefold basic ordering of the ungulates, an arrangement that provides the key to their biology of form[25].



All sense oriented and central ungulates lack the frontal processes found in the strongly metabolic forms. Surely these processes stand in a special relationship to the metabolic organs:



Obviously the hippopotami do not conform to this rule. As primarily aquatic animals they, like the whales, avoid such outgrowths. Still, similar formations are found among the most strongly metabolic of the terrestrial swine, as for example in the wart hogs. Rudimentary facial warts are also shown by the bearded pig and the Javan pig of South East Asia, as well as the bush pig and giant forest hog of Central Africa.

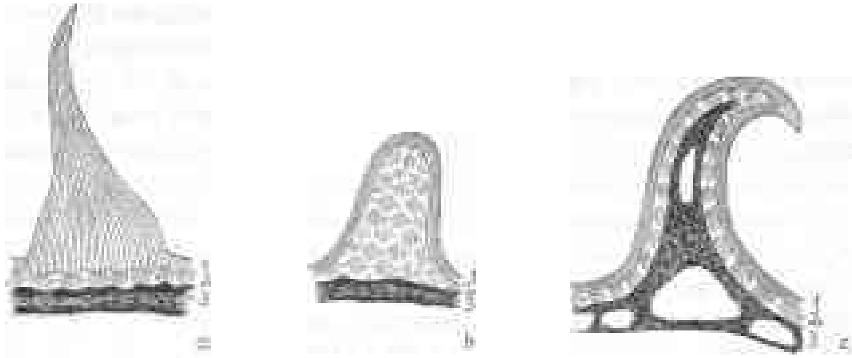
The various protuberances are by no means identical in form, but develop in harmony with the animal's whole organization. Nose horns are quite different from facial warts or horns on the forehead. Even the formative tissue is specific to each kind of outgrowth. To understand the significance of these differences we must examine the structure of the skin.

The skin covering the head usually consists of three layers. The superficial layer, the epidermis, has protective as well as sensory functions. It keeps the inner tissues from drying out and insulates them against mechanical shock. In addition, it contains sense organs, such as touch and pain receptors, as well as sensory hairs. It is well known that a superficial injury to this sensitive layer of the skin can be more painful than a more serious, deeper injury. In the dermis, or middle layer of the skin, most of the processes of blood circulation take place. Here, if they are present at all, the skin muscles are also found. The third, or subcutaneous, layer often has the function of storing fat. In the region of the skull, bony formations arise from this subcutaneous tissue (desmocranium). Thickened proteinaceous material (bone glue) is here permeated with calcium salts that constantly dissolve and re-form, as long as these dermal bones continue to grow. Here we can identify the workings of metabolism.

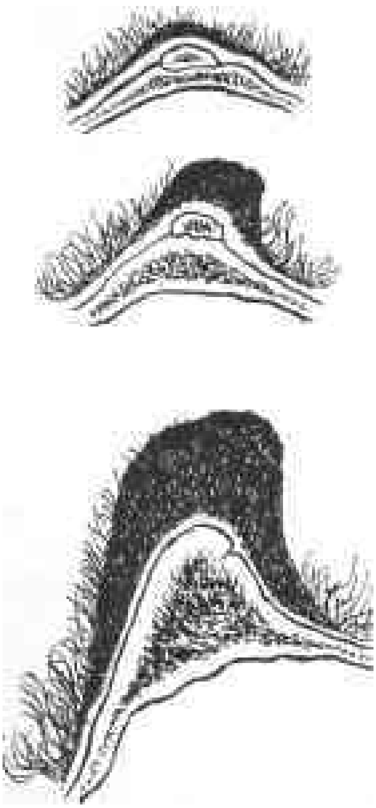
Thus in the skin we find a threefold differentiation of form that recapitulates the structure of the organism as a whole. Magerstädt (1950, 1956) has already identified this tripartite structure in the skin of man, and he has applied his findings to medical research. We shall find this discovery equally useful in our description of the specific form taken by each of the various head processes. For the structure of these appendages is closely connected with the threefold division of the skin.

The rhinos, as a subgroup of the sense oriented, odd-toed ungulates, develop horns that are nothing more than thickened, horny outgrowths of the epidermis, or sensory layer of the skin. The facial warts of metabolically oriented members of the central swine group develop from a thickening of the dermis, or middle layer of the skin, which then changes to cartilage (Broman). Only the true ruminants have appendages that are formed from an outgrowth of bone. At first these develop independently as single bones *(os cornu)* in the subcutaneous region; then, as they continue to grow, they fuse with the frontal bone (Nitsche, 1898; Rhumbler, 1913). These anatomical features of the head appendages are made comprehensible for the first time by a threefold analysis.

The horns' *positions* on the head also follow a definite order. Our initial



43. The layers of the head covering from which the head processes develop in a) the rhinoceros, b) the wart hog, and c) the cow.
1. epidermis, 2. dermis, 3. bones in the subcutaneous region.



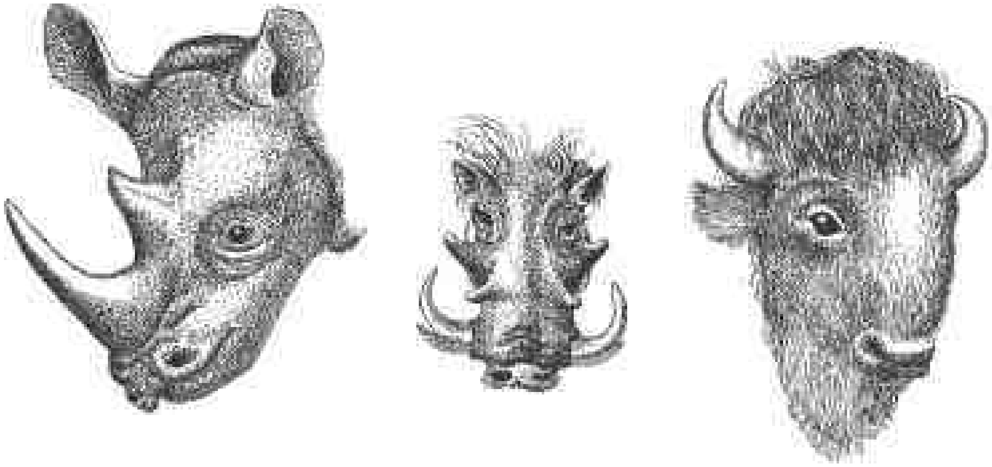
44. The first stages in the growth of a sheep's horn. The horn first develops independently in the subcutaneous region, and later fuses with an outgrowth of the frontal bone (after Brandt and Weber).

examination of the teeth revealed a threefold organization inside the mouth: the front part forms the sense pole, while the posterior part is related to the metabolism. As we might expect, then, the head processes of the rhinoceros are located on the snout; those of the wart hog, in the middle of the face, along the cheeks; and those of the ruminants, near the back of the head. For the first time we are in a position to understand *why* the head processes of the ruminants grow from the rear part of the frontal bone, near the back of the head. And we can also see that the so-called exceptions are really not exceptional at all. Here we witness the awesome inner logic of the organism and experience a diversity that is ordered in a living way, and not merely schematized[26].

Goethe discovered in his zoological studies that the appearance of head processes is always correlated with the absence of certain teeth from the upper jaw:

> No animal, for example, whose upper jaw is hedged by a complete set of teeth has ever carried a horn on its forehead, and it would therefore be quite impossible for the eternal Mother to fashion a lion with horns, whatever efforts she might make; for she has not material enough to plant the rows of teeth complete and to sprout antlers and horns as well[27].
>
> (From Goethe's "Metamorphosis of the Animals," translated by David Luke)

Nature compensates for the loss of one organ with a special development of another. Goethe spoke of the *état,* the internal economy of an organism, the mutual compensation of parts. But why it is precisely the upper incisors that are absent from the jaws of ungulates with head processes, and why the upper canines are also missing from the jaws of rhinoceroses and cattle, but not from those of wart bearing or even horn bearing pigs (see page 285)—these questions Goethe could not answer fully.



45. The placement of the head processes in the rhinoceros, wart hog, and bison.

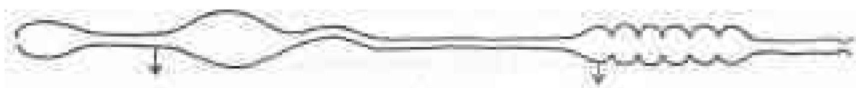
In the following chapters we shall undertake to answer these questions by examining in detail the organization and form of the ruminants bearing frontal appendages (the *Pecora*). This group includes the horn-bearers, or cattle, the antler-bearers, or deer, and the giraffes.

VII The Horned Animals

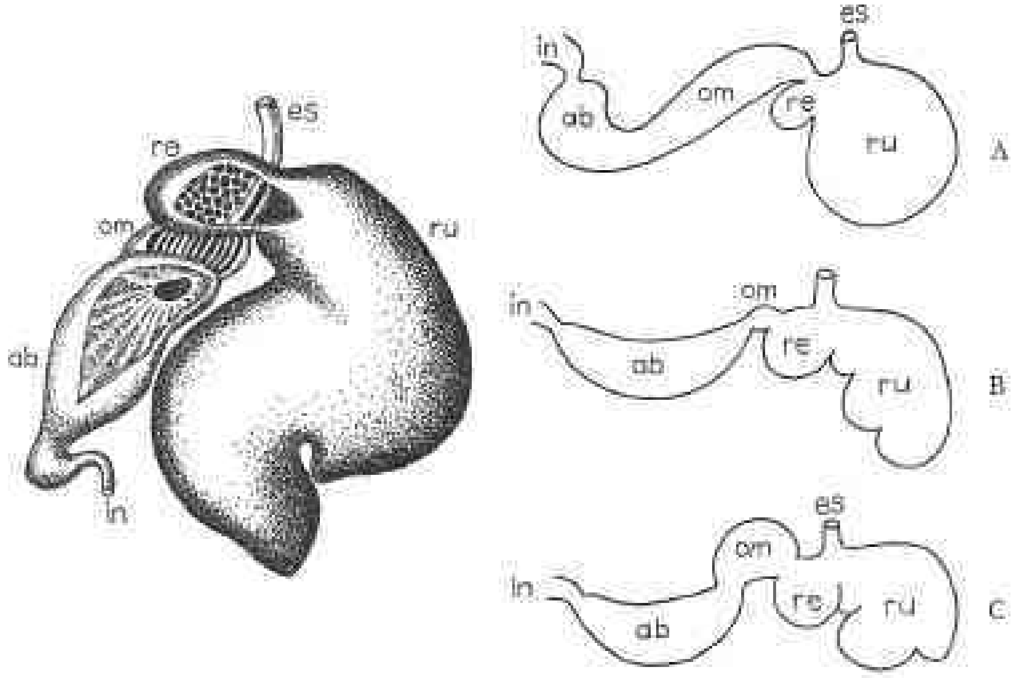
The horned animals are the most highly developed of the ungulates. The cattle form this family's basic type, so the entire group of horned animals is often called the *Bovidae*. All male and most female members of this group have the paired frontal processes we have already found to be associated with strong digestive activity. Thus, before presenting the individual species, it is logical to consider the organ that gives these animals their digestive capacity: the four-part ruminant stomach, which is fully developed in all bearers of frontal processes. Although we are dealing here with organs that lie within the abdominal cavity and therefore cannot be seen from the outside, we need not exclude them from our consideration of form.

The bearers of frontal processes are all either grazers or browsers. The same is true of most other ungulates and many rodents as well, though to a lesser degree among typical, very nervous rodents than among the metabolically efficient species, such as hamsters, marmots, beavers, and porcupines. All these animals must derive nourishment from a food composed primarily of cellulose and therefore quite difficult to digest. Thus, not only the cattle, but the metabolically oriented rodents as well, require specialized digestive systems. We intentionally include in our discussion of the ruminant stomach a description of the digestive tract found in the metabolically oriented rodents, for it is only in contrast with this rodent digestive system that the specific developments of the ruminant system become clear.

The mammalian digestive tract in its unspecialized, general form may be divided into the following parts: oral cavity, esophagus, stomach, duodenum, small intestine, colon, and rectum.



46. Schematic representation of the digestive tract, in longitudinal section.

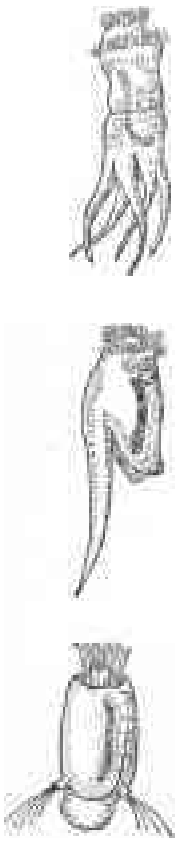


47. *Right, from the top down,* schematic representations of the stomachs of a camel, chevrotain, and bearer of frontal processes (after Boas and Weber).
es esophagus, ru rumen, re reticulum, om omasum, ab abomasum, in intestine.
Left, sheep's stomach (example for C). The reticulum, omasum, and abomasum have been cut open to make their internal surfaces visible. Note the gullet connecting the reticulum and rumen (after Carus and Otto; from Weber).

In cellulose-digesting rodents the colon is enlarged at the point where it joins the small intestine, and there a large sac called the cecum is formed. This sac may even become larger than the colon itself. For example, in the rabbits, closely related to the rodents, it holds ten times as much as the stomach, is longer than the animal's entire body, and almost completely fills the lower part of the posterior abdomen. It is a fermentation chamber in which bacteria flourish. These bacteria break down whatever cellulose the gastric juices have been unable to digest and make even this poor food accessible to the organism.

The digestive tract of the ruminants undergoes a similar modification, but in a different place—not at the back of the digestive system, but towards the front. In these animals it is not the colon but the esophagus that forms, at a point just before the opening of the stomach, a large outgrowth of sacs: the rumen, the reticulum, and the omasum. The original stomach now forms only the last chamber and is called the abomasum. This complete stomach, which is only partly developed in the camels and chevrotains, is definitely four-chambered in ruminants bearing frontal processes. Functionally, then, the lower part of the esophagus has become part of the stomach—indeed, its largest part.

The cow's rumen, which itself consists of two sac-like extensions, can hold up to eight gallons (thirty liters). The importance of this organ is suggested by the fact that the entire ruminant group is named for it. The word 'ruminant' is derived from the Latin *rumen,* meaning 'gullet.' The grass, after being torn off and coarsely pre-masticated, is first gathered here, moistened by the rumen's digestive juices, and attacked by myriads of bacteria, yeasts, and unicellular ciliates. It is broken down chemically and thus predigested. The bacteria are primarily responsible for this predigestion, breaking down fifty to seventy-five percent of all the cellulose consumed. The yeasts thrive on the resultant carbohydrates and multiply, while the ciliates consume the bacteria themselves, as well as other available foodstuff; afterwards, all these microorganisms are digested, as a nourishing source of protein. As much as five percent of the rumen's contents may consist of such protein.



The cow maintains a symbiotic relationship with these microorganisms, assisted by the flowers and insects of the pasture. For the yeasts enter her stomach by way of the flowers, where they live in summer (and are therefore called 'nectar yeasts,' *Anthomyces reukaufii*). During the winter these microorganisms live in the digestive tracts of bees; each spring they return to the flowers and with them find their way back into the stomachs of grazing animals (Klein and Müller, Hartmann).

The ruminants, then, in direct contrast to the rodents, create a place for these microorganisms in the enlarged esophagus, at the very front of the abdominal cavity. The bovine animals have the strongest metabolic capacity of any hoofed animals precisely because they have drawn their digestive processes *forward* into the front of the body—certainly not because they have an overabundance of digestive organs. Even the organs of the anterior body have become involved in metabolic processes. Thus, what we have already seen in the ruminant's outer form, as the accentuation of its anterior body, is also evident in the digestive system, where supplementary stomachs are formed out of the front-most part of the digestive tract. Even at the front of the animal's body, sense processes retreat before the power of digestion.

The rodent's cecum, on the other hand, develops in the posterior digestive tract, in harmony with the posterior accentuation of its outward form. Even the formation of internal organs, then, is consistent with the shape of the body as a whole.

What takes place inside a ruminant's stomachs? Usually a simplified, and therefore incorrect, explanation is given: the food first enters the rumen (according to this explanation), then the reticulum; after rumination it enters the omasum and finally reaches the abomasum, from which it passes over as

48. Three unicellular ciliates from the rumen of a cud-chewing ungulate. *From the top down, Ophryoscolex, Entodinium, Cycloposthium* (enlarged 300 X).

fluid food pulp (chyme) into the intestine. But what actually occurs is quite different (Scheunert; McAnally and Phillipson). In the adult animal the coarsely chewed food first enters the reticulum and from there passes into the rumen; sometimes it bypasses the reticulum and goes directly into the rumen. Thoroughly moistened by huge quantities of saliva (a cow produces fifteen gallons a day!), this chyme, during a period of one half to one and a quarter hours, is passed back and forth between rumen and reticulum, and thoroughly kneaded in the process. It reaches a temperature of about forty degrees Centigrade and ferments strongly. The reticulum's net-like internal surface divides the partly digested food into small lumps, the cuds, and these are brought forward into the mouth and chewed again. During this time the animal usually lies down or stands quietly, completely giving itself over to this task.

The well-masticated chyme is swallowed a second time, and again it enters the reticulum, where it is mixed once again with the contents of the rumen. When rumination is complete, the reticulum allows its contents to pass gradually into the omasum. The latter organ squeezes most of the fluid content out of the pulp, and, with its complicated network of leaf-like folds, grinds down the solid parts, as well. From there the fluid enters the abomasum and is absorbed; then the pulp follows. The abomasum, as we have mentioned, corresponds to the simple stomach of other mammals. Only this stomach has in its walls glands that add their own digestive juices to the food: stomach acids, pepsin, and, during infancy, rennin. Hydrochloric acid kills the microorganisms so they may themselves be digested. Pepsin and rennin break down the protein material. At the abomasum's posterior end a sphincter muscle, the pylorus, gradually releases small portions of the food into the intestine, where it is prepared for use in the formation of the body's own substance. The extreme length of the intestine (about 200 feet, or 60 meters, the small intestine alone being about 180 feet, or 54 meters, long) greatly facilitates this process. In the lower part of the small intestine, a new group of microorganisms is introduced; in the relatively short cecum[28] even cellulose can be fermented again and then rendered useful in the mesocolon. Through the rectum the digestive residue leaves the organism. But every farmer and gardener is aware of the great value of this ruminant dung. Unlike the dry, almost mineralized droppings of mice, cow dung is rich in humus-building nutritional matter for the plants. A composted heap of cow dung may smell like humus, and in the tropics it may even smell like perfume.

In the tropics there is cow dung that under certain conditions—probably after it has dried out slightly and been moistened again with dew—smells extraordinarily sweet, with a scent somewhere between those of roses and vanilla. When I was searching in Costa Rica for the orchid *Cattleya darwini*, I was perhaps twenty times deceived by a wonderful perfume and looked for the orchid among the trees. I never found the orchid, but following the scent I always found cow dung instead. In Java, with Mr.

Bräutigam, who grows a special kind of grass for fodder and fertilizes it with buffalo dung, I noticed the same agreeable perfume and could not doubt its origin (Kuntze in Brehm's *Tierleben).*

The calf, while still young enough to nurse, does not yet make use of its rumen and reticulum; as a rule, it takes only water into these chambers. When drinking milk it closes off the opening of the esophagus just at the point where the rumen and reticulum bulge out, so that a gullet is formed (see Plate 47) through which the milk flows directly into the omasum, and from there immediately into the abomasum. Here the milk protein (casein) is curdled by rennin and the actual process of digestion begins. The opening and closing of this gullet is strongly dependent upon psychological (or soul) factors: if the calf expects milk, has seen it, and is then blindfolded and given water instead, it diverts the water directly into its omasum and abomasum. If, on the other hand, the calf is prepared to slake its thirst with water, it takes even milk into its reticulum and rumen. Evidently, the soul life of this animal is deeply connected with the processes taking place in its four stomachs.

This special digestive capacity of the ruminants is expressed not only by the anterior emphasis of the body, but also in extra outgrowths from the head, the frontal processes. The most extreme example of this development was the Irish elk (Plate 149), which lived during and after the Ice Age, especially in prehistoric Ireland. Each year it grew a new pair of antlers with a span of about 12 feet (3.5 meters) and a weight of nearly 100 pounds (45 kilograms). What a remarkable metabolic achievement! We can understand the meaning of such head appendages only when we see how they relate to the special metabolic organization of the ruminants. Schrammen (1930) characterized them as deposits of metabolic surpluses. But they do not arise by accident, nor are they randomly placed. Even their position at the back of the head has proved relevant to our study of form. What, then, do the various forms of horns and antlers tell us? And what meaning can be found in the very contrast between horns and antlers?

In order to discover this meaning we must refer once again to the ideas of Rudolf Steiner. It has been our purpose throughout this book to show how these ideas can be applied fruitfully to the study of natural phenomena. Admittedly, Steiner's ideas are not easy to grasp, and one's natural skepticism could easily lead him to reject concepts so out of the ordinary. The proof of their validity, however, is in their application. Unusual though it may be to speak, for example, of the threefold division of the animals, we have seen how this idea opens insights into previously unexplained relationships among the mammals. We have seen, too, that when Steiner's concepts are taken rigorously and without bias as the starting point for objective studies, myriad data, otherwise unrelated, come to their support. Even when we fail to comprehend exactly how Steiner came by his ideas, we can attest to the fruitfulness of their application. We must therefore again ask the reader to hold in abeyance, for the time being, any inclination to dismiss the unexpected, and to entertain with an open mind the ideas that follow.

> The cow has horns and hooves. What happens in the places where hooves and horns grow? There an area is formed that sends currents inward in a particularly strong way. There the outer is strongly shut off. Not only the communication through the permeable skin and hair is blocked off, but there the animal is completely cut off so that nothing can stream outward. The formation of horns, therefore, is connected with the entire shape of the animal.... The cow has horns in order to direct back into itself the forces that need to penetrate all the way to the digestive organism; much work is thus created for the digestive system just because of what radiates inward from horns and hooves (1924).

The horn, then, is what closes off the surface of the cow's body! Its outer layer is epidermis that, instead of growing hair, has thickened to form horny layers. These layers of lifeless, secreted protein form a sheath-like covering that surrounds the calcified bony core and is never shed. The slightly twisted core is permeated with blood and full of life; from its base it nourishes the tissue that slowly and steadily forms the horn throughout the animal's life. Anatomically, the hooves are formed in the same way and are also curved inward. The horns and hooves obviously provide physical protection for the animal when it is running or butting, but this is only their external significance. They also take part in the inner activity of the organism. In this capacity they act as a dam to intercept processes that stream outward from inside the organism. Like a concave mirror, they reflect them back again. In the rodents the upbuilding forces that stream out from the metabolic organs are exhausted by the animal's intensive life of the senses; in the ruminants these forces are held back, so that they may flow again into the digestive organs. It is this process that helps to support the growth of bacteria in the rumen. From medical science we know that infectious diseases are caused not by bacteria or other microorganisms alone, but chiefly by the affected organ's predisposition to infection, which allows it to serve as a medium for the growth of bacteria and viruses. In the ruminant organization the flowing back of unused forces provides in the rumen a medium for the development of benign microorganisms.

Cattle need horns, then, in order to realize fully their special metabolic capacities. At the same time, however, the horns are formed by the overflow of this metabolic strength. So it is actually the intimate *correlation* of the two processes that gives the horns form. The one force consists in the exaggerated size and physical mass of the anterior body and the head; the front part of the body is completely closed off and forms horns as the best means of rendering the body's surface impenetrable. The other process is active mainly in the large cavities of the stomach and intestine, in the flowing back of unused metabolic forces that contribute to the extraordinary effort of breaking down the almost indigestible cellulose. The former process is the more physical and material, while the latter is the more physiological and living: the one forms the characteristic shape of the ruminant, while the other makes possible its chemical achievement. The two processes are mutually dependent; each allows the other to take place.

In cellulose-digesting rodents the cecum takes on functions similar to those performed by the cow's rumen. Here the special medium for the growth of microorganisms is created by a physical damming up and concentrating of forces at the rear of the body. Thus in the rodents we find an extraordinary variety of tail formations: hairless and scaly in the long-tailed mice, almost nonexistent in the hamsters, and long and bushy in the dormice and squirrels. The ability to digest cellulose is always accompanied by an increased tendency to develop horny surfaces: thus the tail of the largest European rodent, the beaver, has become a horny 'paddle' covered with scales. In the males, more strongly developed than the females, these tails are broader and shorter (Gaffrey). Its tail, like the cow's horns, actually enables the beaver to utilize its principal food, the young bark of trees (particularly that of poplars and willows). In the extremely metabolic porcupine the hair has even hardened to form large, horny quills, particularly towards the back of the body; some of its South American relatives (for example, the carpincho) have thickened claws like tiny hooves, so that in older systems of classification they were often called the *Subungulata.*

In the enlarged cecum of many of these rodents, a very nourishing substance, rich in vitamins, is formed through bacterial decomposition; these animals actually consume for the second time their own cecal excrement. The food of these rodents, then, like that of the ruminants, is digested twice, but with the important difference that it is not returned to the mouth from an enlargement of the esophagus but from an enlargement of the colon. The content of the cecum (cecotrophe) is excreted at certains times of day and then taken in again as food. It is clearly distinguished from other excrement, which is not eaten again. During the summer this vitamin-rich, fresh food is so nutritious that only a small part of it need be eaten. Cecotrophic nourishment becomes vital during the winter, however. If these rodents are prevented from eating it in winter, they are seized with convulsions and die (Mohr, 1958). The same holds true for the hares and rabbits—closely related to the rodents—whose tails are certainly not accentuated, but who nevertheless emphasize the posterior body.

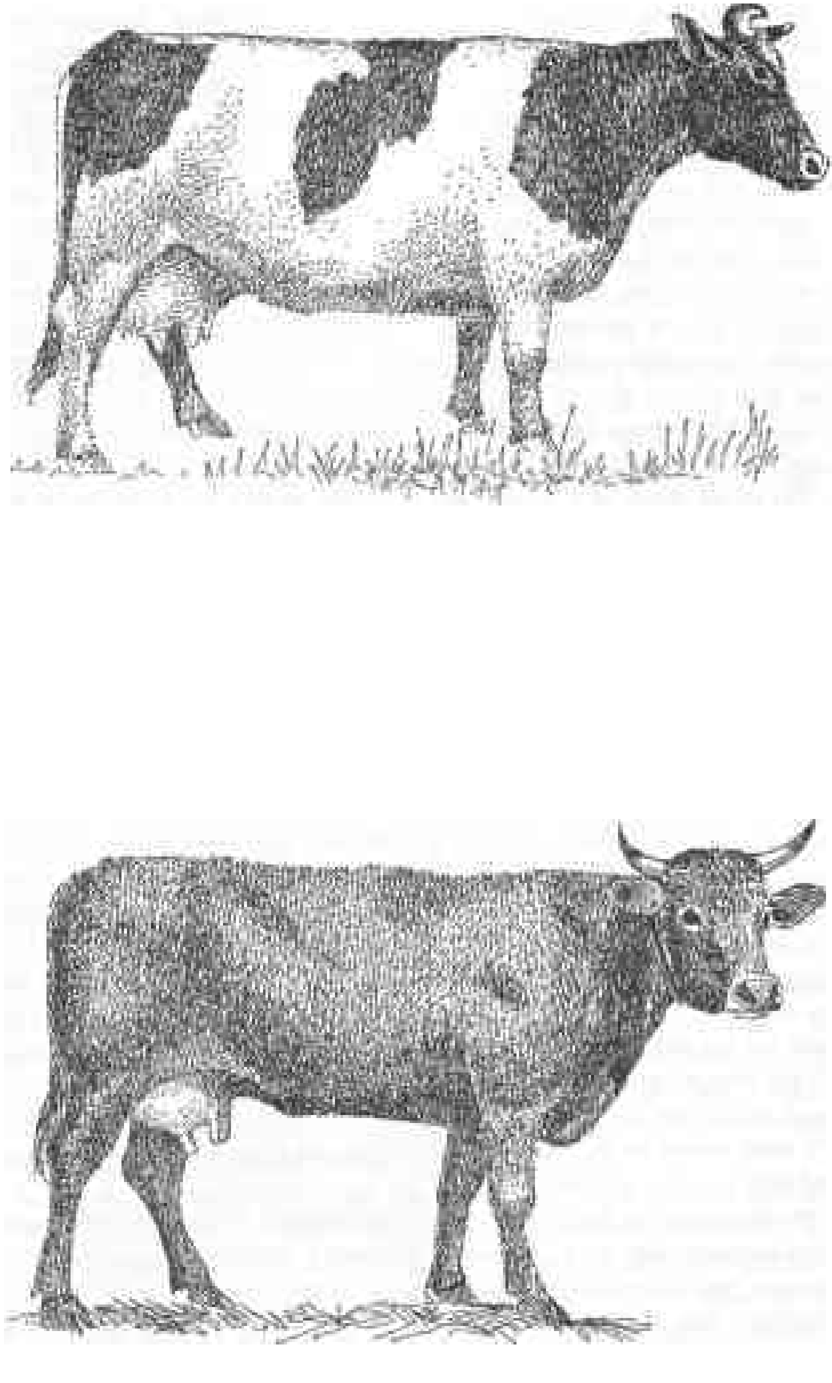
So the rodents, precisely because their orientation is polaric to that of the ruminants, illustrate the connection between the ruminants' visible form and the characteristics of their internal organs. The same processes that take place at the posterior pole of the rodents' body are found in the ruminant at the body's anterior pole. Because the lion is metabolically oriented, it shows a similar tendency toward the over-production of keratin. In this case, however, both poles of the body are slightly accentuated, in the heavy mane at the front of its body and a horny spike in the tassel of its tail.

The cattle give physical expression to the importance of the nourishing, life-giving, and regulating functions of digestion. It is this power of metabolism that continually brings life on earth into being and sustains it. Thus, an abundance of life and peace emanates from these animals. Each of them protects and nurtures within itself an entire world. Secure in itself, the cow is able to pass on this security to others. Ancient cultures actually experienced these qualities in cattle and therefore worshiped them. For the cattle represent the peak in a progression of ever more highly developed animals. It is with real justification, therefore, that the cattle are placed today at the very end of the system of animal classification. For the cow, as a purely metabolic animal, so completely controls its dealings with matter that it is able to give full expression to its own being within the material world. While rodents impress us as unfinished, somehow 'childish' animals, the ungulates, and particularly the bovids, seem to be 'adults.'

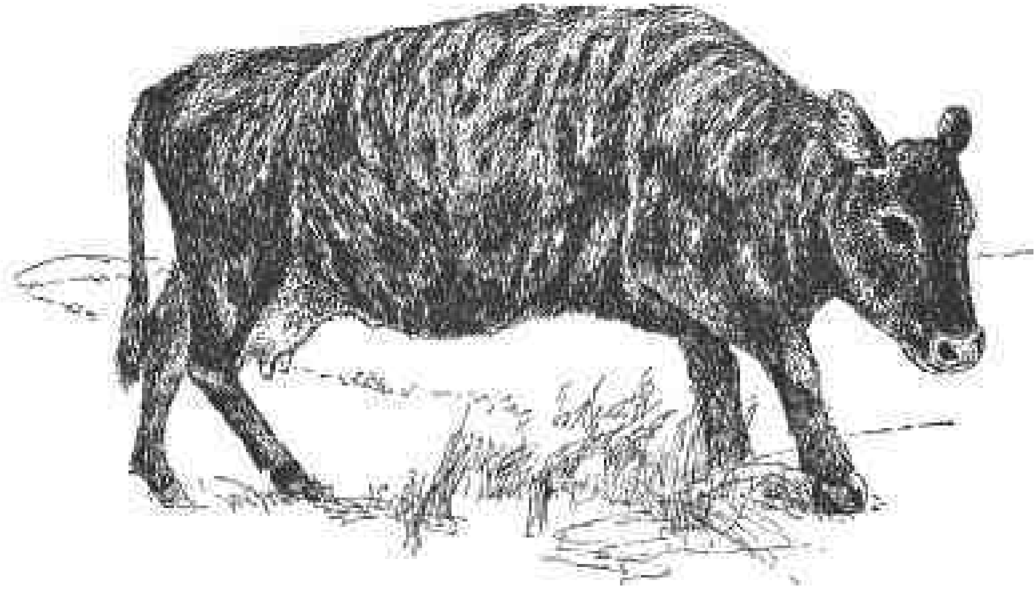
The actual shapes of the horns are as various as they are revealing for our study of form. Thompson, Ritter, and Poppelbaum (1949) have already called attention to the horn's archetypal form: in all bovine animals this underlying form is an *involuted spiral*. This highly restrained, unramified, tightly curved form makes clearly visible the damming processes at work within it. All horns curve around an invisible axis. The shorter and more tightly curved the horns, the more powerful are the damming processes that give them form.

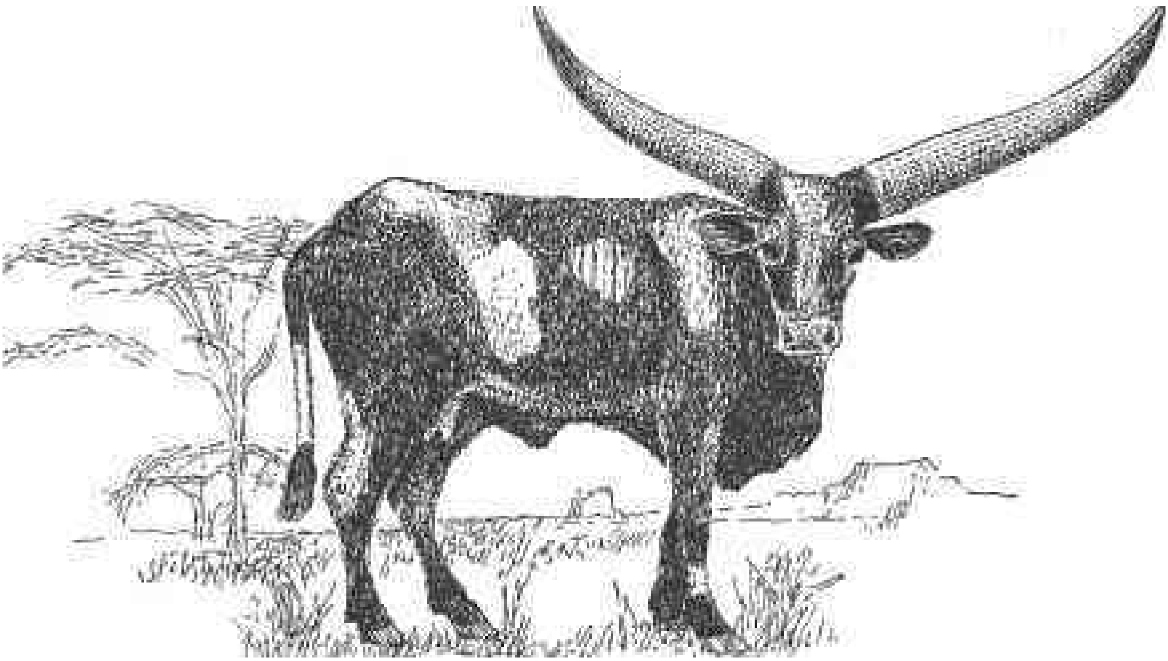
What kind of horns do domesticated cattle have? We can see that the bull's horns (but not those of the ox, since it is castrated and therefore unnatural) are more compact, that is, shorter and thicker, than those of the cow. His head, too, seems broader and shorter than hers; his whole shape is larger and at the same time more compact, with a greatly accentuated anterior body. The cow is more slender, and her horns are long and thin! If we include the form of the udder in our consideration of the body's shape, we can see that the damming forces are weaker in the cow than in the bull. The bull holds back for his self-expression, for the development of his own bodily stature, all the strength gathered by his powerful metabolism, while the cow passes it on to others. She does not exist for herself alone but is open, for example, to the requirements of the calf whom she first gives form within her own body and later provides with milk.

We can trace this small difference further, into the various strains of cattle. In Germany there is a significant difference between the larger North German lowland cattle, particularly the black and white Holsteins of Friesland, and the somewhat smaller, brown or brown-spotted mountain cattle of South Germany. The northern species have shorter horns than the southern forms. In England we find the 'shorthorn,' and the Aberdeen and Angus cattle of Scotland; these, as well as the fjell cattle of Scandinavia, often have no horns at all. In Spain, Italy and Hungary, on the other hand, we find races with very long horns. The most extreme development of this



49. *Above,* Holstein cow of northern Germany; *below,* Bavarian mountain cow.





50. Hornless fjell cow of Iceland, *above,* and longhorned Watusi cow of East Africa.

feature can be seen in the widely projecting horns of the ancient southern-most breed, the Watusi cattle of the Uganda highlands in East Africa.

When we compare the extremes, the hornless Icelandic cattle and the African Watusis, we find the former to be powerful and quite massive in shape, with a strongly accentuated anterior body. The latter, however, are remarkably small, thin-boned, and slender. Apart from their gigantic horns, they even accentuate the hind quarters, which are a little higher than the rest of the body! Thus, it is evident that the form of the body and the development of the horns are correlated. The horns grow largest in animals whose bodily form is least involved in the damming process; they are smallest, and even disappear into the skin, when this itself, because of the strong accentuation of the anterior body, is sufficient to perform the damming function necessary for the animal. Werr (1930) gave the following description of this relationship between horns and bodily shape:

> It is a fact that races with strongly developed, rotund bodies have either short horns or none at all, while in races with slender trunks and strongly developed limbs, we may expect longer, heavier horns to develop.

In either case the bovine organization requires a holding back of metabolic processes at the nerve-sense pole: in the one case this is brought about by the anterior accentuation of the body's own shape; in the other, by the horns, so that the two developments are complementary. The northern races use the entire front part of the body for this purpose; they are the more 'bull-like' animals. The southern races, on the other hand, accentuate the horns; they are the more 'cow-like.' The former are better suited to providing meat, the latter, milk. Without doubt the northern forms are the more metabolically oriented.

These races of cattle have, of course, been domesticated by man. Still, the basic characteristics we have pointed out are by no means the result of artificial breeding alone. What possible interest could a cattle breeder have in elongated horns? The original, basic form was shown only by the wild aurochs, from which all domesticated cattle stem. This animal was completely extinct, however, by the end of the seventeenth century[29]. Fortunately for our study of form, the Spanish fighting bulls (Plate 135) and English park cattle are still quite similar in form to the aurochs. We have also at our disposal unearthed skeletons of genuine aurochs (Plate 134). In addition, a wealth of material (cave paintings made during the later paleolithic period, pictures made by the Babylonians, Assyrians, Egyptians, and Cretans, as well as the most recent ones, painted during the Renaissance) has come down to us from artists who actually saw these animals. The best likeness from the last period of the aurochs' existence is a sketch made in 1525, probably in Poland (Plate 133).

In studying these early pictures we find an animal very similar to modern domesticated cattle. It was a rather large, powerful animal with surprisingly slender, small-boned legs (Plate 134); its head was carried a little above the back. The horns were large, but also thin and pointed; the bull was dark brown, the cow and calf, reddish-brown. The cow was still more slender and slightly smaller than the bull. Julius Caesar remarked on the agility of these cattle in the forest of Gallia: "Great is their power and great their speed; they spare neither man nor beast when they see them."

The variations shown by the wild forms are not so great as those of the domesticated races. Still, the same geographical motif we noticed in the domestic cattle is present in them. The Egyptian cattle, known from many reliefs found in burial vaults and from mummies of the cattle themselves, had a set of horns that pointed upward and was shaped like a lyre. Even the bull was reddish-brown and thus rather 'cow-like' in its coloration. Relics found in the North, on the other hand, show thick, tightly curved horns. These cattle races were distributed over Europe, North Africa and Asia.

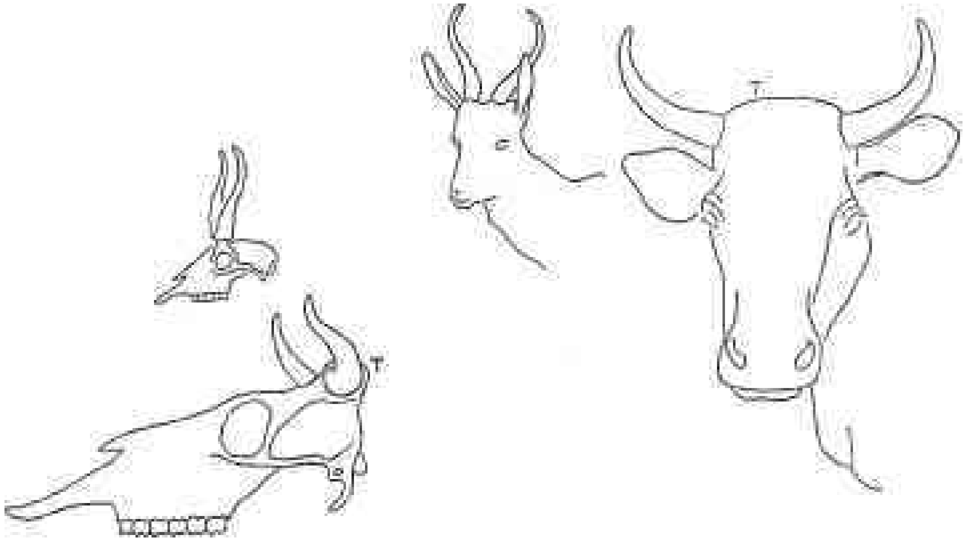
Yet another large bovid once lived wild in the forests of Europe: the bison. Its complete extinction, after two World Wars, has been prevented only with great difficulty, but we may now consider it saved. Although the bison is about the same size and weight as the aurochs, the front of its body is exaggerated even more strongly, and is draped with a dense mane from which the thick, short, tightly curved horns barely protrude. At one time this animal was distributed throughout the northern regions of Europe, Asia, and North America. Of the four races still living at the turn of the century—the European lowland bison, the Caucasian mountain bison, the American plains bison, and the Canadian wood bison—only the first and last have been saved from extinction. Today we are fortunate to be able to see this magnificent animal, which has never allowed itself to be tamed, in zoos and reservations (Plate 136).

What is the relationship, then, between these two European wild cattle, the bison and the aurochs? Zoologically they are considered to be the most highly developed of the bovine animals and are so closely related to one another that they are classified as members of the same genus (Haltenorth, 1963). Yet they certainly represent two different species, since the bison cannot crossbreed successfully with descendants of the aurochs. How do their constitutions differ?

The adult bulls of both species are of about the same weight (over 2000 pounds or about 1000 kilograms), but their physical proportions are quite dissimilar. The dorsal ridge of the aurochs is almost straight, while that of the bison is considerably higher in front because of the animal's high withers. The aurochs carries its head above the level of its back, while the bison's head is always bowed down. The bison, because of its enormous withers, is somewhat taller (about 6 1/2 feet, or 2 meters) than the aurochs (about 6 feet, or 1.85 meters); the combined length of the aurochs' head and body is a little longer (nearly 10 feet, or about 3.10 meters) than that of the former (not quite 9 1/2 feet, or about 3 meters). The aurochs' form, then, is elongated, while that of the bison, especially in front, is more compact and taller. The powerful damming processes and concentrated mass of the bison's anterior body are further emphasized by a long beard, a mane covering only the front of the body, and horns that are thicker, shorter, and more tightly curved than those of the aurochs. Thus, all those characteristics we have come to recognize in domesticated cattle as the basic features of metabolic dominance are exaggerated in the bison. A comparison with the aurochs in its original wild form makes this contrast even more obvious. For not only is the aurochs' entire body elongated and without a chest mane, but even its limbs are more delicate, light-footed and graceful; and its horns are much longer than those of the bison, more pointed, and directed more sharply upward. So the prototype of the metabolic animal is not the aurochs but the bison; and, indeed, if we compare the four geographic races, we see that the highest development is shown by the American plains bison. It is even more compact, has a larger hump and heavier head than the European bison; its legs are shorter, and its horns are thicker and more compressed, scarcely protruding from its mane. These animals once lived in vast herds; on their far-ranging migrations they wandered over the endless prairies, ceaselessly grazing and depositing their dung, thus fertilizing the earth, so that they might return to the same place a year later and feed again in phlegmatic peacefulness. The last surviving remnants of this group have intermingled with the better protected Canadian wood bison; although it is not quite so compact and powerful as the plains bison, it still shows greater evidence of the damming process than the European races do.

The only author who has yet applied our method of observation to the comparison of cattle and bison is Werr (1953). He traces a progression from the species most open to the world, the antelopes, through the goats, sheep, and wild cattle of southern Asia, to its culmination in the domesticated cattle; in this sequence, the bone formation of the head increases in size and width and becomes more and more dominated by the horns. In addition, at the back of the forehead and between the horns, the cattle develop an enormous crest called the *torus frontalis.* Through this development the parietal bones, immediately behind the frontal bones, are pushed further and further back. The bison has no frontal ridge, so Werr has concluded that it is not the bison but the aurochs and its domesticated descendants that have developed the metabolic organization to its highest point.

We nevertheless maintain that the bison is the most powerfully metabolic bovine animal; in the bison the damming of the anterior system, a process that is necessary for a strong metabolism, is accomplished through the accentuated form of the whole anterior body; thus large horns and the *torus frontalis* have become unnecessary. It is also significant that the bison enlarges the interparietal bone; unlike the frontal crest of the cattle, this ridge



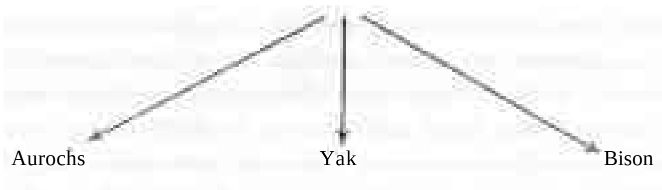
51. Head and skull silhouettes of the springbuck gazelle and the cow. T *torus frontalis* (1/30 X).

is already present at birth, and has reached its full relative size (Bogoljubsky). In the bison, then, not only the frontal bones, but even the parietal bones, located farther back in the cranium, take part in the damming process. Though such structural details are minor, they give testimony to the powerful metabolism of this animal. In the aurochs and its descendants the damming process does not involve the entire bodily form to the extent that it does in the bison; in the aurochs these processes are more narrowly confined to the head, with its frontal ridge and horns. Its horns, therefore, must be longer and larger than those of the bison. Between the bison and cattle we see a difference in form similar to that we have already observed between the northern and southern representatives of the domesticated cattle. The bison, living primarily in the North, has a short-horned, compact organization, while the aurochs, which lived chiefly in the South (Grzimek, 1968), had a long-horned, slender form and was slightly more open to the world. Thus, the bison and the aurochs show the differences we have found already between male and female animals within the same species. The bison is the more 'masculine' and bull-like, the aurochs, despite its size, the more 'feminine' and cow-like.

This difference may also explain why it was the aurochs and not the bison that was suited for domestication. The bison (setting aside the differences between male and female), like the bull, lives primarily for itself. The aurochs, on the other hand, did not allow its great metabolic strength to be completely self-serving. And it is precisely its feminine quality that has made this animal so important for the development of human culture. The feminine nature of the cow lets it give to man what the bison's constitution held back for its own unparalleled self-expression.

Between the contrasting aurochs and bison stands the yak. In earlier times it had a wider distribution than it has today: it now lives only in Tibet, where it can be found wild as well as tame. The wild bull is an enormous animal and attains a weight and shoulder height equal to that of the aurochs and bison. It has massive withers, but these do not rise so steeply above the back as those of the bison do. Shaggy hair covers the entire body, especially along the underside. The horns are rather long but are still tightly curved. It is typical of the wild yak, however, that there is a marked difference between the sexes. While the bull may weigh as much as 1800 pounds (or about 1000 kilograms), the female's weight is only about 700 (350 kilograms); she is therefore much smaller and thinner than the bull. The masculine traits dominant in the bison and the feminine characteristics governing the aurochs are both present in a pure form in the yak: the male is unreservedly masculine, the female, purely feminine. Since both masculine and feminine characteristics are equally well expressed within the single species, the yak may be considered that bovid which owes its character to the formative processes of the rhythmic system. In the domesticated yak, on the other hand, there is scarcely any difference between male and female animals: the male is no larger than the female. Man, in domesticating this animal, has actually strengthened its cow-like qualities.

The wild cattle of the tropics (such as the African short-horned and Cape buffaloes, as well as the Asian water buffalo, the anoa, the gaur, banteng, and couprey) will not be discussed here in detail. In the formation of the skull, all these animals are less specialized than the three forms we have discussed. These three forms thus give the best overall picture of the bovine animals and their threefold relationship.



Closely related to the cattle are the sheep and goats, which also have horns and belong to the same family (the *Bovidae*). The European wild forms of this group are the mouflon and ibex. From ancient times domesticated forms have accompanied man and served him. Since they are so closely related to one another, it is also instructive to compare their differences.

The sight of a herd of sheep awakens some of man's deepest feelings. In their harmonious activity, peaceful herd instinct, diligent grazing, **and** never-ending contentment, the sheep speak easily to the feelings of man. Their wool is soft, warm, rich in fat, and comfortable to wear. Their needs are few.

52. The wild yak of northern Tibet (1/30 X).

Rain and cold, drought and heat, poor food and lack of shelter are all endured with equanimity. In the summer they move through forests and meadows; in the fall, across the stubble of harvested fields; and only in winter must they return to the stable. In places so barren that neither cattle nor goats, horses nor donkeys can find nourishment, the land still furnishes enough food for the sheep.

The ideal conditions for goats are found in the mountains, on steep alpine meadows with many rocks to climb. Each animal goes its own way, relishing a carefully selected leaf, or reaching high into the bushes to browse. The dwarf goat of Morocco even climbs into the branches of trees in order to reach the foliage (Plate 137). A long, slender neck, protruding eyes, forequarters more slender than those of sheep, but stronger hind legs; a large, heavy udder; a pointed little tail; and sharp hooves are all visible indications of this animal's sense-active nature. Unlike the sheep, domesticated goats take cold easily when exposed to rain, require shelter at night, and give sufficient milk only when adequate food is provided.

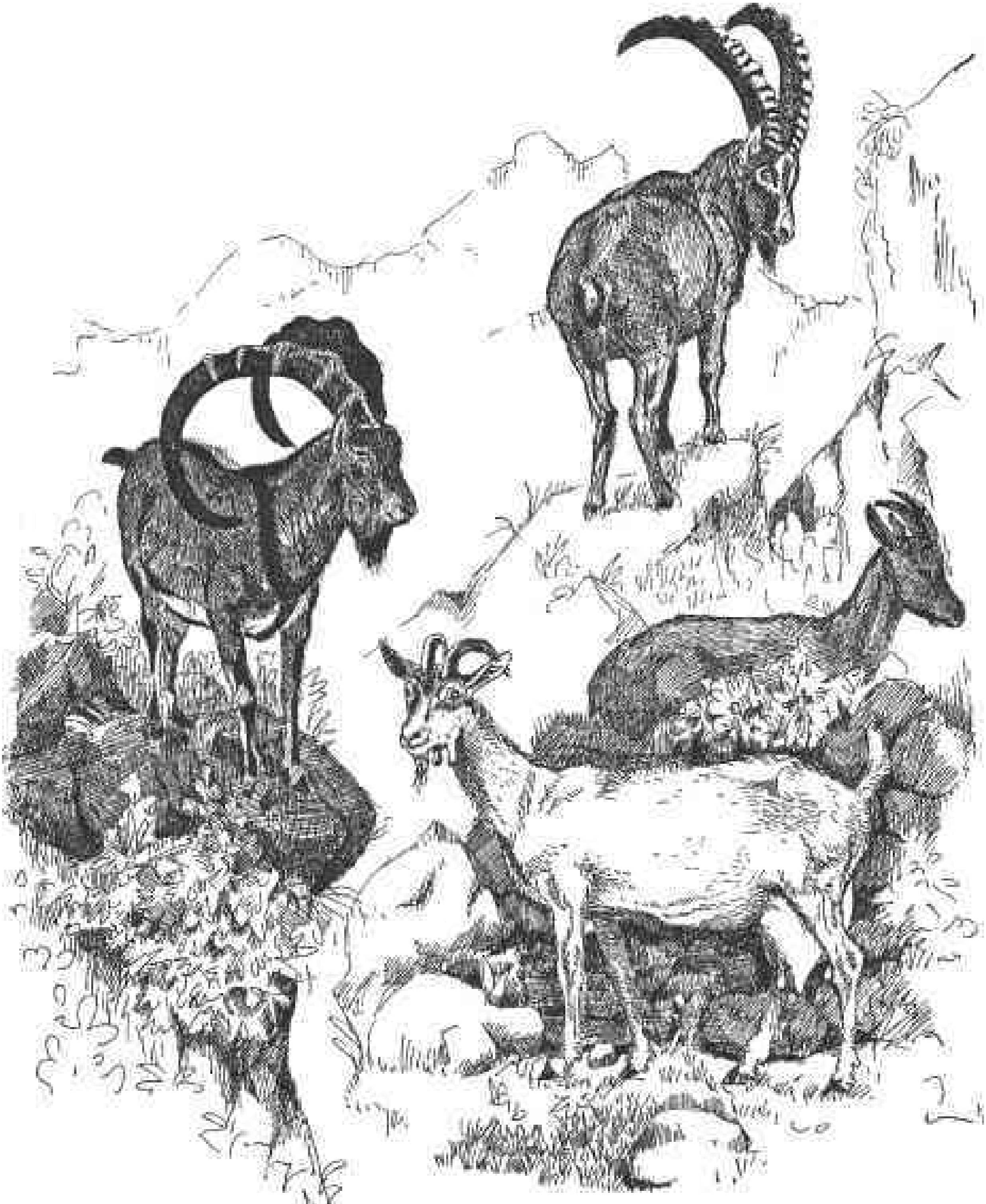
Even in the tones of their voices we can perceive the differences between these animals. Compare the soft 'maa' of a sheep with the restless bleating of a goat. The sheep's voice is certainly the more soothing of the two.

The goat is the more sense oriented animal, while the sheep has given itself over more completely to its metabolism. The goats serve primarily as milk providers, the sheep, as a source of meat and wool. The goats, then, in the sense described above, are more like cattle, while the sheep are more like bison. These contrasts, of course, have been greatly exaggerated in the domesticated breeds; nevertheless, such an exaggeration would have been impossible had the wild forms not already possessed these opposing characteristics.

The wild goats of Europe are the ibexes. Since these animals live high in the mountains, they have no single, unified area of distribution, but live in the separate mountain ranges of Europe, Asia, and northeast Africa. The goats of each mountain area have their own distinctive horn formations. The Pyrenees ibex, the Alpine ibex, and the bezoar goat of the Greek islands show great differences in horn formation. Yet the total of about twenty wild goat forms represents only one species (Kesper). These different types are geographic races and can interbreed without loss of fertility. Indicative of the species are the beard at the tip of the chin, the glands under the buck's tail, and the 'open' bone structure of the face (the ethmoidal notch between lachrymal and nasal bones does not ossify).

Of particular interest to us are the horns. They grow straight up from frontal bones that are not particularly enlarged. Their forms are extraordinarily variable: smooth or knotted, turned inward or outward,

53. *Left*, bezoar goat of Crete, *right*, Alpine ibex with mate (lying down), *below*, white domesticated goat (each 1/15 X).

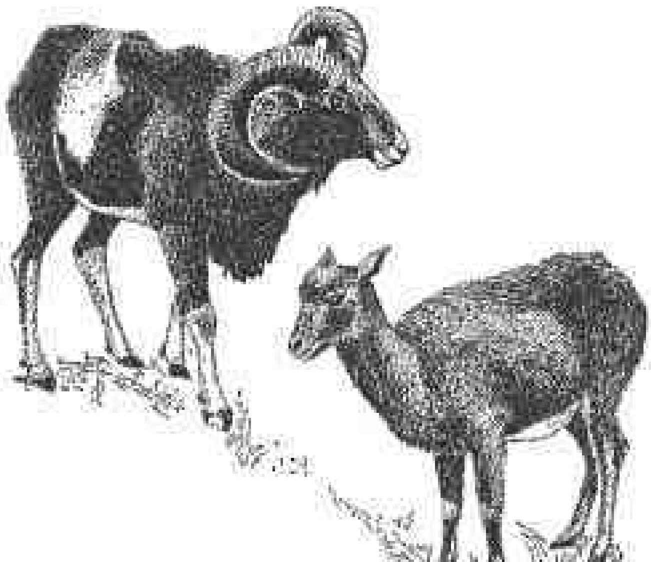


sharp-edged or rounded, tightly twisted or hardly curved at all. Yet all wild forms have certain features in common: the horns are relatively upright, they are never tightly involuted to form a spiral, and never directed towards the sides. The tips of the horns are not widely separated. Although some of the extreme races of domesticated goats no longer adhere to this basic form (Herre and Röhrs), the following characteristic is definitive for both wild and domesticated forms: at the horn's base, it is the inner anterior edge that projects forward farthest, often forming a sharp, regular ridge (the fronto-nuchal ridge) that provides a sharp butting surface. (Plate 55 shows a cross-section of the horn bases of the Alpine ibex.) Even the tur (the East Caucasian ibex), which, with its rounded, broadly compact horns, deviates furthest from the norm, has horns whose anterior edges curve inward.—We mention this small detail because it forms a characteristic motif of the goat's horn.

The wild sheep are certainly no lowland dwellers, but, unlike the goats, they do prefer the slightly lower mountain plateaus to the highest peaks. The goats love mountain ridges; the wild sheep, alpine pastures. In the sheep, too, there is a distinctive horn formation for each mountain area. There are approximately thirty geographic variations and these all belong to one species (Herre and Röhrs) ranging from Asia to the American Northwest (the bighorn sheep). Europe has only one wild sheep, the mouflon (Plate 138). Until the Neolithic Age it was widely distributed (Herre and Kesper) but later disappeared from Europe, except for small remnants in the mountains of Sardinia and Corsica. Since the second half of the last century it has been successfully reintroduced as a game animal north of the Alps.

This European wild race, however, is certainly nothing more than a stunted western form; in the center of this species' area of distribution, the high mountains of central Asia, the fully developed, original form still lives. In the thirteenth century, Marco Polo was the first Westerner to see this large wild sheep. The Marco Polo sheep, named after him, is a mighty animal; with a shoulder height of about 4 feet (or 1.20 meters), it is almost as tall as a stag. It lives at an elevation of about 20,000 feet (6000 meters). A dense mane covers its neck and chest; its whole body is powerful, compact, and equipped with 'mountain-trained' muscles. The full-grown ram has enormous horns; growing in tight spirals out toward the sides, these three-edged horns are covered with narrow bulges. Each of them, measured along its edge, can attain a length of about 5 feet (1.5 meters). Unlike the cow's horns they rise straight up from **a** frontal bone that is not particularly enlarged; yet their bases have become so broad (with a circumference of about 20 inches, or 50 centimeters) that the two horns touch, covering the forehead almost completely. Their anterior face is so broad that no fronto-nuchal ridge can

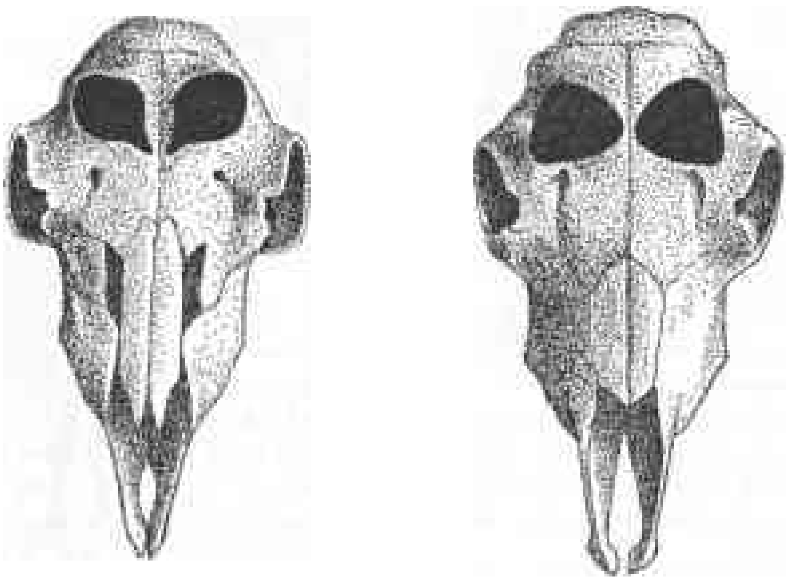
54. The Marco Polo sheep *above*, is almost as large as the red deer (1/20 X), while the European mouflon *below,* is much smaller (1/16 X).



develop. Instead, the bases are sometimes pulled outward to form a fronto-orbital ridge. The sheep's horns, unlike those of the goats, are not oriented towards the front, but spread out towards the sides. Nor are they directed so sharply upward as those of the goats, but curve back and encircle the ears, in a gesture of quiet power (Plate 138).

To the North as well (at the headwaters of the Ob and Yenesei Rivers), and to the East as far as North America, this typical horn formation is shown by all wild sheep. Towards the South and West, the horns become less spectacular, so that those of the wild races of southern Persia, Armenia and Cyprus are smaller and less tightly curved. The Mediterranean mouflon is such a small form, but in comparison with the goats, even this very small sheep still has the more powerful metabolic organization. This metabolic power is indicated in the structure of the sheep's skull, which shows, even in the smallest races, a greater ossification than that of the goat; for all sheep lack the goat's open ethmoidal notch in front of the eye sockets.

Closely related to the sheep and goats are the chamois and musk oxen. As the name indicates, the musk oxen resemble small cattle in appearance; yet they are more closely related to the sheep and goats than to the cattle themselves. They are now restricted to the subpolar regions of North America and Greenland, though during the Ice Age they were found also in northern and even central Europe. As the climate changed, they followed the melting ice as it retreated northward. Because these animals overheat easily, they need the snowstorms and freezing temperatures of the polar North in order to



55. Horn bases of the Alpine ibex and the wild sheep (each 1/3 X).

56. Muskox, of Greenland (1/15 X).

survive. Thus northern Europe, warmed by the Gulf Stream, has become too hot for them and they have died out there. During this century, however, they have been successfully reestablished in Spitzbergen and the Dovre Fjell of Norway, where they have become feral. Here, tranquil and imperturbable, these stolid animals move through the barren, sparsely covered, rocky fields in which they live. "Nothing seems capable of destroying their composure or inducing them to quick movement" (Pedersen, 1964). When winter snowstorms rage for weeks at a time over the arctic landscape, the musk oxen gather in small groups and wait motionless until the storm has passed; then they begin once again patiently to scrape out of the snow the frozen plants that form their only nourishment—and this during five months of complete darkness!

This ability to survive in an environment so inimical to life presupposes a strong metabolism. The animal's overall form—with a coat nearly three feet (one meter) in length, an additional mane in front, high withers and a broad head—is an expression of this strong metabolism. The musk ox is far more metabolic in orientation than the sheep. An appropriate name for it might even be 'sheep ox.' (In any case the term 'musk ox' is misleading, since this animal has no musk glands.)

The constitution of this animal is also expressed in the shape of its horns. In young musk oxen, as in young cattle, the horns begin to grow out diagonally from the sides of the frontal bone and are at first conical in shape; then, as their growth continues, they begin to form a spiral. Later, however, an additional process sets in: the inner, bony core of the horn gradually dissolves in the vicinity of the base and is eventually rebuilt to form flattened bulges. Out of the horn's base, which is narrow at first, a broad plate gradually develops. During this process the two horn bases increase in size to such an extent that they meet at the center of the forehead to form an *single*, broad-surfaced frontal plate: a truly impenetrable damming organ that holds back the animal's inner life forces, while its outer surface is so strong that it can withstand even rifle shots. The horn's bony core, then, has by no means simply hardened to form immutable bone; on the contrary, it is permeated with powerful vital forces and can both tear itself down and build itself up anew. In most horned animals this transformation of the central core proceeds quite uniformly, so that regular spirals are formed. This development of a broadened form in the musk ox is therefore quite significant; the frontal bone, the genuinely metabolic component of all head processes, is especially alive in this animal. Thompson describes the contrast between the living bone and the horny sheath that surrounds it:

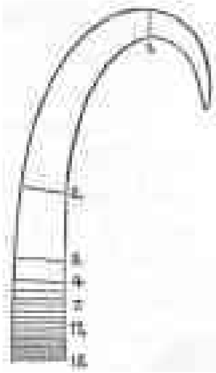
All these characteristics illustrate the cardinal difference between the growth of the horn and that of the bone below: the one is dead, the other alive; the one adding and retaining its successive increments, and the other mobile, plastic, and in continual flux throughout.

Further confirmation of the musk ox's metabolic orientation is found in its overall form and coloration, for the musk ox may attain a height of about 5 1/2 feet (or 1.65 meters) at the shoulder and is taller than even the largest of the wild sheep. Its overall coloring is a fairly uniform brown or dark brown. Its legs, muzzle, a diagonal stripe behind its horns, and the 'saddle' of its center back are all of a whitish color.

Polarically opposite the musk ox is the sense oriented chamois, whose life habits are even more extreme than those of the goats. This animal chooses the highest of the mountain peaks from Spain to the Caucasus and eastern Turkey. Western forms tend to be rather slender, while the eastern ones are slightly heavier. On the average they all remain somewhat smaller than the wild goats and have neither mane nor beard; instead the hair growing along the spine can be raised to form the so-called 'chamois beard.' Consistent with this animal's sense-active nature is its overall form, which is both slender and muscular. In addition, its dorsal coloring is blackish-brown in winter and

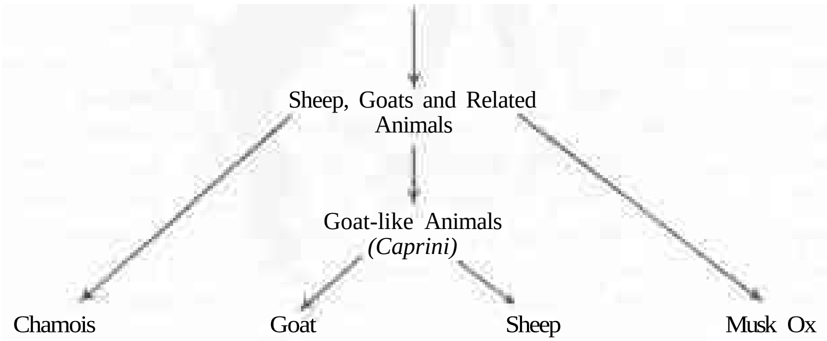
57. Chamois, in the Alps (1/15 X).

yellowish-brown in summer; the underside is always white. Its head has a conspicuous black and white pattern strikingly reminiscent of the badger's. Particularly significant, however, are the horns of the chamois. These grow up vertically from the forehead and then, remaining parallel, they turn back to form the beginnings of spirals. Soon, however, the underlying bone ceases to grow thick and eventually becomes so thin that all trace of curvature disappears. The horns then stand absolutely perpendicular to the surface of the forehead and project forward. Just as the initial curvature of the horns indicates this animal's relationship with the sheep and goats, their subsequent elongation and straightening point to the secondary preponderance of the sense system. Predictably, it is the female that has the longer and more slender horns (see page 127 and Plate 26).



58. The annual growth of the horn in an 18-year-old chamois (1/3.6 X after Couturier and Bourlière).

We may therefore establish the following order among the group of sheep and goats:



The sheep and goats form a connective link between the chamois and the musk ox. Even their appearance seems more harmonious than that of the animals at the poles. This centrality is expressed in many characteristics, but particularly in the formation of the horns. While the basic spiral form is modified in the chamois through a secondary stretching, and in the musk ox through a thickening of the horn's base, both of these modifications alternate rhythmically in the horns of sheep and goats, for a succession of knots and bulges forms along each horn's spiral. Mohr (1958) describes this progression in the ibex:

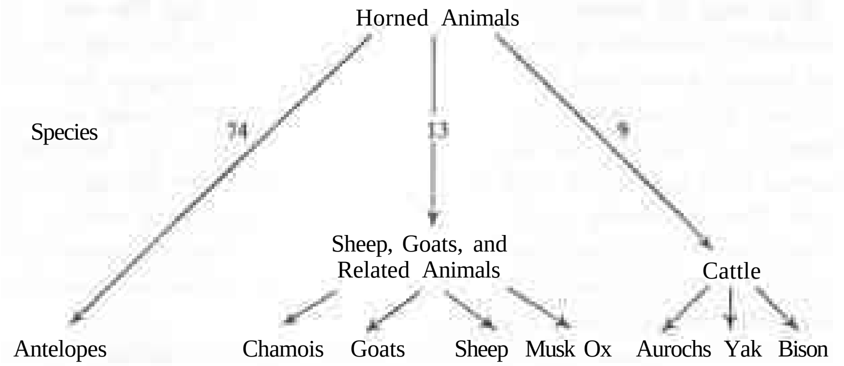
> The newly formed knots announce themselves by a swelling of the forehead skin at the base of the horn. After the knot has emerged, the forehead swelling subsides until the next knot pushes up.

In the ibex these knots are located along the front edge of the horn. In the sheep the same process takes place, but it results in smoother swellings around the entire circumference of the horn (Plate 138).

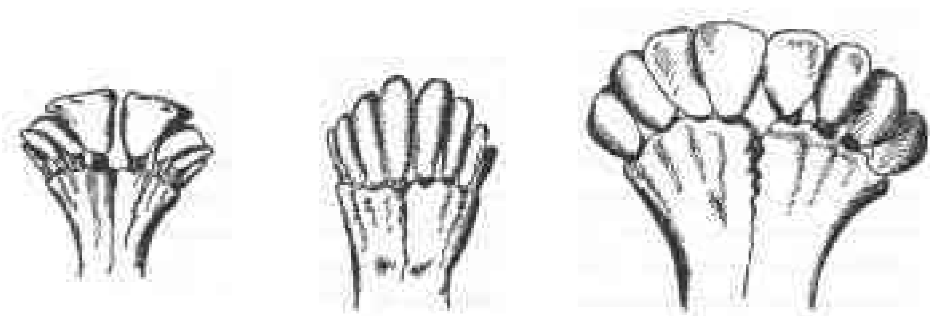
The central character of the goats and sheep is also expressed in a motif we have already encountered in the wild yak among the cattle: the marked difference in shape between male and female animals. In the wild goats as well as sheep, the female is not only significantly smaller than the male, and has a bodily form that accentuates the forequarters less than his does, but she also has very short horns (which are actually much better weapons than his). In many wild and some domesticated races of sheep, the females have no horns at all. In both the chamois and musk ox, however, any differences between male and female horn formation and overall shape are really very slight. The chevrotains, which in the last chapter were designated as the central family of the ruminants, again show marked differences between male and female. Neither sex shows head processes, but the males have large canines that extend far out of the mouth.

The bovine animals, then, and particularly the bison, demonstrate the highest degree of metabolic dominance. Goats, sheep, and their closest relatives develop a restrained, central form of organization within the bovine group. The receptive, sense-active side of this family is represented by the antelopes, which show an extraordinary diversity of form; there are today only 9 species of cattle, 13 species of goats and sheep, but 74 species of antelopes. While the cattle, who hold in check their metabolic forces, also hold back the number of their species, the antelopes are unrestrained in their ability to divide into different forms. No antelope ever attains the organizational complexity of the single cow, but the group as a whole is therefore free to create, in adaptation to different environments, an extraordinary variety of species. This variety is itself an indication of their openness to the environment. What cattle turn to the formation of a few powerful species is used by the antelopes for the development of many different forms. The mediating group of sheep and goats also forms few species, but not so few as the cattle. Instead, as we have seen, each species has divided into several geographical races, capable of cross-breeding. At the same time, however, they have differentiated into forms with such diverse outward characteristics that it was long considered correct to designate each of these forms as a species.

It is only in the antelopes that these processes of differentiation have given rise to completely separate species. From the ox-like eland, with its heavy forequarters, to the smallest ungulate in existence, the hare-sized Bates antelope, which reaches a height of only about 10 inches (25 centimeters), the size alone shows great variation. A few species are distributed over the Near East and India, but most live in Africa. Significantly, there are no sheep, goats, or even deer living south of the Sahara. From the multitude of antelope species, other forms arise to substitute for these missing animals, both resembling them in bodily form and occupying their position within the faunal balance of the area. (The kudu and its closest relatives substitute in this way for the deer family.) We cannot here discuss the antelopes in further detail, so a first, rather tentative survey of the horned animals, as seen from a threefold point of view, must suffice[30]:



In closing, we touch upon one final motif, the threefold structure of the dentition. The lower incisors of metabolically oriented species are all of equal breadth, so that even the lateral incisors are well formed. In the antelopes and even in the European chamois, the lateral incisors are quite small in comparison with the dominating front-most pair. The sheep and goats show a central condition.



59. *Left to right,* the formation of the frontal teeth in the lower jaws of the impala, goat, and bison (after Sokolov).

VIII The Antlered Animals

The deer, like the horned animals, are ruminants, but of a very different kind. For no antler-bearing animals, not even the semi-domesticated reindeer of the North, have ever been completely tamed. A deer belongs in the wilderness. It lives in vast connected forests, whether on windy mountain peaks or in humid lowlands. Shyly and in secret, the herds move through the forests; for wild animals have learned to fear man. Because he has brought nearly to extinction all the great carnivores—such as the bear, wolf and lynx—man, through selective shooting, must himself maintain a precarious biological equilibrium among the animals that remain. This shyness and fear, then, are not a part of the deer's real nature. Where it is not threatened by man, it is a daylight animal and moves in great beauty, free and unrestrained in the bright sunlight.

Even in today's almost cultivated forests it is a wonderful experience to meet with a wild stag. Unexpectedly large and powerful (Plate 140), this animal is nevertheless slender and long-limbed. The doe, who lacks antlers, makes an elegant, if less striking impression. The male, the real 'stag,' is all self-expression. With head held high, he gallops through the herd, the points of his antlers flashing in the sunlight (Plate 139). The antlers tower high above the rest of the body, thus accentuating its anterior pole. As research in animal behavior has shown, the antlers serve primarily to intimidate other members of the species, especially during the rutting season. Two rival bucks generally settle a dispute by bluffing rather than fighting; they use their antlers as weapons rather infrequently.

There are several different explanations of the antlers' significance, and each is certainly valid in its own way:

1. The antlers are weapons.
2. The antlers are signals meant to intimidate.
3. The antlers are outlets for metabolic surpluses.

The third explanation traces the influence that metabolic processes have on the antlers (see Schrammen, 1930). The first regards them simply as tools directed towards a specific purpose, while the second interpretation begins at least to take into account the significance of the antlers' form as such. Even this second explanation is incomplete, however, since the antlers are not simply signals 'addressed' to other members of the same species; they express something quite specific about the stag's own nature.

Men familiar with the deer have long revered it, attributing to its antlers a unique significance. In Europe, where the hunting tradition is very old, any forester is proud to have a stag in his domain; to him the stag is the living symbol of the forest and of his own calling. Surrounding the hunter and the stag, a whole mythos has grown up, with its own language and customs. Though many hunt only for adventure, and some, taking the place of the bear and lynx, may even feel a kind of hunting lust, there must be something more to this fascination the deer holds for hunters. In hunting journals, for example, writers make constant reference to the 'noble stag'—his majesty, his beauty. But such a romantic view can only blind us to the deer's reality. What is this animal, really?

When we see a deer standing next to a cow, we perceive at once how little the former is burdened with bulk and heaviness. It seems much more sensitive than the cow, far more awake to its surroundings. Though also a ruminant, the deer is not so completely dominated by its metabolism as the cow. Steiner (1924) found the sense-active nature of this animal to be deeply connected with its antlers: just as in cattle the impenetrable layers of horn hold back *within* the organism its powers of digestion, so the deer's antlers, even in their external form, are vents through which excessive metabolic capacities can flow *out of* the organism, thus freeing the animal to become more sensitive and graceful in form.

How do the antlers develop to perform this function? Like the horns of cattle, they begin as bony structures on the frontal bone and are covered with skin. The upper layer of skin, however, does not thicken to form plates of horn but remains alive; covered with fur, it continues to grow along with the bone. This living skin, or velvet, clings tightly to the antler as it grows. The damming process so essential to the horned animals does not occur in the deer; so the antlers need not be constrained by horny sheaths or bent into tight spiral formations. On the contrary, they branch out! The centrifugal direction of the hair's growth is typical of the antlers.

The antlers are quite sensitive as they grow, since no horny sheaths protect them. The deer therefore avoids touching anything with its antlers so long as they are covered with velvet. Large blood vessels lie within the velvet; and the skin covering the knobs is hot and stretched taut, as in an acute inflammatory condition, while the dark blood flowing underneath it makes the knobs appear black. Not a dead, horny sheath, then, but the free activity of living blood gives shape to the antlers. Rhumbler (1911) demonstrated that it is the path taken by the branching blood vessels that determines the branched form of the antlers.

The contrast between horns and antlers extends also to their rate of growth, for the horn grows slowly larger at its base, while the antler grows out quickly from its knobby points. About an inch and a half (4 centimeters) at each tip remains soft and pliable; only below this point does ossification set in, bringing the process of growth to an end. Only in the reindeer can tines that have already ossified still form additional outgrowths, so long as they are covered with velvet (Bubenik). In the cow's horn the underlying bone, which grows slowly and rebuilds itself continuously, remains alive throughout the animal's life. In the hastily grown antlers, however, ossification is quick and final. The antlers of the red deer develop in approximately 150 days, during the spring and early summer. This mighty formative activity is followed by a complete withdrawal of life forces. Over the now lifeless bone the blood within the velvet coagulates, and the velvet, while still moist, is rubbed off in tatters on shrubs and trees. The light-colored, bony tines are dyed dark brown by the tannin and resins in the tree bark. (In treeless moors and on the northern tundra the antlers remain light in color.) Eventually, through use, the points are scraped white again.

Now the antlers are complete. Two naked bones rise up from within the animal and reach out into space, increasing their own surface area by their branching. How different they are from horns! The latter seal off the body's inner forces within its surface, while through the antlers the body's inner forces are thrust outward. The antlers create openings through which the animal can establish its special connection with the outside world. And this process allows the antlers to grow rigid and die, for *within* the body no bone can die while the animal remains alive. The antlers are worn by the deer during fall and winter; and when the sap begins to rise again, at the melting of the snow and not before, the living bases of the antlers, the roots, become active once again. They dissolve the bony substance above them and loosen the intermediate layer, freeing themselves of the dead structure. Thus the antlers are shed (Plate 142). A scab forms where they have broken off and is soon replaced with regenerated skin; there, after a pause, new antlers will begin to grow. This cycle is repeated each year.

The horns, in their unbranching simplicity, are never transformed in this way. They are never shed, and their growth is therefore evenly sustained, though it becomes slower as the horn thickens. At most, each pregnancy of a cow imprints a ring of weakened horn formation, so that the number of her pregnancies may be counted from her horns. In all other respects, the horn's growth is scarcely influenced by the cycle of the seasons. There is only one horned animal that actually sheds and re-forms its horny sheaths each year: the pronghorn antelope of North America. Yet this is also the only animal whose horns are forked! The horn's sheath, penetrated thoughout with long hairs that connect it with the bony core, branches out to form forked prongs. Here again the exception proves the rule, for in this case the spatial shape itself and the way it changes through time are correlated. In other words, this animal's horns are not only shaped very much like antlers, but behave like them.

These different characteristics of deer and cattle, so beautifully taken up by the different head processes and expressed either in branching antlers or in spiral horns, show that the deer is the animal more open to the world and more active in its senses, while the cow is occupied with its inner processes and has the stronger metabolism. This evaluation has been worked out in detail by Werr (1930), Ritter (1935), and Poppelbaum (1949).

But we may carry the findings of these researchers a step further, by asking whether the antlered animals are, in fact, fully polaric to the horned animals, or whether they owe their special character to whatever equalizing, rhythmic processes have been active in the evolution of the ruminants. This question was first raised for me when I discovered that the upper canines, which are absent in most ruminants, are always present in the red deer. They are small and stunted, and in comparison with the other teeth, virtually without function. Yet they are present and thus point to the workings of the rhythmic processes. If we trace this phenomenon further we even find in some non-European deer large upper canines up to 4 inches (or about 10 centimeters) in length, which, like those of the water chevrotain, extend far down out of the mouth. Here, the canines are clearly more strongly accentuated than the molars! At the same time, of course, the crescent-shaped folds on the molars (see page 106) and the complete absence of upper incisors still mark these animals as ruminants. These animals, the tufted deer, muntjak, Chinese water deer, and musk deer, have only small antlers or none at all. Vestiges of upper canines similar to those of the red deer are still possessed by a significant number of other deer with fully developed antlers; such is the case in nearly all Asian species.

The coloration of the deer is another indication that they might be central, rather than metabolic, animals. The European roe and red deer have reddish-brown coats that turn grey-brown in winter; the undersides lighten, especially in the roe deer, to white. We find, therefore, not the uniformly dark brown coloring of the fully metabolic animals, but an almost 'sense-active' coloration. During the first month of life, however, the fawns of both the roe and red deer show another coloration, which we have not yet discussed: along the dorsal side their coats are strewn with light flecks, arranged in long rows (Plate 144). What is the meaning of this special coloration of the young? The answer to this question will lead us closer to an understanding of the deer's special character.

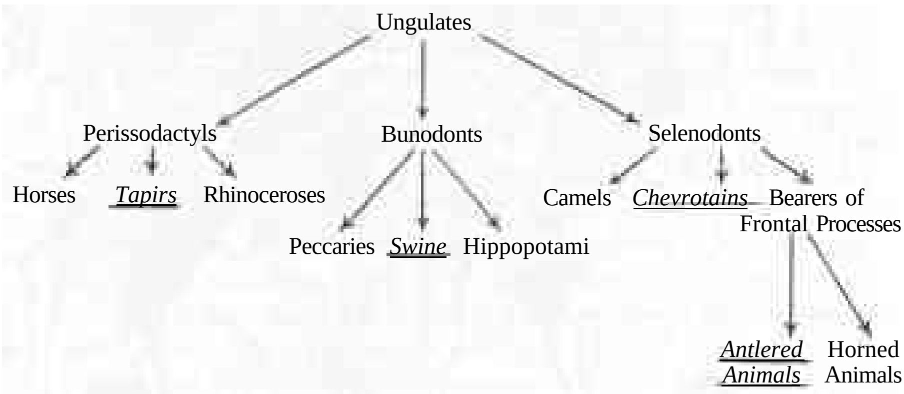
The young of almost all deer are spotted, as are the adults of many species, for example, the fallow deer, the Indian axis deer, the Eld's deer of Indo-China, the sambar of the Philippines, and, in summer, the Asian sika, barasingha, and hog deer, as well as certain races of musk deer. Even the European red deer, in the Atlas Mountains and near the Caspian Sea, remain spotted as adults. And in the Carpathian Mountains and the Balkans, as well, many stags with pale spots have been found (Dyk).

This spotted coloration is deeply connected with the basic organization of the deer and is recognized as one of their characteristic features. Most

 60. The axis deer is spotted even as an adult (1/13 X).

biologists, however, have been content to regard this coloration merely as camouflage that allows the helpless fawn to blend in with the dappled shadows of the forest leaves. They go on to explain that natural selection favored those animals in which random mutation first produced these spotted coats. But it remains unclear why the young of other forest ungulates, such as the Asian rhinoceros, the peccaries of South America, and the European elk, are unspotted. Many have ascribed such exceptions to the 'evolutionary accident' in which the mutation in question *did not* happen to occur. And this explanation generally lays to rest all further questioning, since it cannot be proved or disproved.

At the same time, however, this explanation shows how the theory of natural selection, in its wholesale application, can be misleading. For if we stop here, we cannot go on to discover the important relationship that exists between this spotted coloration and the basic constitution of the deer. This pattern of longitudinal spots also occurs in the young of other ungulate groups but is not evidence of any close relationship among them. Specifically, this coloration appears among the odd-toed ungulates in the tapirs (Plate 37), and among the bunodonts in the swine (Plate 126)[31]. If we add the chevrotains, which remain spotted even as adults (Plate 42), the following distribution of species with spotted coloration results:



A threefold interpretation shows that this spotted coloration is a definite motif of the rhythmic, central organization. Its occurrence, then, is by no means accidental but is quite definitely ordered. Where does this spotted pattern occur in other mammals? As we might expect, it is found in rich variety among the carnivores. Classic examples are the jaguar (Plate 81), leopard (Plate 157), cheetah (Plate 80), snow leopard, ocelot (Plate 158), serval, clouded leopard, Pardel lynx, spotted hyena (Plate 14), the young of the lion (Plate 105) and puma, and even the harbor seal (Plate 9), leopard

61. The thirteen-lined ground squirrel of North America is both spotted and striped (1/2 X ; after Burt).

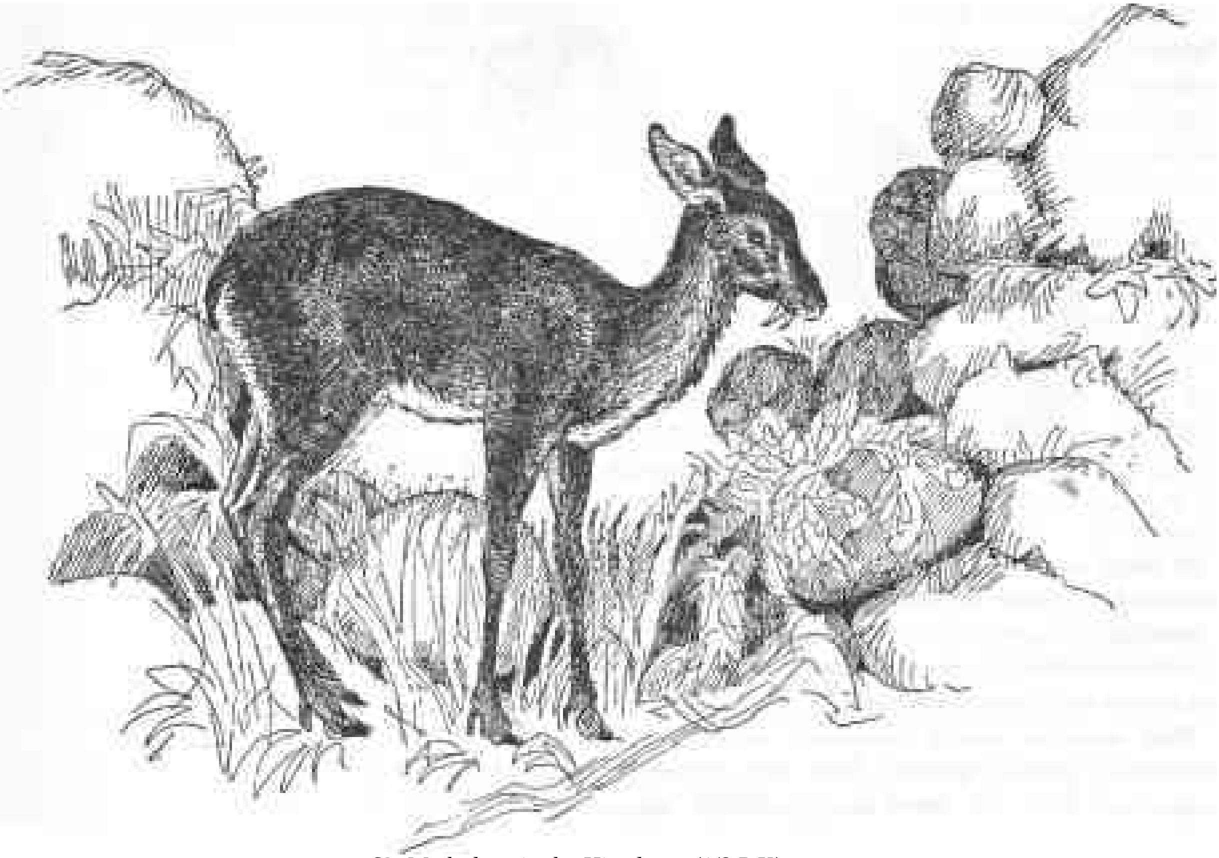
seal, ringed and hooded seals (Plate 10), and some others, as well as some whales. In the cat family, the most central group of rhythmic, central mammals, this spotted coloration is, as it were, at home. But we also find it, if rather sporadically, even among the central rodents, such as the chipmunks, the spotted suslik, and the thirteen-lined ground squirrel.

Here again we find a relationship dictated by internal necessity. The sense-active animals typically have light brown upper sides and white undersides, while the metabolically oriented animals typically have a uniformly dark coloring. Between these two stand the actively mediating forms. These show neither a simple division between light and dark or complete unity of coloring but a rhythmic alternation between light and dark. Such a spotted pattern is entirely congruous with the carnivore's harmonious form[32]. All colorations, then, are representative of the particular animal's total organization. The classic representatives of each group thus present an archetypal picture, both of internal organization and outward coloration and form.

Harvest Mouse	Leopard	Bison
(Rodent)	(Carnivore)	(Ungulate)

Turning once again to the deer, we find that the spotted coloration of the young, like the presence of canines, supports our contention that the deer, too, are animals formed by the rhythmic processes. In them the ruminant ungulate type attains a certain harmony and avoids overemphasis of metabolic processes. And in this harmony lies the beauty of the deer's nature.

Neither is a certain 'carnivorous' influence to be denied in these animals. A rutting stag, particularly the roebuck, which occasionally attacks even man, is extremely aggressive. The deer are among the most dangerous animals found

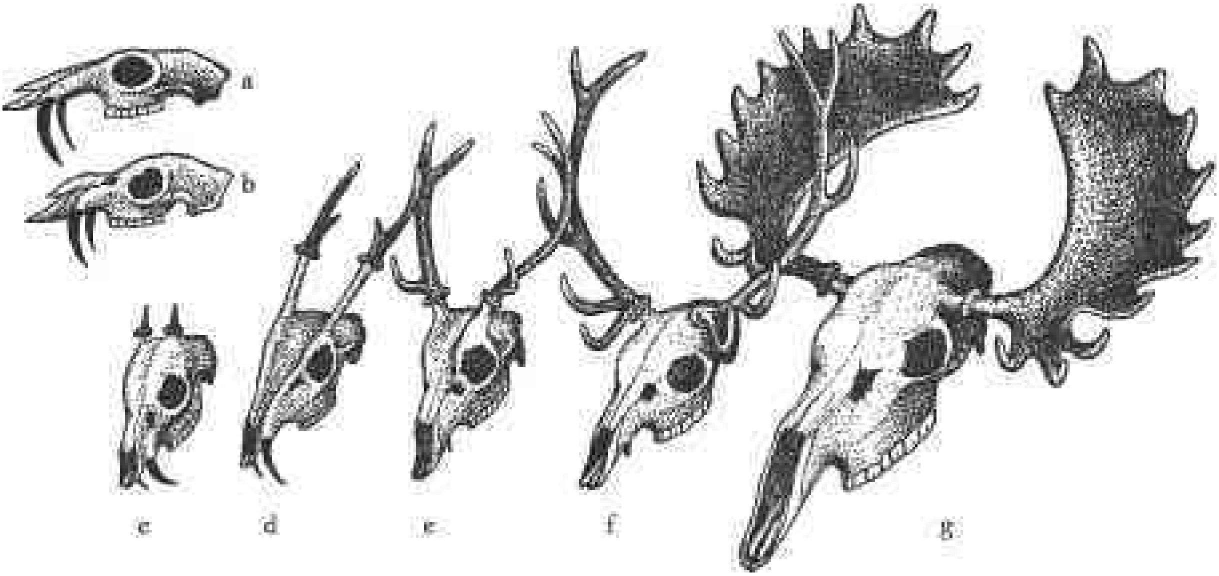


62. Musk deer, in the Himalayas (1/8.5 X).

in zoos. They cause more accidents than the carnivores (though admittedly in part because their keepers underestimate them). Unexpected attacks sometimes occur, in which a keeper may be wounded by an animal's antlers. The roe deer are seldom grouped as families in zoos, because in such close quarters, the bucks fight among themselves, often doing injury even to the does.

Walking through a forest at evening, just as darkness is falling, one sometimes hears an angry, penetrating bellow. Many an evening walker takes this sound for the barking of a large dog. But it is the roe deer giving voice to its displeasure at being disturbed. Both bucks and does 'raise the alarm' in this way. The European red and fallow deer also bark in warning, as do many other, non-European species, such as the wapiti cow. (Both the doe's call to her young and the stag's rutting call sound quite different from this.) This bark of warning, or more accurately, of annoyance, has a definite 'carnivorous' quality.

There are great variations among the antler forms of the different species, and these are closely related to the workings of the rhythmic processes. In order to understand this relationship we must consider once again some of the



63. Relative sizes of the canines and antlers of the male a) musk deer, b) Chinese water deer, c) tufted deer, d) muntjac, e) hog deer, f) red deer, g) moose.

primitive South and East Asian deer, which do not have antlers but have instead remarkably long canines. These teeth (in the musk deer and the Chinese water deer) can even be moved voluntarily, through the action of muscles. In the tufted deer there appear tiny, primitive, unbranched antlers that remain hidden beneath a tuft of long hair on the forehead; yet the canines are already noticeably shorter than those of deer without antlers.

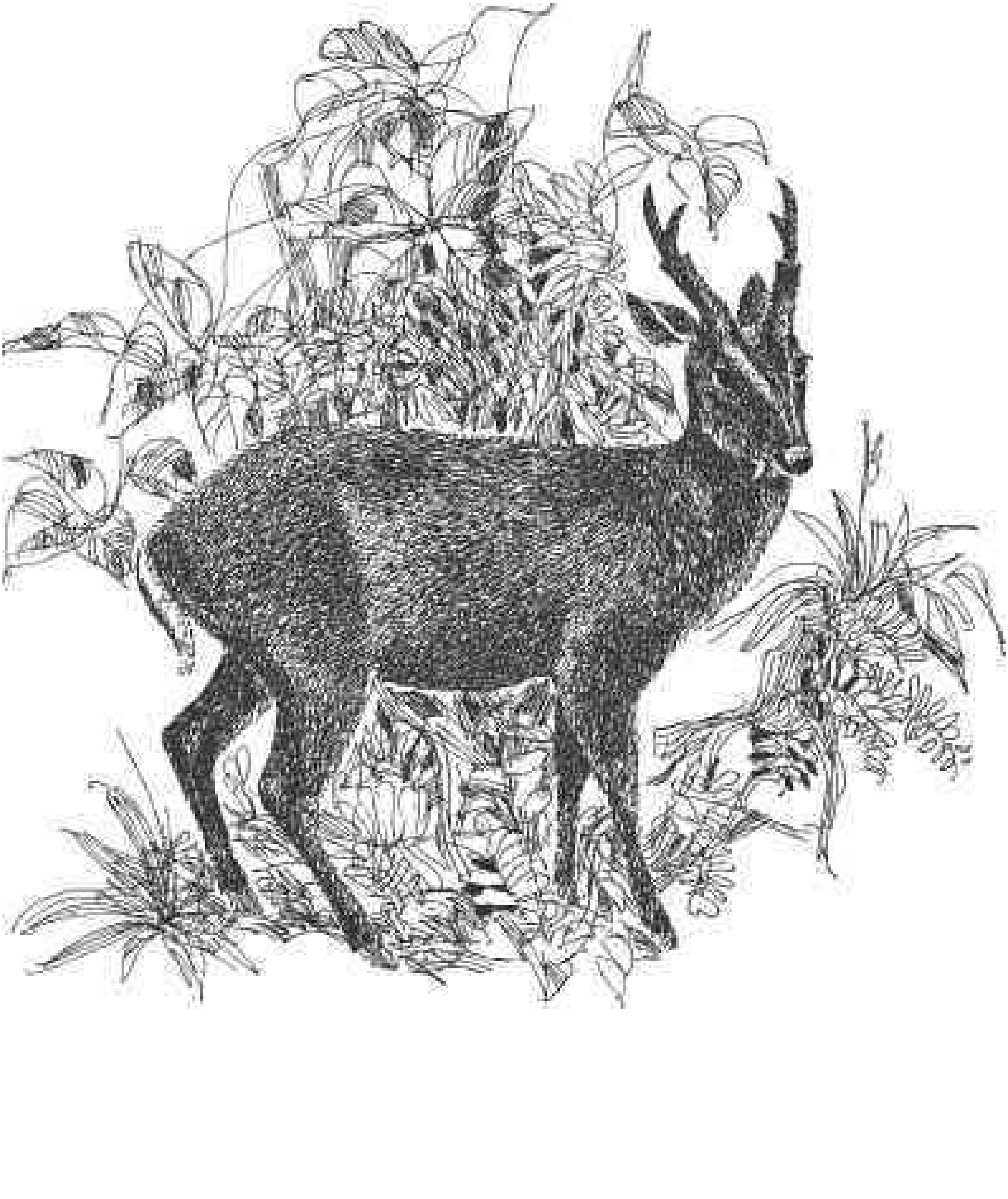
At the other extreme we find deer with fully developed antlers and canines that have degenerated to tiny stumps. Those species with an antler formation so massive that it tends toward a palmated form lose even these vestigial canines; in the Eurasian reindeer the last vestiges of canines are hidden beneath the skin of the gums; in the Alaskan caribou, the fallow deer, moose, and the extinct Megaceros, even these are absent. The smaller the canines, the larger the antlers (Roger). The less the rhythmic, carnivorous processes are diverted to the formation of teeth, the more they can be turned to the development of antlers.

This transition from the primitive to the fully developed deer is made visible in the muntjac of Southeast Asia. Since it is a mediating form, the central, rhythmic processes predominate in it. It barks so much like a dog that its common name in German is the 'barking deer' *(Bellhirsch)*. In captivity this animal has eating habits that have never been observed in it in the wild state: it greedily devours—as incredible as this seems in a ruminant—all kinds of meat, both raw and cooked. (Even the red deer always eats its own discarded velvet and thus for a short time also becomes 'carnivorous.') The male muntjac has fully developed upper canines that extend down from the mouth and attain the extraordinary length of about 4 inches (10 centimeters). At the same time he has the most basic branched antler form: small, forked antlers. Most remarkable, and for our purposes most important, are the roots that connect the surface of the skull with the antlers themselves, for these are unusually long in this animal. They begin as a pair of bony ridges far forward on the skull, at the very base of the canines, and from there they grow up along the entire bone structure of the face until they finally reach the antlers. Because of this feature the muntjac is often called the 'rib-faced deer.'

This animal offers concrete evidence for our hypothesis that the canines and antlers are connected: *The formative processes of the antlers originate in the region of the canines.* For the roots form the alveolar ridge, in which the canines are set, and at the same time nourish the antlers' growth. In the more primitive deer the processes that normally give form to the antlers still produce canines. In the more highly developed species, with their more dominant metabolism, these processes withdraw to the rear of the frontal bone, where they appear in the formation of antlers. In the muntjac, then, both canines and antlers are present, and both are much smaller than the roots that connect them. We see from this example that the antlers are formed by processes the metabolism has taken over from the formation of canines. In the central ungulates, the swine, the canines themselves may even become 'antlers,' as they do in the babirusa of Celebes (see Plates 161 and 162).

The Indian hog deer has roots that still extend as far as the ridge of the eye socket but are no longer connected with the canines themselves. The latter have degenerated into small stumps, while the antlers are six-pointed, and the roots have shrunk to a size that is normal for most deer species. Thus the hog deer forms a transition between the muntjac and the more highly developed deer. Yet even in this animal the frontal bone is itself able to develop antlers out of its own porous, internal structure (the diploë), if the root has been forcibly broken off (Bubenik and Pavlansky).

Antlers, like a cow's horns, are outgrowths of the frontal bones. Therefore, unlike the outgrowths of the rhinoceros or the wart hog, they grow up from the back of the head, in accordance with the animal's ruminant constitution (see Chapter VI). As we have seen, however, their form, unlike that of a cow's horns, is not compressed into a spiral; instead, it branches out. Although it is certainly true that the deer's sense-active contact with the outside world is visibly expressed in this branched shape, this expression is nevertheless only one aspect of the antlers' form. For the antlers do not simply branch out in all directions: the points not only project out and away from one another, but they also turn back towards one another. They alternately branch out and turn in, expand and come together. At first the antlers divide; then, near the top, they begin to come together again. Thus they enclose a spherical space, along whose circumference the antler tines curve (Plate 141).



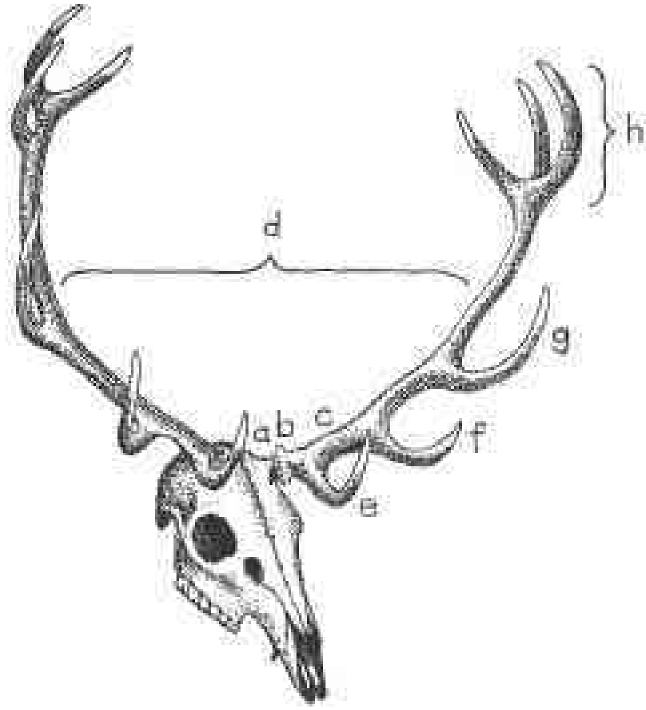
64. Muntjac, in the jungles of Southeast Asia (1/10 X).

This basic form of the antlers is described by Thompson, who has studied the geometric forms of nature (see also Poppelbaum, 1949). According to Thompson the antlers are to be visualized not so much as axial stems (or beams) giving off branches (or tines), as part of an outspread, spherical surface. It is this spherical shape that leads to the formation of tines and, in some species, even of palmations. But even in the case of unpalmated, beamed antlers it is helpful to picture the velvet as part of a spherical surface that contains the blood vessels along whose paths the bone develops. After the velvet has died the antlers remain, as visible remnants of this spherical surface. Thus we speak of the 'cup of the antlers.' If we tried to mold a pair of antlers out of clay our first attempt would probably be rather disappointing. However, if we then took an orange and molded the clay around its spherical curves, we would come much closer to a natural looking antler form. For the ends of an antler cannot reach into the sphere or extend out from it (Thompson).

This is the principle underlying the form of all deer's antlers, including the red deer's. This species is distributed from the Atlas Mountains in North Africa, over Europe and Asia, and even into North America. Its form is different on each continent, and has subdivided into several geographical races. The European form is certainly not typical. For its antlers, once they have developed ten points, largely abandon this spherical basic form. At the ends of its antler beams, it forms the 'crown,' so highly prized by European hunters that it has made them blind to the normal antler shape. The red deer of Asia (the marals and hanguls) and of North America (the 'elk,' or wapiti) generally have antlers without crowns. The basic antler form is, as we shall demonstrate, that which evenly encircles a spherical space above the head.

It is this balanced, spherical form that makes the red deer's antlers among the most beautiful of the entire deer family. They are not directed so much towards the front as those of the American Virginia deer, nor so far back as those of the Chinese Père David's deer. They do not rise so steeply upward as those of the roe deer, nor do they spread out so far to the sides as those of the moose. In addition, they have neither so few tines as those of the Indian axis deer, nor so many as those of the northern reindeer. The red deer's antler beams describe a harmonious curve, turning first out toward the sides, then upward, and finally slightly toward one another; the tines are well proportioned and branch out at regular intervals. Together they surround a spherical space (Plates 66 and 69).

This spherical shape does not spring up immediately. Only in the second year of the animal's life do small, unbranched broaches appear, to be replaced in subsequent years by antlers with an ever increasing number of points. Year by year the lower points, such as the brow and royal tines, move lower and project farther and farther apart, eventually forming the lower part of the sphere. Since the roots themselves become shorter and thicker with each passing year, they assist in this process by lowering the branches and causing



65. The antlers of the European red deer: a) root, b) burr, c) antler, d) antlers, e) brow tine, f) bez tie, g) royal tine, h) crown.

them to project ever more widely. Most of the tines added during the course of the years grow from the upper ends of the beams. To balance this development, the bez tines begin to grow from the lower portions of each beam, just above the brow tines, once the antlers have developed ten points. Brow, bez, and royal tines together reach lower every year, become longer, and turn more and more towards the front and sides; meanwhile the upper part of the beam lengthens and develops additional points. This spherical form is most perfect when the stag has reached its prime, at about ten or twelve years. Then, as he enters old age, the number of points decreases, so that he may finally have as few as eight.

Many authors have pointed out that the stag's formation of antlers is comparable to the doe's bearing of a fawn. In all species except the reindeer, antler formation, like pregnancy, is regulated by hormones secreted by the endocrine glands. The formative processes at work in the posterior pole of the female are transferred to the anterior pole in the male. The formation of a mane around the neck of the stag (*i. e.,* at the anterior pole of the body) also emphasizes his masculinity, while the lack of antlers emphasizes the femininity of the doe. The doe, therefore, even in the overall shape of her body, is more sense oriented in form, while the stag is larger and has the stronger metabolism.

An obvious difference in form exists between male and female deer. This is even greater than that we found between male and female goats and sheep, in which we first recognized such differences as signs of a rhythmic, central orientation. The deer, as the most central bearers of frontal processes, are the archetypes of this phenomenon. With the exception of some reindeer races, all female deer lack antlers; and even in the reindeer the female's antlers are much smaller than those of the male. The deer family *(Cervidae),* then, according to all we have here discussed, may be placed as a central group next to the fully metabolic family of the cattle *(Bovidae).*

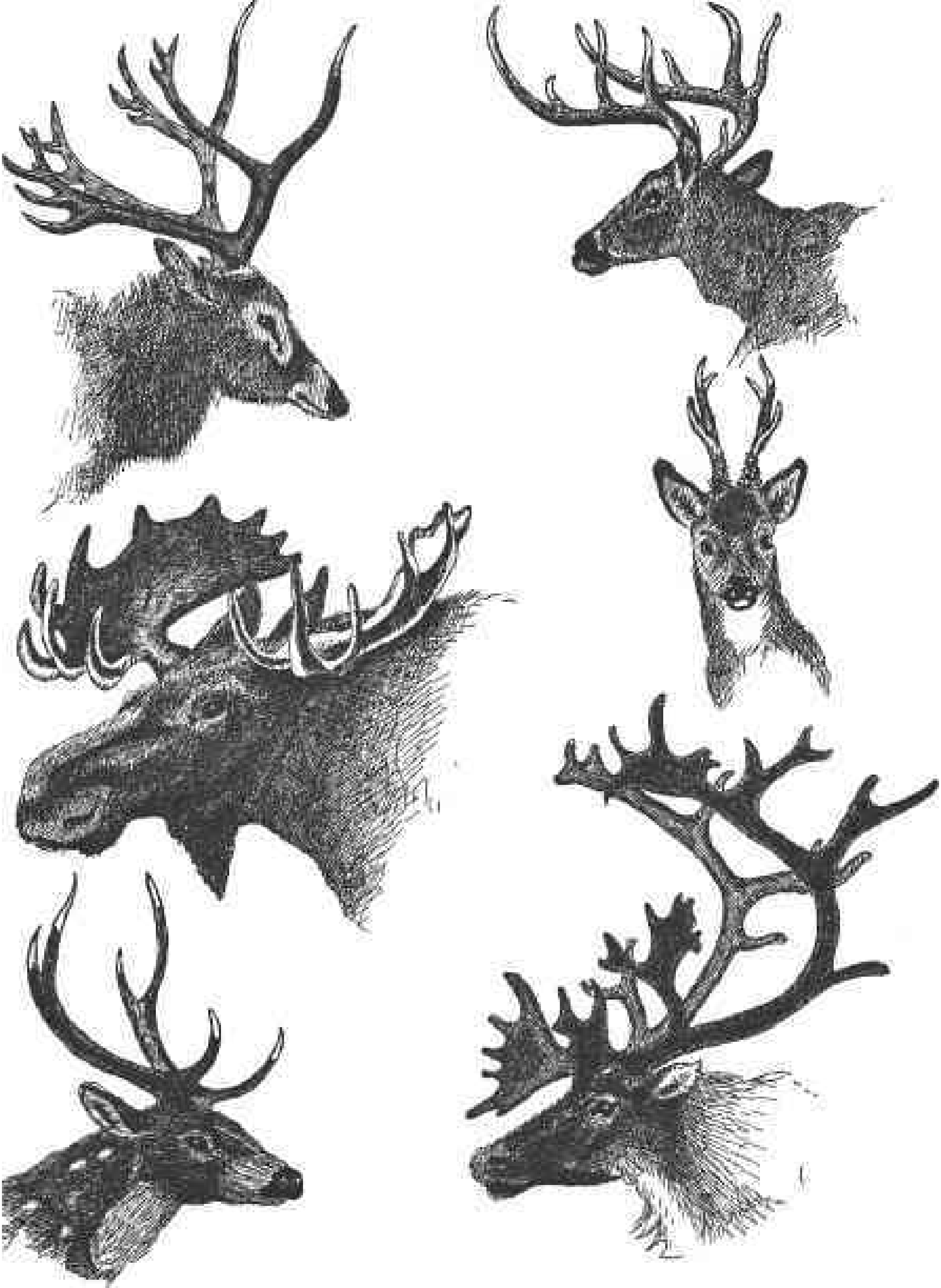
Having completed this general discussion, let us direct our attention specifically to the European species. In addition to the red deer, these are the roe deer and the moose. These three, in terms of size, coloration, and body shape, could be taken as paradigms for the biology of form. The red deer is the most central member of the deer family, while the roe deer has the greatest degree of sense activity and the moose has the most powerful metabolism.

The roe deer is rather small for a ruminant. It has the reddish-brown dorsal and white ventral sides typical of all nerve-sense oriented animals. The body's shape is accentuated in *back,* and even the buck has no neck mane (Plate 143). Wonderfully graceful, it springs effortlessly over thickets and underbrush. This member of the *metabolically oriented* ruminant group brings into *sense-active* form the *rhythmic* processes of its deer-nature. In this animal all three tendencies of the threefold organism play into one another, so that even the dull metabolic-life processes are brought into harmony with the senses and illumined by them. Grace and comeliness are embodied in this small deer.

The male roe fawn grows antlers even during its first year of life. By its first autumn—that is, by the time it is about six months old—it has already begun to form the roots of its antlers. These lean slightly toward one another, point toward the center, and develop tiny knobs about one- to three-quarters of an inch (0.5 to 2 centimeters) in length; their velvet is soon rubbed off and by January they have been shed. Immediately, the next set of antlers begins to grow, the unbranched broaches, whose velvet is rubbed off in April; these remain in place throughout the summer and are shed only in November. Until the following April forked antlers grow, and these are cast off in September or October. From November on, the six-pointed antlers develop. This is the final antler form, which is grown and cast off each year and increases its size and strength, but never its number of points (Plate 145).

The time sequence of the roe deer's antler formation is of particular interest because it begins so early and proceeds so rapidly. The red deer forms only

66. The antlers of several deer. *Left to right above,* Père David's deer (China) and Virginia deer (North America); *middle,* moose and roe deer; *below,* axis deer (India) and reindeer (circumpolar).

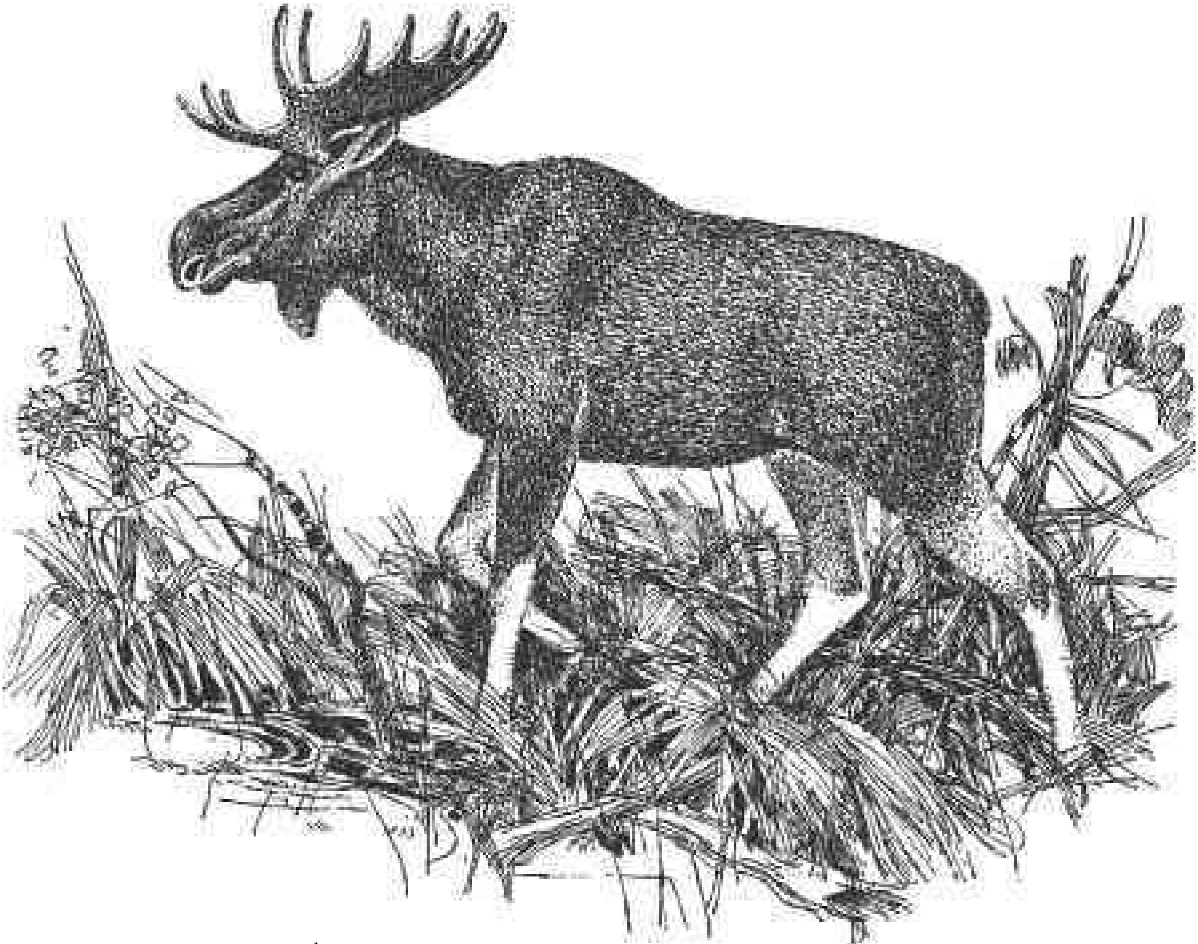


the roots of its antlers during its first year of life, and only in late summer of its second year do its first broaches appear, at a time when the roebuck of equal age has already shed its second set of antlers. The roe deer's antlers, therefore, must necessarily remain at a more primitive stage of development than the red deer's, never developing more than three points on each beam. Nevertheless, even this six-pointed form surrounds a roughly spherical area. This 'sphere,' however, is stretched upward and is more narrow and elliptical than strictly spherical in form. The straightness found in broaches is never abandoned completely, even by those East European and Siberian races (such as the tien-shan deer) that develop a total of eight, or even ten or twelve points. In addition, the lowest points, the brow tines, branch off high above the burrs, and, unlike those of the red deer, do not move downward each year; thus, the elliptical space they enclose never reaches down as far as the burrs.

This acceleration is so much a part of the roe deer's sensitive organization that we find it manifested in many other aspects of this animal's form. For example, the lower jaw's front-most milk teeth are replaced by permanent ones during the animal's first year of life, while the red deer replaces them only during the second. In addition, the roe deer, like many sense-active carnivores (such as the weasel, marten, and so forth; see page 66), mates in July or August; embryonic development is arrested at the blastocyst stage, and the embryo retains microscopic dimensions until December. Then, embryonic development resumes, and the fawn is finally born in May or June. Only if the doe has failed to conceive does she mate again at the beginning of December, omitting the characteristic pause in embryonic development. The red deer and moose, on the other hand, mate in August and give birth in the spring, without any interruption in the development of the embryo.

In Middle Europe the moose lives wild only in East Prussia and Poland, although in prehistoric times it ranged over all of Germany and as far as the southern slopes of the Alps. In northern and eastern Europe, as well as northern Asia, and Canada, it still exists in great numbers. This is a gigantic animal, the largest living deer, and with a shoulder height of almost 7 feet (2.10 meters), it is taller than a man. (The red deer is only about 4 1/2 feet, or 1.40 meters, tall, while the roe deer is about 27 inches, or 0.70 meters.) The mighty Alaskan moose may even attain a height of about 8 feet (2.50 meters) at the shoulder (Plate 147).

As the animal polarically opposite the roe deer, the moose does not have dark upper and light lower sides, but is a uniform brownish-black. Even the calves are unspotted—an exception explained by this metabolic animal's tendency toward uniform coloration. At birth the calves are as large as fully grown roe deer, and although they are reddish-brown at first, they soon turn darker. Fully grown moose of both sexes accentuate the front part of the body. High withers are formed; the hooves and therefore the tracks of the



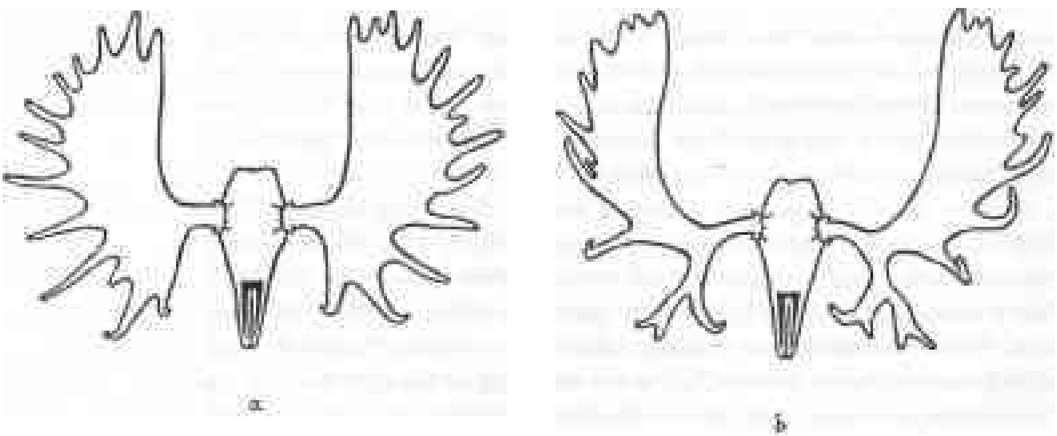
67. European elk, or moose ($^1/_{24}$ X).

forelimbs are always larger than those of the hind feet. There is no mane, but a cartilaginous dewlap hangs down from the throat. The eyes are relatively small and dull in appearance. The skull is extraordinarily long, the skin of the hairy muzzle droops loosely, and the neck remains short and thick. How different from the long-necked roe deer with its relatively short head, large, expressive eyes, and smooth, shining nose!

And the moose's antlers? Like those of the red deer, these begin to grow only at the end of the first year of life, that is, in May of the second calendar year. From the beginning, the roots point out toward the sides. The first broaches are complete by the fall; during the following spring they are shed. With each passing year, broader, more widely separated beams develop, adding more and more points. Only at the beginning of the fifth year do the antlers form palmations between the points, thus assuming their characteristic form. Until the moose's prime, these palmations increase both in size and number of points, grow increasingly broader, and at the peak of their development may weigh as much as 55 pounds (25 kilograms) and have a span of about 6 feet (2.90 meters). As the animal grows older, the points, beginning at the back and moving forward, begin to round off, so that the palmations' edges become somewhat wavy. The antlers scarcely point upward at all, but spread out toward the sides and back. Antlers with fully developed palmations are shed soon after the rut, towards the middle or end of October (Kramer). The surface of the wound is covered over and remains closed for four months! Only in March do the new antlers slowly begin to grow again; from May on they grow more quickly, and by the beginning of August they are complete.

Unlike the roe deer's small antlers, which grow up quickly and remain in place for a long time, the antlers of the moose are closed off at the bases for as long as possible. The antlers, in their finished form, are carried only for a short time. For this reason the moose's metabolic forces stream out from it to a much lesser degree than they do from other deer. The moose, therefore, can hold these forces back and turn them more completely to the formation of its own powerful body. As we have mentioned, the moose's antlers are not directed upward like those of other deer, nor do they branch out, and their great mass makes them virtually impenetrable. Along the lower sides of the palmations, impressions left by the meandering course of the blood vessels are to be found—an indication that the slow-moving venous blood has been concentrated here. In the growing antlers of the roe deer, quickly flowing arterial blood is active, while in developing moose antlers, venous blood, with its tendency gradually to come to rest, is at work. Thus, the palmated antlers of the moose are in complete accord with its powerful metabolism, since it is the form of its antlers that enables this animal to retain within itself its strong digestive capacities.

We even find the typical division of food requirements among these three European deer. The sensitive roe deer is inordinately fond of delicacies.



a b

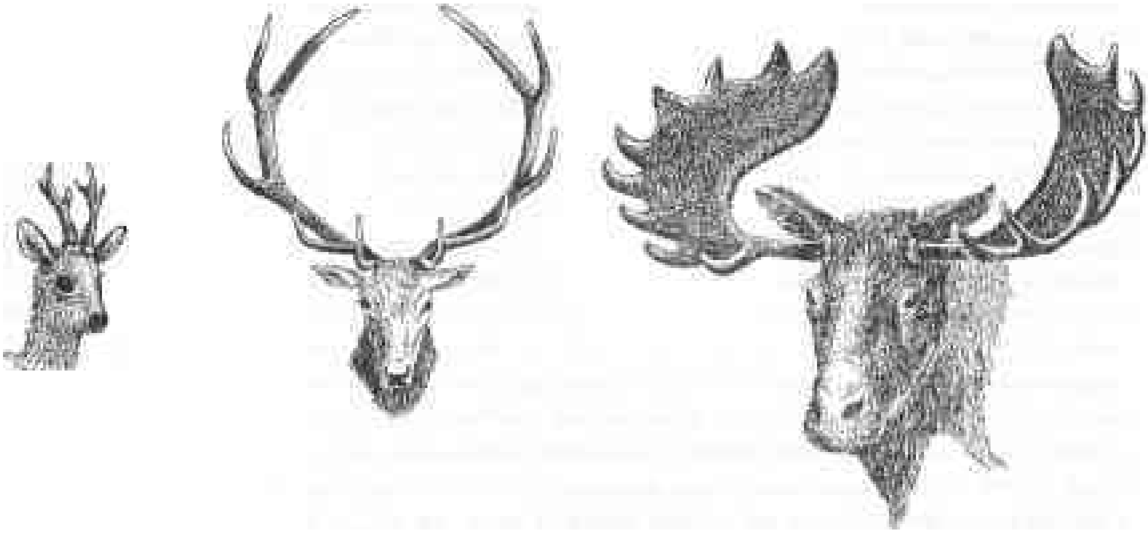
68. Antlers of the moose: a) Eurasian race (Finland), b) American race (Canada).

Fastidiously it chooses only the most succulent herbage and buds, as well as tender shoots and nourishing grains. On a diet of hay alone it dies. The red deer does not disdain the roe deer's favorites; **still,** it is primarily a grass eater, and (to the forester's dismay) it also strips the bark from trees. The moose, however, feeds primarily on leaves, twigs and the bark of trees, of which it daily consumes at least a hundred pounds. This animal's very constitution seems to demand that it come to grips with the nearly indigestible cellulose, lignin and tannin found in such foods. It particularly savors the branches of poplars and willows. Some of the branches it devours may be thicker than a man's finger, yet in its droppings only a small residue of wood fiber is to be found. It can even subsist on pine needles! An extraordinary number of different trees are stripped of their bark by the moose. It rarely bothers grain fields but resorts instead to swamp plants and their bulbs; for it loves the water, where it frequently wallows and bathes, above all (Plate 146). It needs the swamps, bogs and marshes. An area that provides both a marshy landscape and a large supply of twigs and tree bark is absolutely necessary to the wild moose's existence.

Characteristic, too, for each of these species is its whole way of moving. The roe deer is quick to take flight; swift and agile, it bounds off into the distance. It can also live in unforested regions, since its ability to flee quickly fully compensates for the lack of cover it finds there. Unlike either the red deer or the elk, this animal's flight behavior is instinctive and innate (Schmidt). The red deer prefers wide, extended woodlands and especially those areas where man is least likely to be found; there it can move freely. The moose, when disturbed, does not flee at once. With remarkable deliberation, as unobtrusively as possible, it soundlessly steals away. If it cannot hide, it trots away calmly, maintaining a steady pace for miles, until it feels safe once more.

This brief survey brings us to a first threefold classification of the deer, whose relationship, as we have seen, is revealed even in the formation of the antlers themselves. To summarize, we find harmony and balance in the spherical form enclosed by the antlers of the red deer, while the roe deer's tiny antlers rise up so steeply that this basic spherical form is stretched upward. Polarically opposite is the broad, flattened spheroid enclosed by the moose's palmated antlers. In addition, the spheroid surrounded by the roe deer's antlers never reaches down as far as the burrs, while in the red deer it extends downward gradually during the course of the animal's lifetime, and in the moose even the roots point out toward the sides and thus are adapted from the very beginning to the formation of a spherical shape.

The lowest, or brow, tines of the roe deer's antlers are added only high above the burrs, far above their normal position. In the red deer both brow and bez tines are well developed and assume their normal, low position, while



69. *Left to right*, heads of male roe deer, red deer (hangul) and moose.

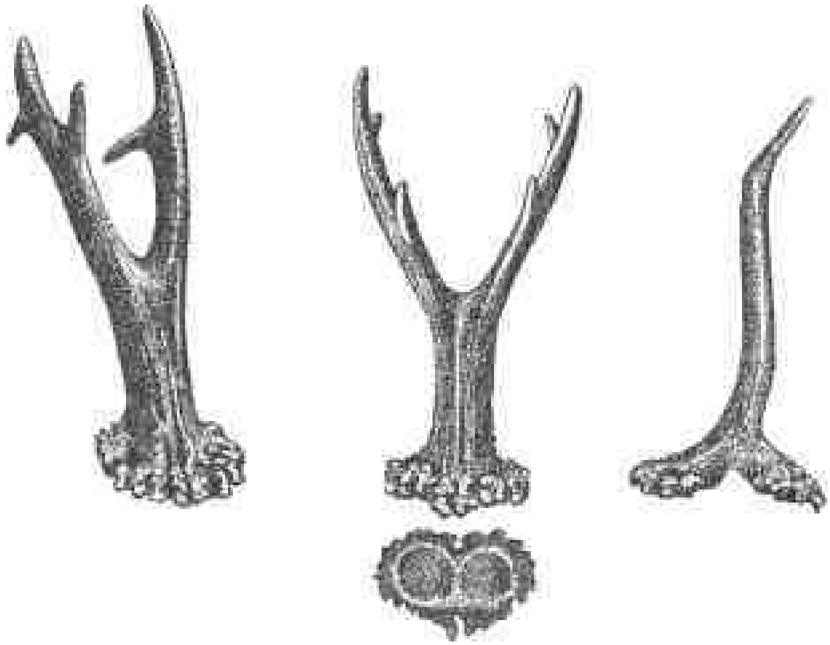
the upper portion of the antlers is equally well developed. The moose's antlers, however, always remain within the low-lying area of the brow tines. The roe deer seems bent on completing the upper part of its antlers as quickly as possible and in its haste appears to skip the area of the brow tines. The moose's antlers, on the other hand, develop slowly and never grow much beyond the region of these lowest tines. Only the red deer develops both areas equally—*and* between the two it forms its characteristic royal tines. The harmony we find expressed in the red deer's antlers as polarities and their mediation gives visible expression to the harmony that unites these three species as a group.

We have already discovered a similar threefold relationship among the frontal processes of the horned animals. The sense oriented chamois, as well as many antelopes, has horns that point almost straight up, while metabolically oriented forms, such as the musk ox, cow and bison, have thickened horns, directed out toward the sides (Plate 51). This similarity between the horned animals and the deer is even more apparent in the central members of the antelope group. The gazelle, even in the formation of its horns, corresponds to the roe deer; the kudu to the red deer. Although the underlying form of the antlers is the sphere, and that of the horns is the spiral, the two show corresponding variations in form. Thus, while the basic variations shown by the antlers of the European deer are of course deeply characteristic of these animals, they are present at the same time in other groups of hoofed animals.

We understand the deer correctly only if we recognize in them the same sensory, metabolic and rhythmic processes that give form to *every* mammal. The nerve-sense pole of any animal is directed outward, towards the surrounding world. It is this outward orientation of the senses that gives the animals their long, pointed muzzles. The metabolic system, by contrast, is primarily oriented not towards any outer goal but towards the expansion of its own form in space. It lives entirely within itself: physiologically creating its own substance, and morphologically shaping its own space. And the space it creates tends toward breadth and expansion even where it extends into the head. Thus the molars of mammals always stand farther out to the sides of the head than do the incisors, which come close together at the front of the mouth. As we have mentioned before, metabolic and sensory processes occupy space in very different ways. For every life process prefers, or even creates for itself, its own specific kind of space. Space, then, is biologically relevant, and it is only the living form that enables us to discover its significance.

The centering processes we have found associated with the senses and the processes of expansion we have seen in metabolism are active not only in normal antlers but also in anomalous formations. Goethe was particularly interested in anomalies, since it is precisely in them that the many formative possibilities of normal structures become most clearly visible. In the antlers, as in other living forms, the formative possibilities are far greater than that of the normal shape alone. And even the normal form is much more variable in the antlers than it is in the horns. Quite frequently one antler beam has more points than the other. For example, one antler beam may have five points and the other, only four. These would be called odd-numbered ten-pointed antlers, though they have only nine points; in this case one refers simply to the doubled number of points on the larger antler beam. Other frequent anomalies are multiple-beamed antlers, in which additional roots are present (thus demonstrating that in principle the entire frontal bone is capable of forming roots with antlers). Such multiple beams are found occasionally both in European and non-European species (Nitsche, 1898). Here we are interested primarily in those anomalous forms found in the European roe deer, red deer and moose.

In the roe deer it may happen that the roots lean toward one another to such an extent that the two beams, though growing from separate burrs, fuse to form a single structure above the center of the head. This growth toward the center may even cause the burrs themselves to fuse, so that the two antlers share only one burr between them. In this case the beams join along a central line and divide again into two branched sections. (One of the examples shown in Plate 70 is an odd-numbered six-pointed pair of this type.) The fused burrs project forward farthest along the seam that joins them, as does the beam section, which forms a slender, bony ridge. In back the fusion of the burrs is less complete. Even in these structural details, then, the interplay of metabolic processes, which tend to expand, and nerve-sense processes, which tend to concentrate and move forward, can be clearly seen. In an article published by Brandt (in 1897), we even find an example of a single point growing from

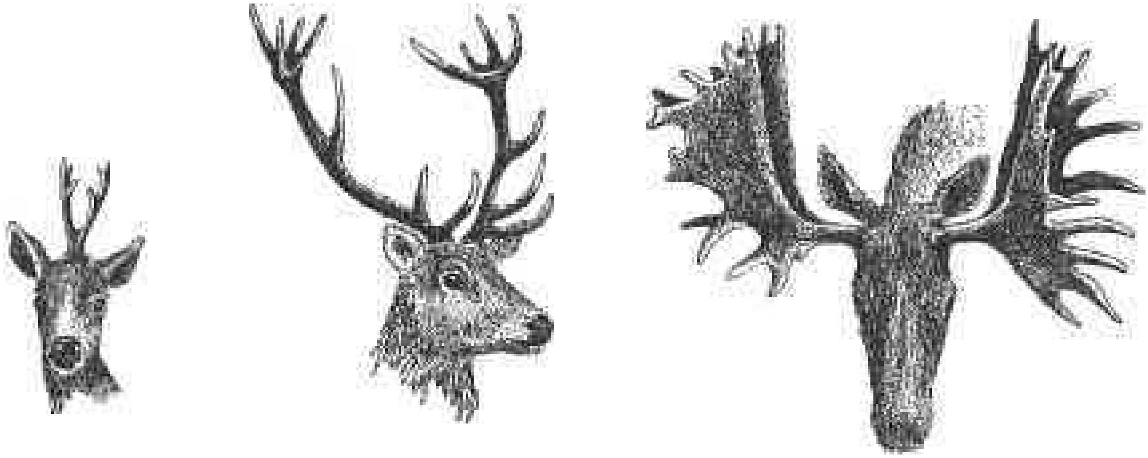


70. Anomalous roe deer antlers (1/2 X; after Nitsche, 1898, and K. Brandt).

two separate burrs and roots. In this case the tendency of normal antlers to center above the axis of the head has been realized completely. This kind of abnormality, the median fusion of beams, is known only in the roe deer.

In the antlers of the moose, on the other hand, we find the following abnormality: the antlers may add extra points that reach down, below the palmations' edges. This process may even affect the palmations themselves, so that each beam forms two partially fused, palmated lobes. Instead of the single-beamed condition of the anomalous roe antlers, paired double palmations arise from the gigantic antlers of the moose. While the one no longer creates a sphere in space, the other has made a 'double bottom' for it. The former reduces even further the physical substance of its normally small antlers, while the latter grows antlers that are quite large and extraordinarily heavy. While the space the antlers seek to encompass nearly vanishes in the single-beamed roe antlers, it is given excessive substance by the four palmations of the moose antlers. In the roe deer the originally paired beams reach too far *into* the normal antler space; in the gigantic moose, they extend too far *out from* it, thus exaggerating their innate tendency towards breadth.

The European red deer, with its harmonious antler space, tends toward a regular, spherical form. Does this animal also show anomalies typical of its constitution? Yes, though in this case the spherical form is not altered so much as it is multiplied. At the upper end of each beam there may be tines that reach into the primary space, as well as out from it! These surroyal tines



71. Typical antler anomalies in European deer species: single-beamed roe deer antler (after K. Brandt), red deer antlers with crowns, and double-palmated antlers of an American moose (after Nitsche, 1891).

are often clustered in a circular form, so that the upper end of each beam encircles a separate, smaller spheroid. These are the 'crowns' of the European red deer (Plate 148). This formation, abnormal in comparison with those of non-European races, is nevertheless consistent with the underlying form of the antlers. Occasionally, the North American wapiti may also develop crowns, but their occurrence is quite rare in comparison with that of the European race (Linke). This 'abnormal' form, which has become typical of the European red deer, also shows a wonderful organic order[33].

Plate 72 shows, in chronological order, the fossil antlers of the prehistoric red deer[34]. This survey, based on the work of Beninde (1937), shows that at one time even in Europe, the basic, crownless antler-form prevailed in this animal. The crowned antlers developed only relatively recently, during the glacial period. Since Beninde's illustrations generally show only one beam of each antler pair, we have reconstructed the essential features of each full set, in order to show the spatial shape it surrounds.

The earliest forms show well-developed brow and bez tines. These provide a good base for the primary antler space. In *acoronatus* the highest fork has already thickened to form 'crab claws,' while the *priscus* form has the first three-tined crowns. These, like the crab claws, are turned inward, towards the space surrounded by the antlers. In *angulatus* new crown spaces have begun to separate from this primary antler space, but by means of an elongated tine that is still directed inward, they maintain their connection with it! This elongated spur grows smaller in the late *angulatus* forms, thus enabling each crown to create an independent space of its own. By the end of the Ice Age the *primigenius* deer shows a fully developed crown space that is definitely directed out toward the sides.

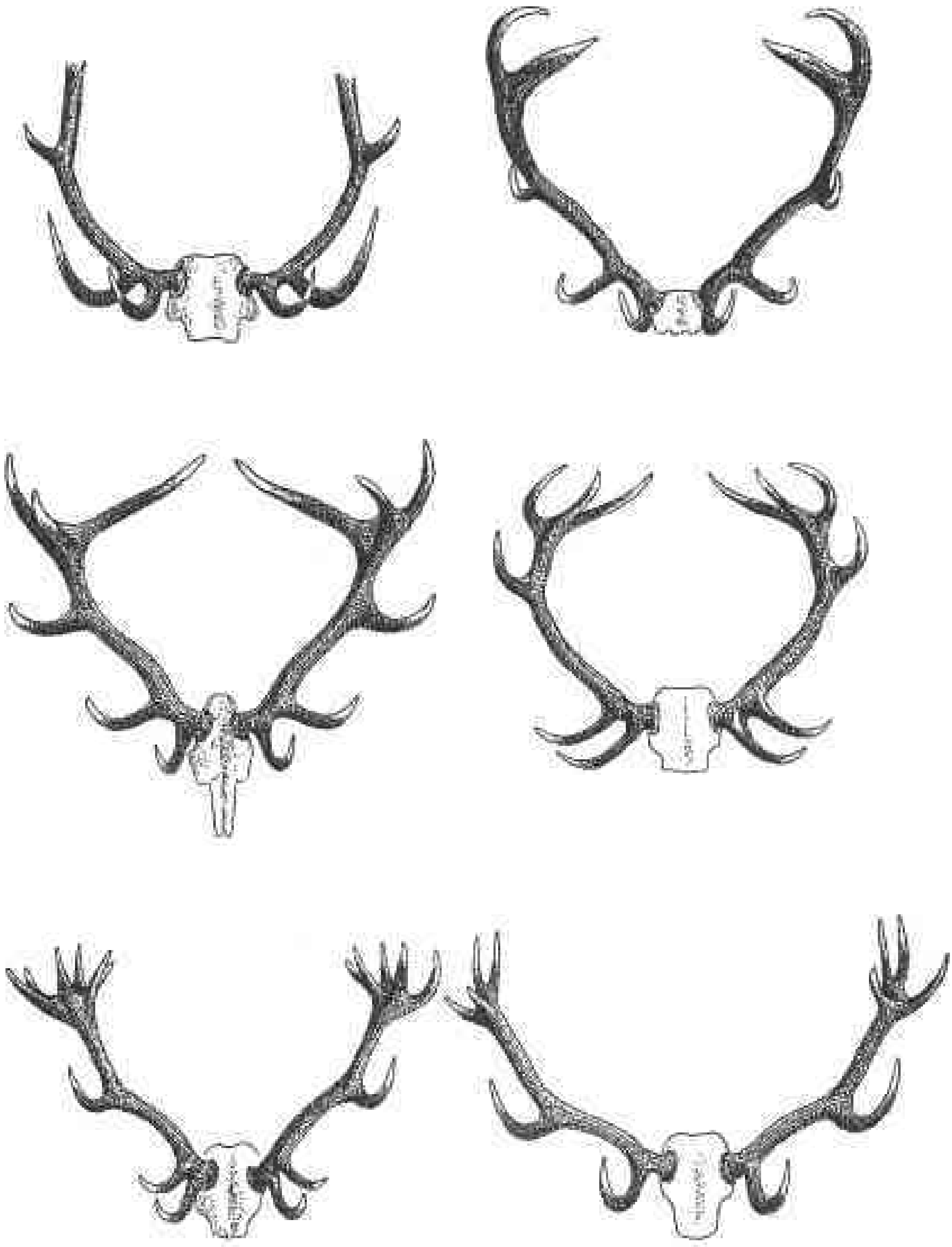
Here we see the actual sequence in which the European red deer formed the crowns of its antlers, gradually withdrawing them from the primary antler space and separating them from it, until each of them came to recapitulate in smaller form the original spherical shape. Thus, each crown forms an additional antler space at the end of each beam, stemming from the original but totally independent of it. The *angulatus* antlers represent the transitional form, since their crowns help to form the common antler space as well as their own separate spheres.

In the *primigenius* deer, with its fully developed crowns, the bez tines are sometimes lacking or only partially developed—quite the opposite of the earlier forms, in which bez tines are prominent, while crowns are absent. During the Ice Age, then, the formation of the crowns proceeded in the upper area of the antlers at the same steady rate as the reduction of the bez tines in the lower region. With this reduction of the bez tines, the original, spherical shape of the antlers was noticeably altered. This fact offers further evidence that the crowns developed at the expense of the original antler shape.

Only after the end of the Ice Age, during the present geological era, has the European red deer established balance between the crown and bez tine regions of its antlers; now both are fully developed (Plate 148). Today's North African Atlas deer, however, still preserves something of its late Ice Age character. Its antlers are usually without bez tines and therefore occasionally develop the wide, cup-shaped crowns typical of the Ice Age deer.

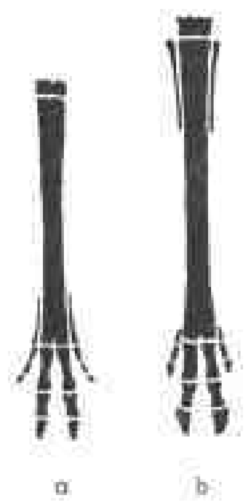
In concluding this chapter we turn once again to the structure of the deer's teeth. We have already demonstrated the connection between canines and the rhythmic processes of any animal species. Thus, the elongated canines of the primitive deer species give testimony to the basic rhythmic character of the entire family of deer. In the fully evolved species, as we have seen, the canines have been reduced to mere stumps in the course of the antlers' development. In species whose rhythmic orientation has diminished in favor of polaric developments, even these stumps are no longer found. Thus among European species, only the central red deer possesses vestigial canines. Both the roe deer and the moose show some development of canines during the embryonic stage, but only in the rarest instances (8 %, according to Nitsche, quoted in Rau) are these tiny vestiges retained by the adults of either species. These developments are consistent with those of other, non-European species

72. The development of the antlers in the central European red deer of the Ice Age. *Left to right, above,* the first European red deer, from the green sand marl layer (between the Pliocene and Pleistocene beds) found in Hundsheim/Vienna, and *Cervus elaphus acoronatus* from the early Günz-Mindel Interglacial, found in Mosbach/Wiesbaden. *Middle, Cervus elaphus angulatus,* from the early Mindel-Riss Interglacial, found at Steinheim a. d. Murr, and *Cervus elaphus angulatus,* from the late Mindel-Riss Interglacial, found at Steinheim a. d. Murr. *Below, Cervus elaphus,* from the same Steinheim layer, but slightly higher, and another example from the end of the last (Würm) Ice Age (after Oloff and Beninde).

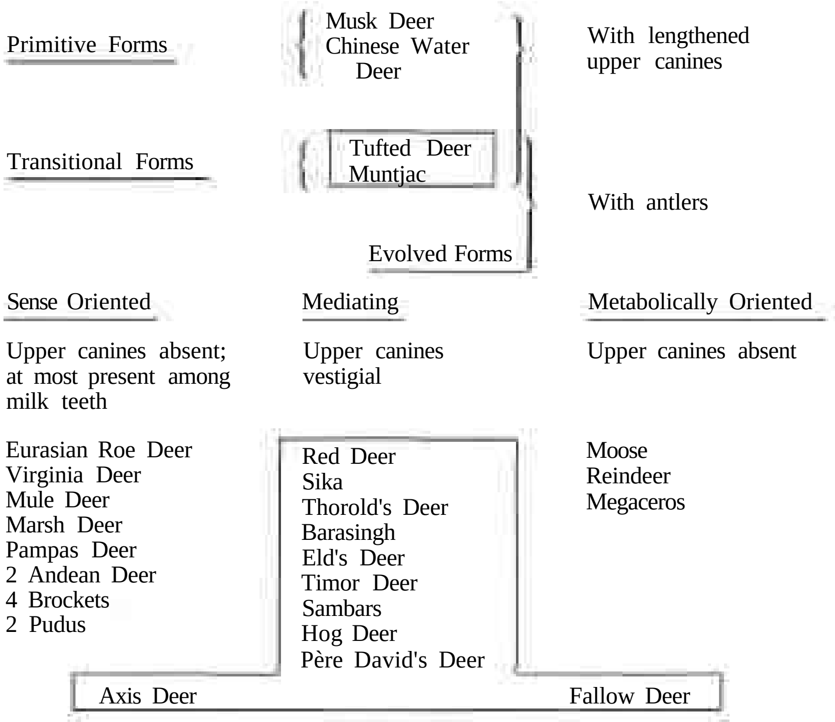


as well. Thus, as we might expect, all the extremely metabolic bearers of palmated antlers, including the reindeer, fallow deer, and the extinct Megaceros (Plate 149), completely lack these vestigial canines. These teeth are also lacking in species which, like the roe deer, have become sense oriented. To this group belong all forms that are restricted to North and South America. These species are about twelve in number and vary in size from that of the mule deer to about half the size of the roe deer. The pudus, for example, are only about 14 inches (or 35 centimeters) high at the shoulder. While young, these tiny animals still have upper canines, though they have lost them as adults. Nearly all species closely related to the red deer, however, have vestigial canines throughout life—an indication of their central position within the deer group.

Modern taxonomy divides the deer into two groups, according to the structure of their metacarpal bones. Those species in which the stunted vestiges of the second and fifth metacarpals of the forelegs are located near the phalanges are grouped together as the telemetacarpal animals; those species in which these bones lie closer to the carpus are called plesiometacarpal. In the following survey, all living deer species are so arranged that their positions within the threefold order, the presence of upper canines, and the position of the metacarpal bones may be seen. We also include the extinct Irish elk (Megaceros), since it was contemporaneous with man during prehistoric times. Although this animal is often classified erroneously with the fallow deer, it is actually telemetacarpal.



73. Bones of the forelegs in the deer family: a) *Telemetacarpalia*, b) *Plesiometacarpalia* (after Oloff).



(The plesiometacarpal species appear within frames; all others are telemetacarpal.)

In comparing these animals we find that the concept 'plesiometacarpal' has real meaning in nature, for animals in this group are all 'central' forms, in our usage of the term. This is the case in all species closely related to the red deer, since, in both size and antler shape, they form a completely uniform group. Nearly all plesiometacarpal antler bearers have stunted upper canines. Only in the Indian axis deer, the most sensitive species, and the fallow deer, the most metabolically oriented member of this group, are these vestigial canines absent. The tufted deer and the muntjac, mediating forms between the primitive and the more highly evolved species, are also plesiometacarpal. This feature, then, is obviously connected with the dominance of mediating processes among the deer. All extreme forms, on the other hand, are telemetacarpal: the most primitive species, as well as both the extremely sense-active and metabolically oriented forms. The telemetacarpal group, then, has no inherent unity, but includes the extremes[35].

In the above survey the central position of the red deer is once again made evident. In earlier times hunters had an intuitive understanding of the special meaning of this animal's upper canines. Thus the custom arose of mounting these teeth in gold or silver and wearing them as ornaments. We, too, may recognize these vestigial canines as a sign of the perfected harmony of the red deer itself.

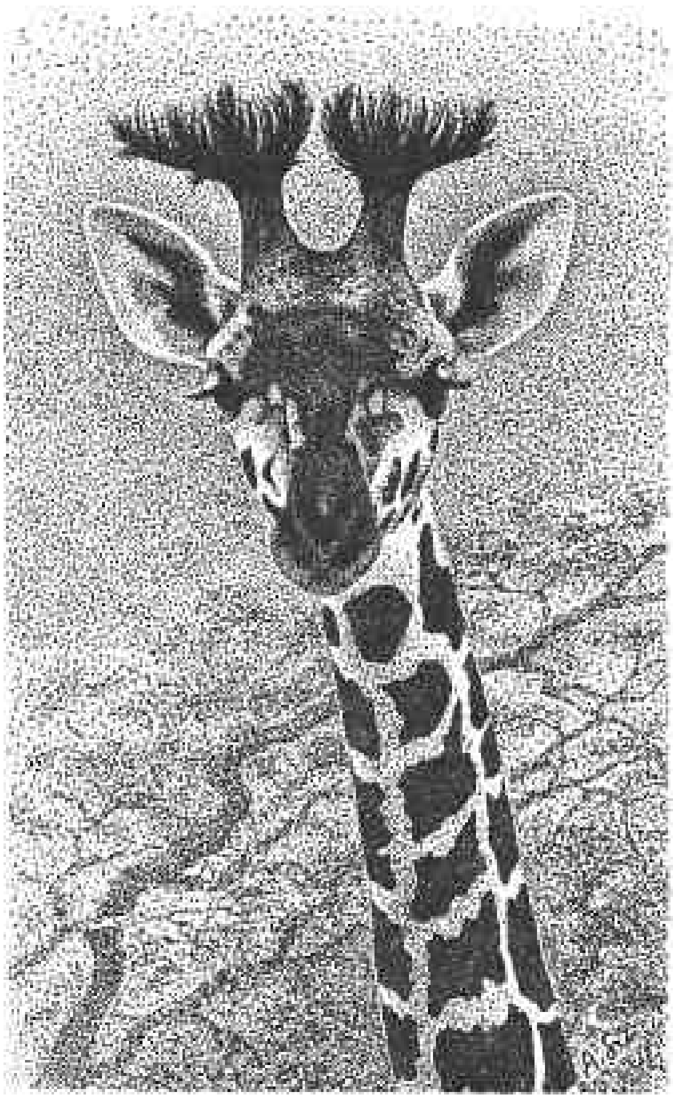
IX The Giraffes

The giraffes are truly remarkable creatures, whose extraordinary body proportions demand a thorough examination of their basic shape. Closely related to the horned and antlered animals, they are fully developed ruminants. Their paired frontal growths, however, are neither genuine horns nor antlers, so that these animals must constitute a last, separate family among the bearers of frontal processes. There are only two species in this family, the well known giraffe of the savannas (Plate 152), and the okapi, a rain forest dweller (Plate 153). Both are found wild only in Africa.

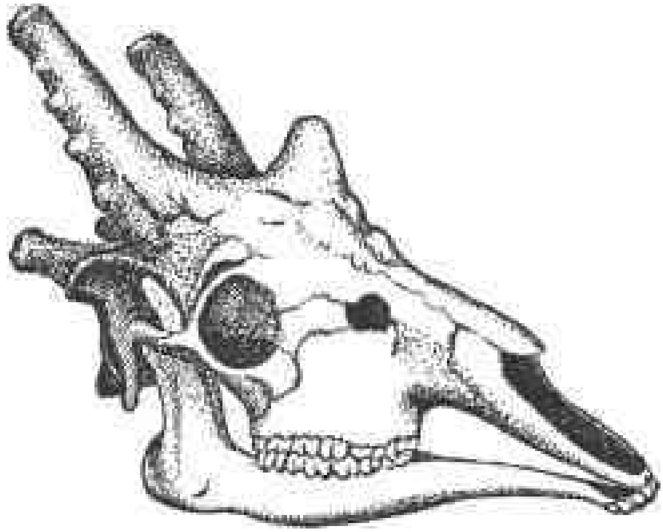
A gentle animal, the giraffe has an exceedingly narrow head and large, expressive eyes with long lashes (Plate 150/151). The Arabs have given it many poetic names, and from the Arabic word *geraph* (seraph), 'the lovely one,' its present name is derived.

Disproportionately large and erect, the giraffe has overly long legs, a very short trunk, which drops off steeply towards the back, and an extremely long and powerful neck that carries a rather elongated, slender head. This animal's entire form is exaggeratedly vertical. From the outset, then, we may assume that this is no rhythmic, harmonious organization that we have before us, but a highly sense oriented one. As we might expect, there is no trace of upper canines.

And what do the frontal processes themselves reveal? In the sense-active roe deer, as we recall, the antlers develop quite early, and remain rather small throughout the animal's life. The giraffe's frontal processes are present even before birth, in the form of two fur-covered, bony pegs, about 2 $^{3}/4$ inches (7 centimeters) long; their development, then, begins even earlier than that of the roe deer's antlers. Birth is not hindered in the least by these bony protuberances (the *os cornu*), since they have not yet fused with the frontal bone and simply fold back when birth takes place. And precisely because these bones begin to develop so early, their later growth is limited even more severely than that of the roe deer's antlers. In the fourth week they fuse with the skull, and over the entire course of the animal's life they attain a length of less than 12 inches (30 centimeters). Straight and tilted slightly backward, they stand next to one another. The skin covering them does not harden to form horn, nor is their fur ever rubbed off; they neither hold back inner capacities nor are they rhythmically shed and formed anew. In the full-grown male the upper end of the bone remains exposed and is surrounded by a rather high tuft of upright, black hairs. The skin covering the bones remains permanently open. Occasionally the tufts spread and lay bare the tops of the pegs.



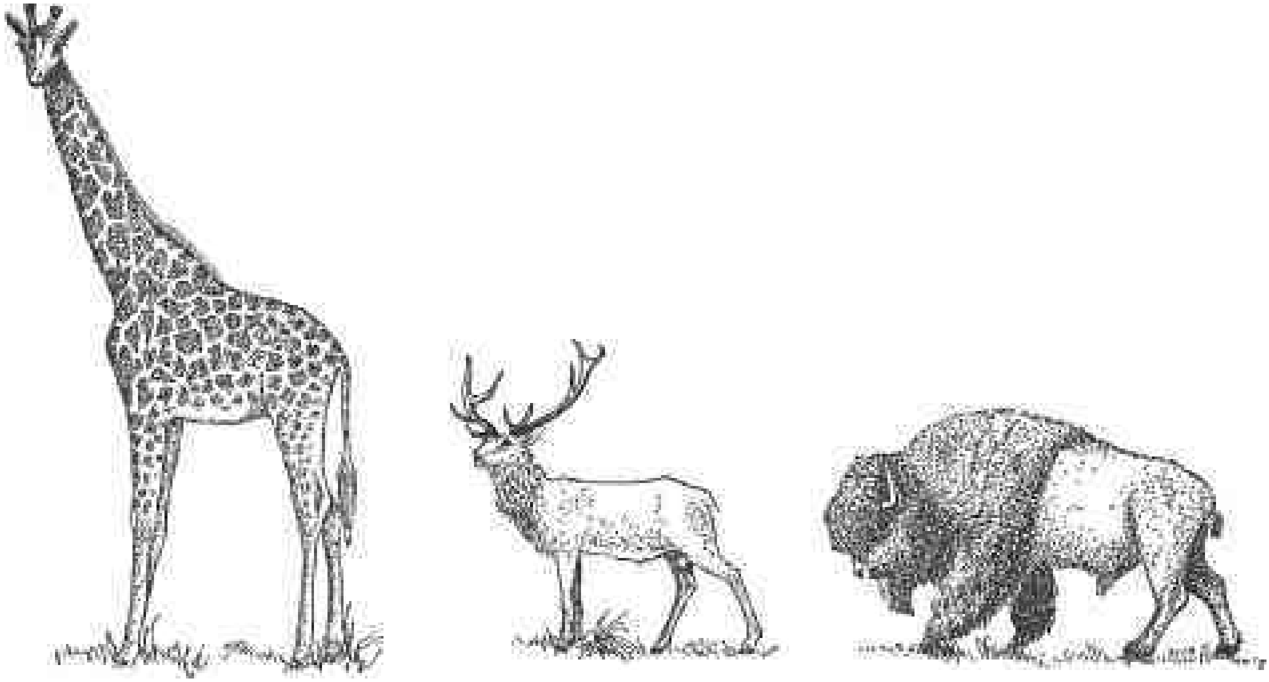
74. The hair and skin of the giraffe's horns remains open at the top. This half-grown animal was photographed by the author in the Ngurdoto Crater National Park of Tanzania, in 1973 (drawing by A. Suchantke).



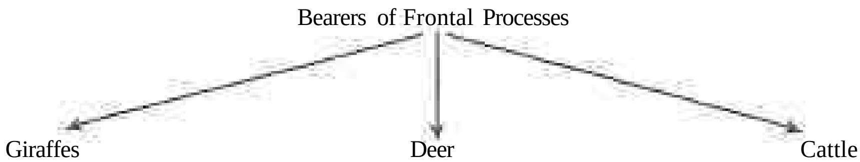
75. Skull of a giraffe bull found near Mount Elgon in Kenya, with the 5 horns usually found in this northern race *(Giraffa camelopardalis rotschildi).* Note the series of medial, lateral and medio-lateral knots (1/9 X, after Broman).

The presence of frontal growths indicates a basic organization dominated by the metabolism, and the giraffes are in fact ruminants and selenodonts. But the way these processes develop points to the strong secondary influence of the sense system. This sensory influence is further indicated by the presence of a third, *unpaired* outgrowth, which arises on the median line of the head, in front of the paired 'horns.' In addition to these three horns, the bull of the enormous Abyssinian giraffe may even grow a second pair of horns behind the first, thus developing a total of five bony processes. Only the original pair rests solely on the frontal bone; the unpaired horn extends forward, so that it rests partly on the nasal bones, while the posterior pair rests partly on the parietal bone. On the ridges above the eye-sockets, additional, very small protuberances are often found. In very old bulls, several protuberances can be seen on the two main horns. Thus, while bovine horns remain unbranched, and the deer's antlers branch out, the multiple growths of the giraffe subdivide, as it were, so there is no longer any connection among them. Multiple processes develop instead of additional points on the original pair.

One bovine animal, the tiny four-horned antelope of India, also has multiple horns; as a member of the bovine group, however, it lacks the median horn. And it is just this median horn that identifies the giraffe as the bearer of frontal processes that is most open to the environment. The giraffes, then, are truly polaric to the cattle. Only if we bear this in mind can we understand fully that the deer are the central ruminants, and the cattle are those most completely given over to the metabolism.

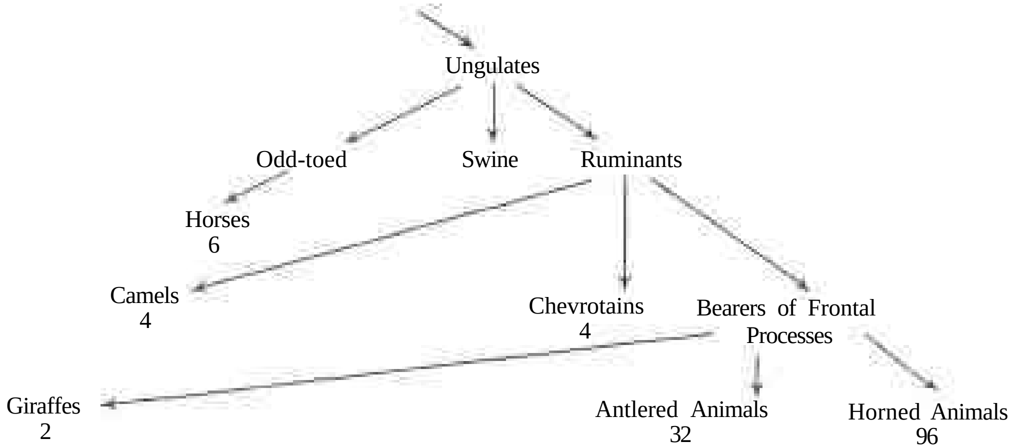


76. Compare the differences in form shown by the giraffe, red deer, and bison (each 1/60 X).



What its head processes only suggest is shown fully by the giraffe's overall form. Contrast with it the bison, whose head is bowed down, permeated with the forces of the metabolism, or the deer, with its beautifully proportioned head and trunk. The giraffe's head towers high above the metabolic realm. The same forces that are dammed up at the front of the bison's body, and that give harmonious shape to the deer, give form to the giraffe's elongated neck; for this animal lacks damming processes to hold back the powerful life forces of its ruminant nature. The giraffe is so exaggerated in form precisely because it is both highly sense oriented and strongly metabolic. If we compare it with the other sense oriented ungulates, the horses and camels, we see that the horses show a beautiful harmony of form; in the camels the opposition between metabolic and sense systems has led to an unharmonious shape; in the giraffe these opposites have reached the greatest possible degree of tension.

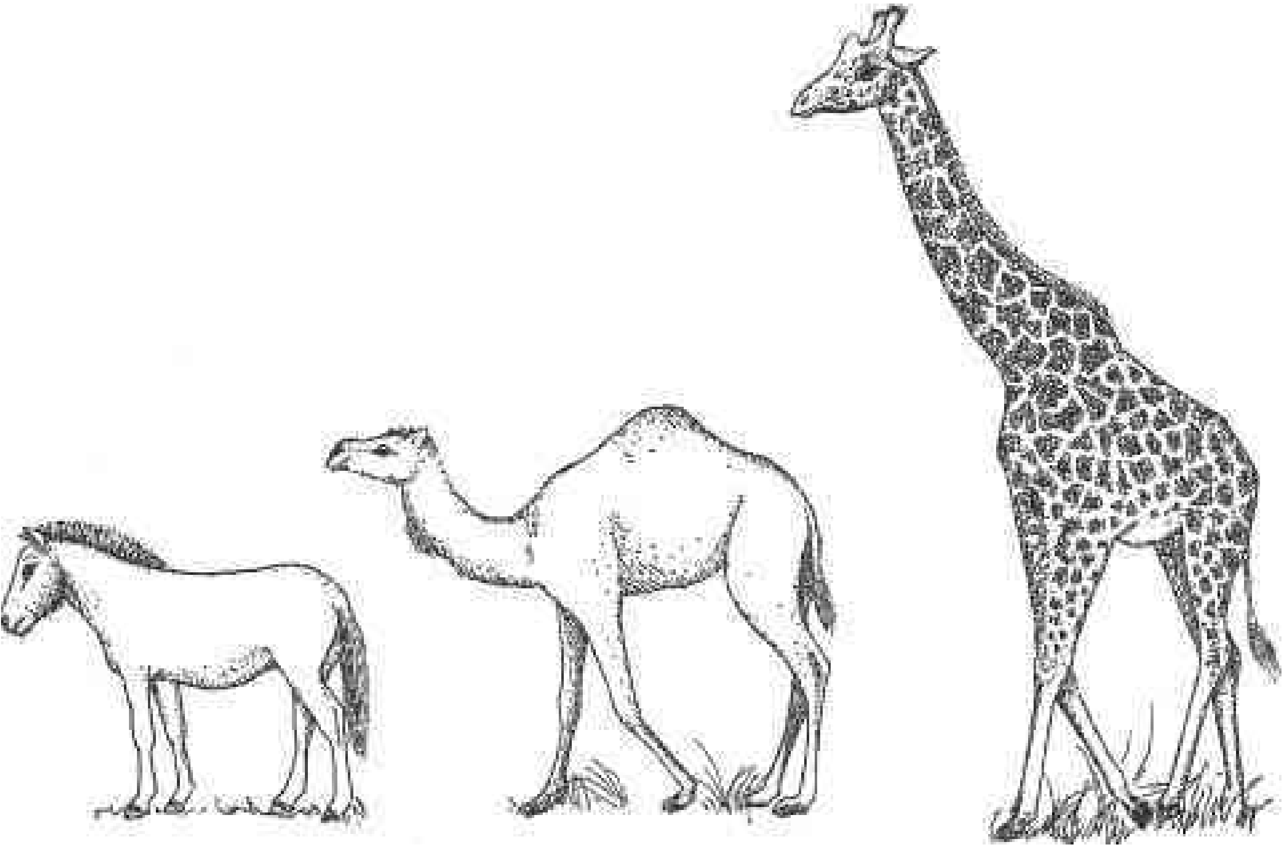
The more any one system is emphasized in a species, the greater are its formative possibilities. In the horse group, we find among horse, donkey, wild ass, and zebra no great variations from the basic equine form. The camel's shape varies from that of the large, heavy-bodied dromedary to that of the graceful little vicuna. Among bearers of frontal processes, however, we find—extending from the oxen, sheep and goats through the incredible variety of antelopes to the deer, and finally the giraffes—a spectrum of form that expresses not only the vitality of the single animal but also the powerful formative forces active within the group as a whole. These variations in form may be expressed in the following diagram:



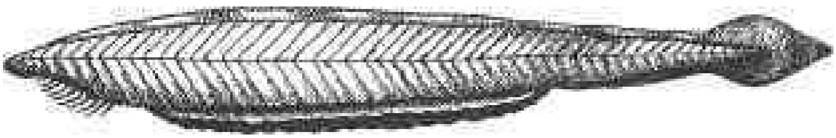
From this diagram we can see that differentiation into a large number of species is not (as we have indicated previously) connected solely with a strengthened sense organization, but also occurs when the sense organization is added *secondarily* in an animal dominated primarily by its metabolism. The metabolic species, since they have the most powerful formative possibilities of any mammals, are able to bring forth many different forms when they attain (as, for example, the antelopes have done) open contact with the outside world.

Horses, camels and giraffes share one anatomical feature, and this establishes a connection among them, despite the fact that they are also quite distinct from one another as groups: they have no dew claws (lateral hooves). What is the significance of this peculiarity in the limb organization?

The simplest of the higher animals, the well-known lancelet *(Amphioxus)*, uses for locomotion the fin-like edges of its body. These 'fins' are unpaired in the region of the central nervous system but paired in the area of its metabolic functions! The same is true of the genuine fishes, in which paired pectoral and pelvic fins are present, but whose dorsal, caudal, and anal fins, which grow along the spine, remain unpaired. In the course of evolution the



77. Horse, dromedary, and giraffe, the three ungulates whose limbs are most specialized (each 1/45 X).



78. Lancelet *(Amphioxus),* showing unpaired and paired fins (natural size).

importance of paired limbs increases to the detriment of the unpaired ones. Not the spinal column, which protects the nervous system within it, but the limbs, so closely connected with the realm of the metabolism, become the genuine organs of locomotion. The head is the first to lose its limb function; it metamorphoses to take on the functions of biting and chewing. The spinal column and tail, in the lung fish, salamanders, snakes, lizards, and birds, are used less and less for locomotion, until in the mammals they serve this purpose only sporadically (as in the South American spider monkeys). Finally, the paired limbs predominate. Thus we can see how the function of locomotion has joined with the metabolic system.

In the mammals the two pairs of limbs form the basis of a wide spectrum of formative possibilities. How are these limbs modified?

In the odd-toed horse, the middle toe is favored. The condylarths, ancient ungulates whose fossil remains date from early in the Tertiary period, retained the basic five-toed form. In *Eohippus*, however, the horse's first known ancestor, toe reduction had already begun; this animal, no larger than a fox, had four toes in front and three behind. As the Tertiary period wore on, specialization of the limbs continued in successive stages. One after another, the lateral toes shrank and disappeared. At the same time the middle toe thickened to form a hollow bone the size of the thigh-bone, and its nail became a single, solid hoof. The modern horse, when it is an embryo two centimeters long, still shows the second and fourth toes as dew claws next to the dominant third toe (Krölling). These, however, begin to disappear after a short time, and in the fully developed animal they are found only as two small splint bones, attached, as stunted vestiges, to the third toe. The five-toed limb, then, is the basic form that underlies even the hoof of the solidungulates; but in these animals it has been utterly transformed, so that the third toe has become dominant.

This transformation becomes clear when we apply to the formation of the limbs the spatial significance we have already discovered in the head processes. There are at work in the hooves of the odd-toed ungulates, particularly those of the horses, formative forces that pull the spatial form in toward a center! The versatile hand has been centered; towards a single goal it speeds at a gallop. Whatever is received by the horse's sharp senses flows easily as reaction into the forward-directed limbs. The wild horse is an ungulate oriented completely toward distant goals. Thus, any formations that spread out laterally, even dew claws, have been discarded.

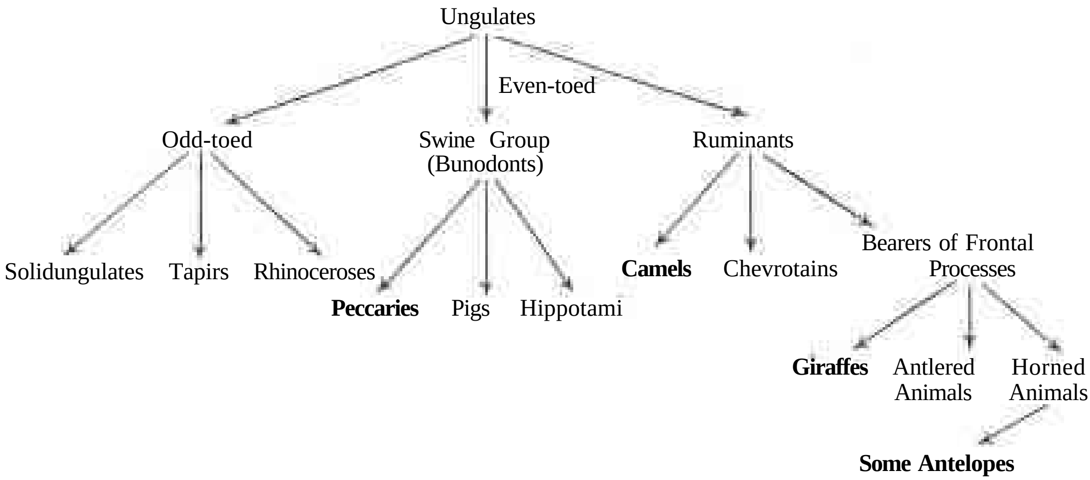
The rhinoceros, however, since it has turned once again towards the metabolism, has developed the second and fourth toes as strong lateral hooves next to the middle toe and therefore has a total of three hooves on each foot. The central tapir is the odd-toed ungulate whose limb formation remains closest to the original form: its hind legs, like those of the rhinoceros, have three toes; but the forelegs still have four, so that only the first, the thumb, is missing from the original five-toed form. But among the four remaining toes the third dominates, so that even this animal's limbs remain centralized in form.

Like the tapir, the even-toed ungulates have four-toed forelimbs, but the third toe is not singled out as the largest. There is no central hoof: all hooves turn out, away from the limb's axis. The third and fourth toes form the main hooves, the second and fifth, lateral toes, or dew claws. All bunodonts and selenodonts are even-toed. So the primarily metabolic orientation of this ungulate group is revealed for the biology of form even in the uncentered arrangement of the hooves. The dew claws, directed laterally and slightly backward, are never lacking in the typically metabolic ungulates. In abnormal cases they may even attain the size of main hooves (as illustrated in the anomalous roe deer hoof shown in Plate 159).

There do exist some even-toed ungulates in which the dew claws have disappeared completely. This is roughly parallel to what takes place in the horses, among odd-toed ungulates. These animals, with their paired main hooves, are, of course, even-toed, but since their lateral hooves no longer develop we may assume that they have secondarily established an increased contact with the world around them. In the peccaries we have seen at least the beginnings of this process. They, like the horses, are sense oriented ungulates, yet because they are members of a central group, they cannot reach the final stage. Their forefeet still retain both dew claws. The hind feet, however, greatly reduce the outermost or fifth dew claws, discarding the 'most lateral' toes first. Thus, these sensitive members of the swine group have four toes in front and only three behind. This increased specialization of their limbs also allows the metacarpals to fuse partially and to form (in marked contrast to the other members of the swine group) at least the beginnings of a cannon bone.

In the camels and giraffes, sense oriented members of the extremely metabolic ruminant group, dew claws disappear entirely. Not even vestiges, such as the horses' splint bones, remain. The formation of the limbs, then (in its reduction of the lateral toes), is fully consistent with the overall constitutions of these sense oriented members of a highly metabolic group. Within the diverse group of horned animals, there are other significant 'exceptions' among certain sense-active antelopes, such as the pygmy antelopes, impala, and pronghorn, in which dew claws are absent. Most other antelopes have very small dew claws, placed high. As we might expect, the deer, as central ruminants, forego any such specialization of the limbs.

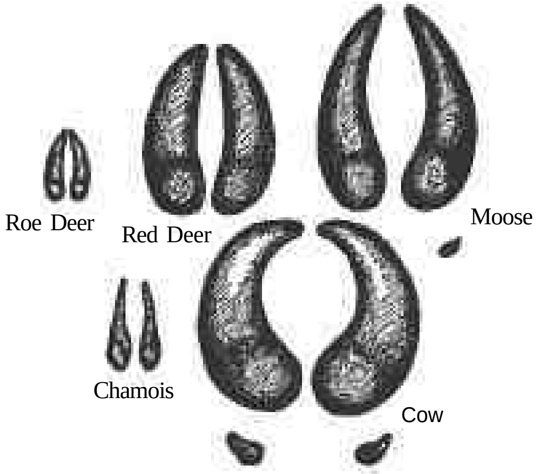
In the following survey, forms with reduced dew claws appear in bold face type. With remarkable regularity, sense-active forms, open to the surrounding world, show this characteristic reduction. What could only be considered rather curious exceptions when seen in isolation become understandable at once when seen within the organization of the whole.



It is interesting to note that the formation of the hooves is closely connected with the various kinds of head processes. The horns of the rhinoceroses, odd-toed ungulates, are in an unpaired position; those of the even-toed ungulates, by contrast, are paired. König (1967) also noticed this organizationally consistent relationship:

> That hooves and horns are mutually determined becomes immediately apparent when we compare the odd- and even-toed ungulates with one another; for in the even-toed ungulates both horns and antlers are formed in pairs. They develop as bilaterally symmetrical organs. The rhinoceros, on the other hand, as an odd-toed animal, grows horns in the middle of its face. Even when there are two horns, they stand one behind the other along the median line of the nose. Here we can see that the odd-toed condition is operative even in the formation of the horns, just as the even-toed condition leads to the formation of symmetrical horns and antlers (p. 217).

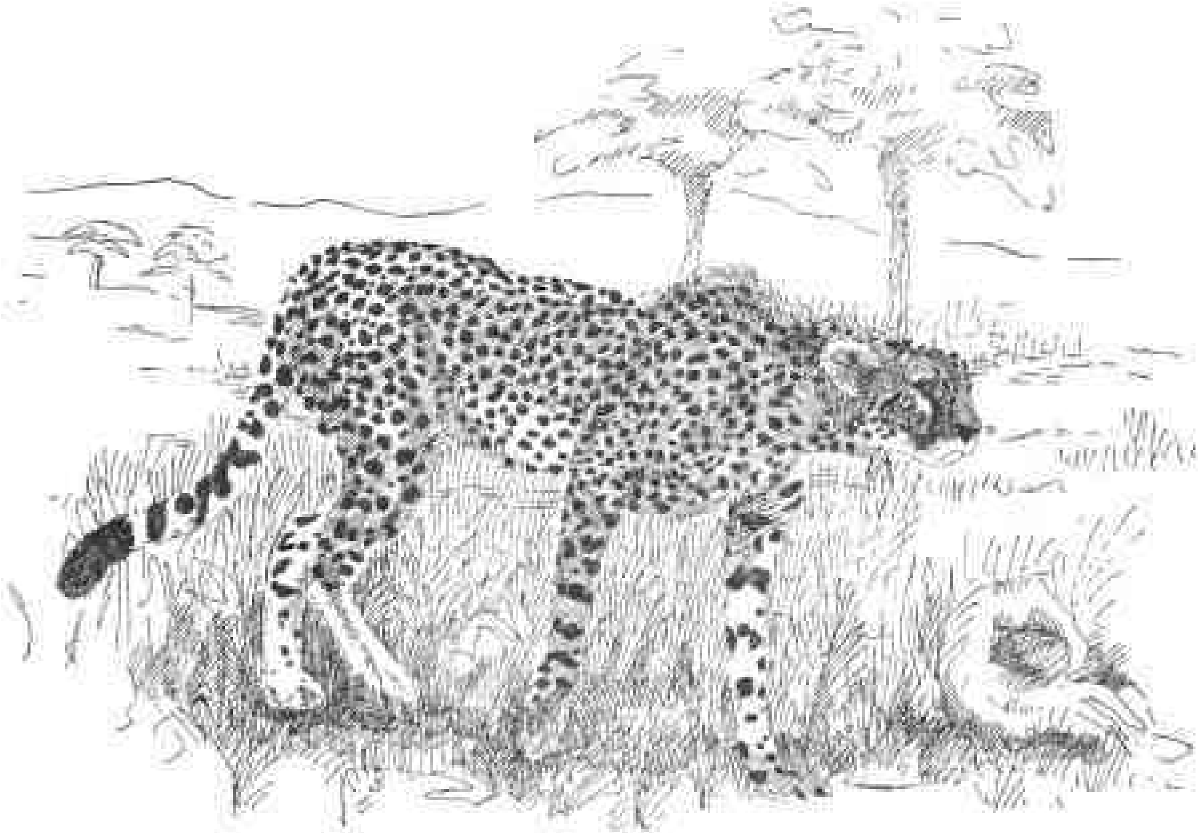
We are now in a position to understand how perfectly the living organism shapes its relationship to space, how each detail visibly conforms with the animal's entire constitution[36]. In centered formations the life processes directed toward the outside world prevail; in formations that project towards the sides and tend to form spirals, those processes that shape the organism's own form are dominant[37]. The hooves of the cow, like its horns, curve to form a spiral. Plate 160 shows the hoof of a merino sheep that was kept suspended so that its hooves would not wear off naturally and it could be displayed as a curiosity at fairs. Its hooves grew to form spirals like those of its horns. In the chamois, with its upright horns, the hooves are narrow and sharp. Similarly formed are those of the roe deer. In the red deer a harmonious relationship prevails, but in the elk and reindeer the tendency towards spiralization begins again. The sense oriented horses, camels and giraffes, despite their size, do not have spiral hooves. Thus we can comprehend, from the very tracks it leaves behind in the ground, the animal's whole nature.



79. Tracks of a few European ruminants (all 1/6 X).

The ungulates, as mammals dominated by the third, or metabolic-limb system, vary widely not only in the development of the digestive system but also in the formation of the limbs. In our threefold survey of these animals we have seen that groups listed on the right side of the chart develop the greater specialization of the metabolic system, while those on the left have the more specialized limbs. Careful attention to such details will also enable us to discover the underlying relationships that unite the members of this group. Is there not at work here, in the natural ordering of large groups, a process similar to that underlying the polarity established by the individual animal between its metabolism and limbs? Within each organism the metabolic and limb processes are quite distinct; yet they are also closely connected. Is it not reasonable to ask whether these processes could have operated similarly in the course of evolution, thus leading to a natural ordering of groups, determined by inner necessity? The riddle of the single organism may well be the same as that of the whole system of related animals, so that they shed light upon one another when compared. Perhaps even the relationship itself derives from an over-arching 'organism', which, like the single animal, can be defined in terms of the biology of form. The highly developed limb formation of horses, camels and giraffes, reveals how the limb system—in the ordering of the group as well as in the single animal—is the outwardly directed counterpart of the metabolic system.

It is therefore not surprising that the specialization of the limb system, like that of the organs of metabolism, is restricted almost entirely to members of the ungulate group. Among the carnivores, as we might expect, there are few real runners. The canines are fairly well developed, although rather



80. The cheetah, which is able to run at speeds approaching 65 mph., is distributed from South Africa to India (1/12 X).

unspecialized, 'limb animals,' somewhat open to the outside world. (We have therefore placed them to the immediate left of the metabolically oriented seals, page 68.) The cheetah, a singular species whose position within the cat family is rather isolated, is certainly some kind of limb animal. This long-legged, slender large cat, with its doglike paws (its claws, unlike those of all other cats, are not retractile), is the fastest running mammal. Yet, unlike the wolf, it cannot maintain its speed over long distances. Among the rodents, of course, such limb animals are almost entirely lacking; perhaps we could consider the South American mara as such (see Plate 29).

Let us now apply to the central ungulates the idea of a living organism that underlies each animal group. We know from the single organism that the system of propagation lies between the metabolism and the limbs. We have also discovered that in many central members of the ungulate group outward shape is largely determined by the animal's sex. In the yaks, sheep and goats, for example, and especially in the deer, we have found striking differences between the forms of male and female animals. All male deer have antlers (and/or lengthened upper canines), while all females, with the exception of the reindeer, have neither; and even the female reindeer's antlers are much smaller than those of the male. In the chevrotains, too, as well as the pigs (see chart, p. 152), the male has canines that are much more strongly developed than those of the female. The upper canines of the wild sow, in contrast to those of the boar, grow downward. The male babirusa alone has elongated canines (Plate 161, 162). Male and female tapirs, as members of a sense oriented group, show only slight differences in form.

Significantly, however, these differences are found once again among metabolically oriented carnivores. Among terrestrial carnivores these differences are especially noticeable in the lion, and they are even more pronounced among aquatic forms. Only the male harp seal, for example, shows conspicuous coloration. Among fur seals, the males are much larger than the females. The male walrus has larger tusks than the female does, and only the males of hooded and elephant seals have large, inflatable nasal sacs. Only the male Cuvier's beaked whale has two teeth, and his coloration is also different from the female's; the male narwhal has a long single tusk. In the central member of the toothed whale group, the killer whale, there is an even greater difference in size: the male is twice as large as the female and has a much longer and steeper dorsal fin than she does. In the sperm whale, too, male and female animals show marked differences in size.

Among the rodents, on the other hand, we find no comparable contrast in form; in them the third system has too little influence.

As we have observed, this sexual dimorphism (as biologists refer to the contrast in shape between male and female animals) is most pronounced, among mammals, in the deer family. The stag has the more metabolic form, while the doe's is more sensitive. The reverse is true, however, of reproductive processes. During the rut the stag becomes very excited; he forgets to eat or sleep and lives only to keep close watch on his rivals and on the does. (It cannot be denied, of course, that the aggressive character of the rhythmic constitution also plays into this behavior.) The doe, on the other hand, is peaceful and phlegmatic, and for many months devotes herself completely to carrying her fawn.

In geographically extreme areas the deer's sexually determined differences in form undergo a certain leveling. The female reindeer has antlers—though, as we have said, these are smaller than those of the male. As a member of the deer species living farthest north, she, like the male, develops a powerfully metabolic form. In the southern parts of their range (Canada and Siberia) close to half of all female woodland caribou lack antlers, while all barren ground caribou and Eurasian reindeer, living further north, bear them regardless of sex (Burt).

These strengthened metabolic processes are also apparent in the reindeer's flattened antler beams, which tend to become palmated. In their development, unlike that of the antlers of all other deer, it is not the sex hormones that are primarily active, but the direct forces of metabolism. For a finished set of antlers, as long as the velvet remains alive, can even add extra points if the reindeer receives particularly nourishing food—a development that would be utterly impossible for any other kind of deer (Bruhin). It is undoubtedly this strengthened metabolic capacity that has enabled the reindeer to become the only semi-domesticated deer species on earth.

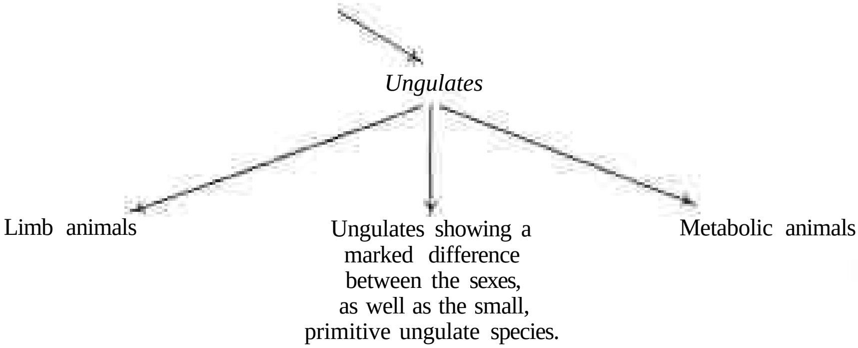
Tropical deer never show palmated antler formations and at most develop antlers with only a few tines. And it is only in tropical areas that small forms without antlers, such as the musk deer and Chinese water deer, live. The males of these tropical species, then, take on a shape more typical of female animals. The harmonious, central deer, which show an obvious difference between the sexes, live in central latitudes.

As extreme as some members of these central groups may become in the expression of their particular characteristics, they all manage to retain rather basic, original features, compared with those of the purely metabolic or limb oriented animals. We have noted many times that such central animals often remain smaller than the polaric forms, as in the case of the pigs (between the horses and cattle), the chevrotains (between the camels and cattle), and the deer (between the giraffes and cattle). In addition, the digestive system and limb formation remain somewhat primitive. Thus the tapir, the central odd-toed ungulate, retains four toes on each front foot, though both the horse and rhinoceros, its closest relatives, have highly specialized limbs. In the chevrotains the ulna and radius have remained unfused, and in the water chevrotain of central Africa, even the third and fourth metacarpals are still separate—a unique feature among the ungulates. These animals also stop short of developing a complete, four-part ruminant stomach. The swine, too, have many primitive characteristics (see p. 102).

All these examples express for the group as a whole something quite similar to what is expressed by the reproductive processes of the individual animal. For it is in this realm that the primitive stages of development are recapitulated ever anew in the young. In the ungulates then, as animals dominated primarily by the metabolic-limb system, it is not surprising to find the smallest and most basic forms in the central families.

	Shoulder Height	
Among the tapirs, Roulin's tapir (of the Andes)	~ 30"	(~ 80 cm.)
Among the swine, the pygmy hog (of the Himalayas)	10-12"	(25-30 cm.)
Among the chevrotains, the smaller Malayan chevrotain	8-10"	(20-25 cm.)
Among the deer, the Chilean pudu	12-14"	(30-35 cm.)
Among the central antelopes, the royal antelope (of West Africa)	~ 10"	(~ 25cm.)

The rhythmic character of the royal antelope, a member of the bovine group, is expressed by the fact that it quite willingly eats meat, and sometimes even has small canines[38]. All these small forms spend their lives surrounded by an abundantly nourishing tropical vegetation. More than any other ungulates they have retained the most childishly original, primitive form of this animal group (Plates 163—165). As such, they belong within the natural order of ungulates, an order whose differentiations reveal the basic characteristics of the threefold metabolic-limb system.

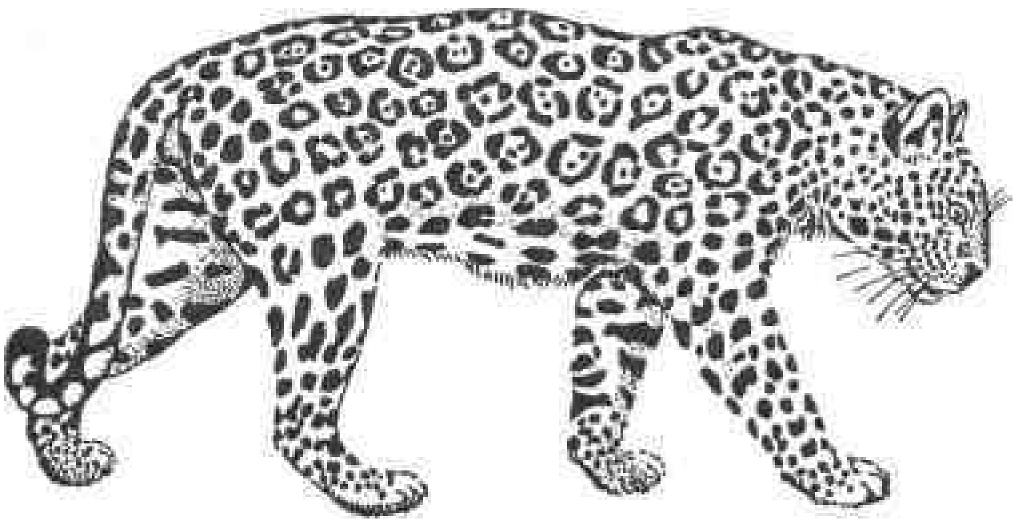


Just as the limb formation of the giraffe has given us a starting point from which to examine the limbs of all the mammals we have studied thus far, its unusual coloring provides us with an opportunity to bring together and compare the coloration of the mammals. With a certain reserve we suggest here a few of the broad outlines of this comparison. It is clear that the coloration and contrasting patterns of undomesticated animals have an extraordinarily close connection with the unique nature of each animal species. Indeed, the internal organs, the skeleton, and even the body's overall shape vary less among species than the coloration does. Because the animal's coloration is so easily observed, we might be tempted to generalize about it. However, this would obscure our understanding, for it is in the coloration itself that the *singularity* of each animal species is most strikingly expressed. Bearing this in mind, we may go on to ask whether certain basic, frequently appearing types of coloration may be found in all mammalian groups.

We have found again and again that within any particular group the sense oriented representatives, such as the mice, squirrels, weasels, porpoises, the guanaco, and the roe deer, have a white ventral side and a darkened, often reddish-brown dorsal side. This remarkable color pattern, which distinguishes the dorsal from the ventral areas, gives expression to the specific organization of each of these species. The strongly metabolic representatives of any particular group, such as the bison, moose, Bactrian camel, hippopotamus, rhinoceros, sperm whale, bear, and beaver, veil themselves in a uniformly dark brown, or even black coloring. In contrast to the sense oriented animals, which sharply divide their dorsal and ventral colors, the purely metabolic animals have an indifferent coloration that seems to close the animal off within itself. In discussing the deer we discovered that the coloration of central mammal groups becomes comprehensible when compared with those of the two polaric groups. Thus the chipmunks, ground squirrels and susliks, the spotted and striped small and large cats, civets, hyenas, and many seals and whales, as well as the young of tapirs, pigs and deer, have a rhythmically alternating color pattern. On their coats light and dark colors alternate in an active rhythm, giving expression to each species' own particular constitution.

If we accept as hypothesis this idea of the 'threefold division of coloration' and become quite familiar with it, its significance will gradually be revealed to us. A metabolically oriented animal, such as a cow, gives the impression that its life is buried deep within its almost too powerful body. We look into the eye of a cow as though into the depths of a well; this animal's fundamental being is founded upon life processes deep within its body. Its visible surface remains only the indifferent covering of a rich inner life.

The exact opposite is true of purely sense oriented animals. Highly sensitive, nervous, reacting instantly to every sense impression, a wood mouse



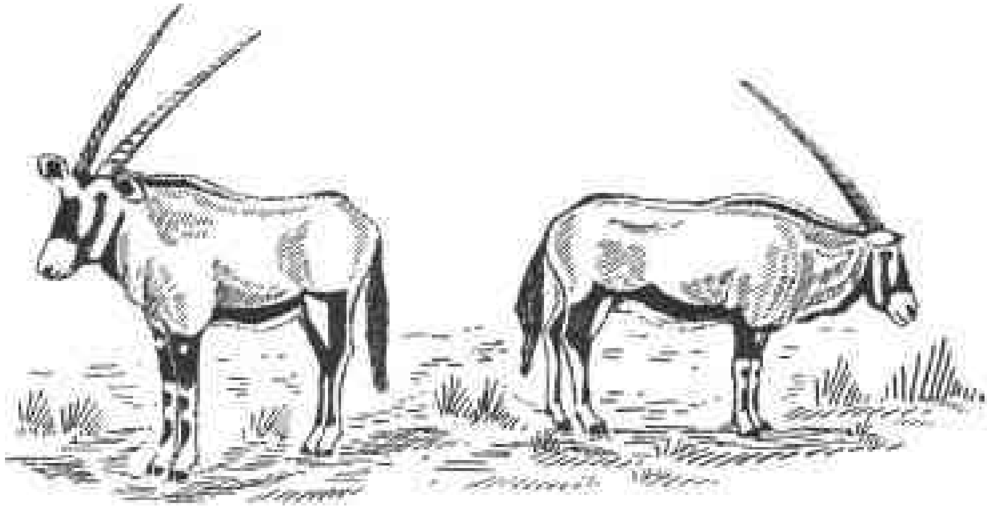
81. The jaguar, of tropical North and South America, has a coat covered with black rosettes (1/11 X).

or dwarf weasel seems to live more outside its body than within it. Such an animal is always 'beside itself.' The beady, black eyes of the mouse are wide open to the outside world. Its life seems to be structured from without, by the strongest of all sense impressions: the difference between the free, open space in which it moves, and the solid ground on which it treads. Perhaps its coloration, too, is determined by this experience.

The well-proportioned carnivore, however, is neither so completely occupied with its own metabolism as the bovid, nor so entirely devoted to the outer world of the senses as the rodent. In it, rather, essential processes take place in the transitional area between inner and outer worlds, on the surface of the body. What muscular activity animates the bodily contours of the jaguar! How alive is the expression in the eyes of a cat (Plate 156)! Mammals dominated by the formative processes of the middle system are those which develop the most beautiful coloration patterns. In these animals more than any others, the surface of the body speaks directly to our observation.

If the natural coloration of an animal is, in fact, connected with its overall constitution, we should expect to find that a detailed study of the constitution of any particular species would lead to a better understanding of its coloration. For example, within groups formed primarily by the sense system, we might expect animals with relatively dull senses and strong metabolic capacities to strengthen the connection between coloration processes and the surface of the body, thus bringing these processes to outward expression. We have already discovered the conspicuous contrasting patterns on the heads, necks or backs of such species as the hamster and the mole rat among the mice; the porcupine, the most extremely metabolic of the rodents; the polecat among the weasels; and the badger among the martens. In contrast to the purely sense oriented animals, these species, like the purely metabolic ones, have a dark underside; yet the upper side, with its expressive patterns, usually beginning at the head, remains light.

Although it would be worthwhile to consider the implications of such a pattern, we shall now confine our discussion to the phenomena themselves: when we compare the opposite animals, the sense oriented members of the ungulate group, the results are equally striking. Is it possible that the strong formative forces at work within the powerful bodies of these animals might extend even to the body's surface and mark it with new designs? This is the case in all wild horses (Plate 154), the classical example being of course the zebra (Plate 155). Of all ungulates, these wild horses show this contrasting coloration most strongly. Broad black and white stripes on the body, and narrow ones on the head and limbs, are, in their strict alternation, less a protective coloring (von Boetticher) than a part of the animal's own constitution. For the horses are limb animals, open to the outside world, and thus able to display outwardly their strong inner capacities. The tarpan, the extinct ancestor of our domesticated horse, still had striped upper legs. These stripes are even found in some domesticated breeds, such as the fjord horse of Norway



82. The oryx, which lives in the plains and semi-arid lands of Africa, has sharply contrasting patterns on the head and limbs, as well as long, nearly straight horns (1/30 X).

(Plate 154), which has preserved much of the original form. Occasionally these horses even have striped necks (Krummbiegel, 1958). The donkey, a close relative of the horse, also has striped legs and shoulders. Because they are open to the world, all these metabolic animals have a ventral side as light as that of the purely sense oriented animals.

This coloration tendency also appears in other limb oriented ungulates, such as the giraffes. The strange, narrow-lined, net-like color pattern of the large giraffes can now be understood (Plate 152). This coloration, with its conspicuous pattern and white underside, identifies these animals as the bearers of frontal appendages opposite the cattle. The small woodland giraffe, the okapi, even has prominent zebra-stripes on its shanks (Plate 153). Like those of the horses, these horizontal stripes are confined primarily to the limbs. Perhaps we might also include in this group of outwardly-oriented, limb-accentuating ungulates the African oryx with its strongly marked limb and facial patterns, as well as the European chamois, with its less conspicuous facial stripes. It is certainly worth the effort to trace all these correlations, for only then may we begin to develop an adequate understanding of the processes at work in coloration.

	Sense Animals	*Nerve Animals*	*Central Animals*	*Limb Animals*	*Metabolic Animals*
Dorsal Side:	Darkened	Patterned	Rhythmically	Patterned	Darkened
Ventral Side:	Lightened	Darkened	Patterned	Lightened	Darkened
Examples:	Mice	Striped Field Mouse	Cats	Zebras	Wild Cattle
	Rats		Leopard	Wild Ass	Moose
	Dormice	Hamster	Jaguar	Tarpan	Hippopotamus
	Flying Squirrel	Mole Rat	Tiger	Okapi	Rhinoceros
	Red Squirrel	Porcupine	Harbor Seal	Giraffe	—
	—	—	Ringed Seal	Oryx	Right Whale
	Weasel	Polecat	Sea Leopard	(Chamois)	Sperm Whale
	Porpoise	Marbled Polecat	Hooded Seal		Elephant Seal
	—	Skunk	Many Whales		Walrus
	Guanaco	Badger	—		Brown Bear
	Roe Deer	Honey Badger	Chipmunks		Sea Otter
			Spotted Suslik		Sable
			Spotted Deer		—
					Beaver
	Dual Coloration		Richly Patterned Coloration		Uniform Coloration

This compilation enables us to make a first overall survey of these correlations and offers many possibilities for further study. Above all, however, we must keep its structure flexible in order to avoid reading into it, or extrapolating from it, more than the phenomena themselves express. The analytical intellect, with its tendency to compartmentalize, would be most gratified to discover straightforward, unambiguous 'rodent,' 'carnivore,' and 'ungulate' colorations. The above chart shows, however, that the large systematic unit to which an animal belongs is less important in determining its coloration than its particular constitution and its position with regard to its closest relatives. It is for this reason that the entire field of mammalian coloration proved so difficult to understand in the past. The specific pattern of coloration is often determined at the point of differentiation into individual species.

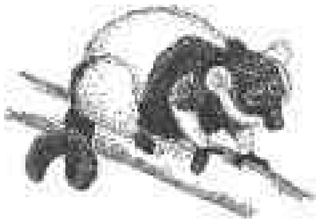
If we succeed in applying the threefold evaluation of mammalian form even to the individual species—as we have attempted to do here—we may look with greater discernment at the 'open secret' of patterns on the animal's coat. Much remains unclear: Why do we not find a light ventral area in the eared seals? Why does no camel have horizontal stripes on its legs? A better understanding of such 'exceptions' might well reveal connections between coloration and the threefold constitution even more extensive than those discovered thus far. In the meantime, as we have seen, many organic regularities are already apparent. The fact that the stripes of limb animals appear specifically on the *limbs* is surely not without meaning. And this meaning is underlined by the fact that the opposite cases, those forms designated at the end of the fifth chapter as nerve animals, have contrasting patterns centered on the head and along the spine. The former usually show transverse stripes, the latter, longitudinal ones. The mediating animals show a wide spectrum of loose, rhythmic patterns: the more sense oriented members of this group, such as the genet, serval and ocelot, are more apt to form longitudinal designs, while the more metabolic members, such as the tiger, tend towards transverse patterns, even on top of the head.

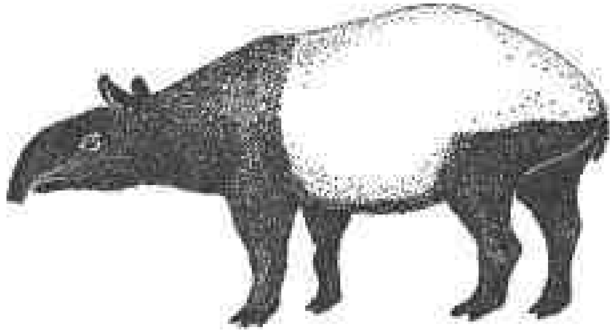
The connections between transverse patterns in metabolic-limb animals and longitudinal patterns in sense oriented ones may also be observed when both patterns appear on the same animal! In the European wild cat for example, the limbs and sides of the body are vertically striped, while the head and central back show a longitudinal pattern. Here the two patterns merge subtly, and the activity of the nerve-sense and metabolic-limb systems becomes visible on the same animal's coat. This pattern can be observed best in young wild cats, but it can still be seen in somewhat faded form in adults and in striped domesticated cats. The most complete interpenetration of these polaric coloration tendencies is seen in the rosettes of the leopard and especially of the jaguar, in which longitudinal and transverse striping tendencies have apparently merged in the formation of spots surrounded by twisted rings (Plate 81). The way in which these spots differ on the various parts of the body allows us to observe directly the living processes of coloration.

It should be evident that tightly alternating patterns, with a tendency to subdivide, are usually seen on the coats of the sensitive animals, while broad patches of color appear on the more sedate species. There is also a rare but therefore even more interesting pattern in which large areas of black and white alternate. The following species show this pattern:

Among the Carnivores:	The panda of China The harp seal of the Arctic The ribbon seal of the Arctic The Commerson dolphin off Cape Horn The killer whale of all oceans
Among the Ungulates:	The Malayan tapir
Among the Primates:	The ruffed lemur, The sifaca, The indri } of Madagascar The guereza of East Africa.

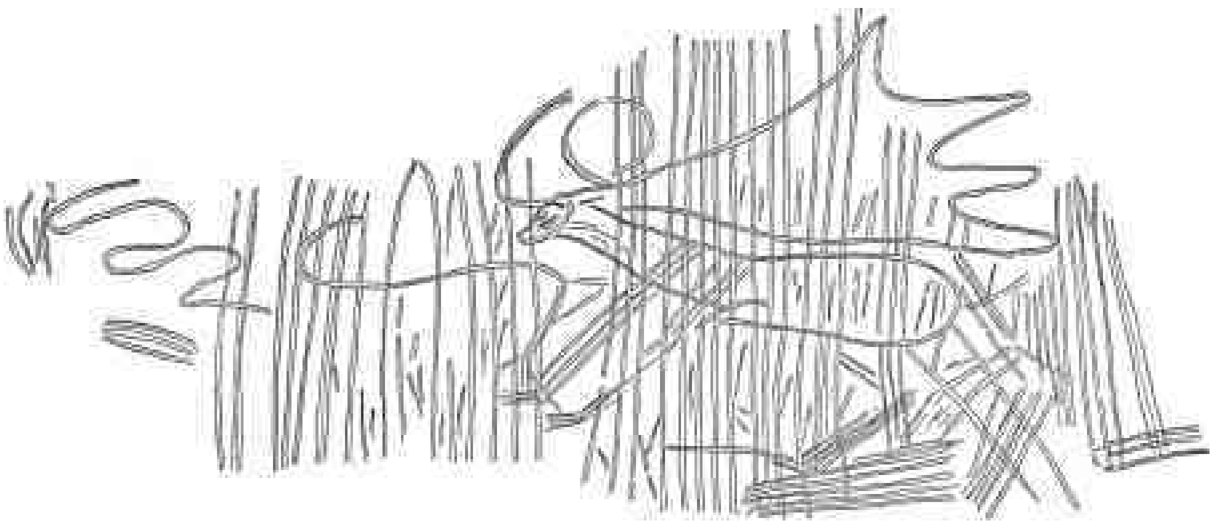
83. Animals in which large black and white areas alternate. *From the top down, left,* ruffed lemur and guereza (1/17 X), *right,* panda, Malayan tapir, harp seal, ribbon seal, and Commerson dolphin (1/25 X).




None of these are extreme forms within their own groups, and an interplay between contrasting colors is therefore possible. But in this case the patches of color do not follow close upon one another, but remain large, thus demonstrating the metabolic strength that is to be found in these animals despite their basically rhythmic organizations. The panda, for example, is the largest member of the rhythmically oriented raccoon family[39]; by nature this animal is strictly herbivorous, feeding on shoots and leaves in the bamboo forests of its home. The above listed seals and dolphins are well-balanced representatives of the metabolic branch of the carnivore group. The Malayan tapir, as a central odd-toed ungulate, shows a striking 'intermediate' coloration, which falls between the narrow, black and white pattern of the zebra and the uniform color of the rhinoceros. The ruffed lemur, sifaca and indri, the largest of the lemurs of Madagascar, belong, like the guereza, to a middle group (see pages 242, 255, 266), and yet at the same time they are completely herbivorous and have a powerful metabolism.

A further application of the methods begun here would probably enable us to reconstruct more accurately than ever before the colorations of extinct animals. Yet even now certain conjectures seem possible, as in the case of the Ice Age Irish elk. Predictably, this largest of the deer had palmated antlers and lacked any vestige of upper canines. It must have been a thoroughly metabolic animal, for each year it produced a new antler mass of nearly one hundred pounds. A close relationship with the fallow deer has long been assumed, so that reconstructions of the Irish elk often show a coat covered



84. The only known sketch of an Ice Age Irish elk, found in the French cave Pech-Merle (Aurignacien, 1/20 X; Lemozi).

with white spots. Based on our observations of living animals, however, we suggest that in all probability this animal had a uniformly dark coloration, even on its ventral side. It is likely that even the young, like those of today's moose, were without spots. This assumption may some day be confirmed by cave paintings made by men who were contemporaneous with the Megaceros. (The only sketch known today—found in 1922 in France—reveals nothing about coloration.)

Most previous attempts to find meaning in the coloration of animals have assumed that it always serves some purpose, either as an adaptation to ensure survival in a particular environment, or as a signal for members of the same species. Of course it is immediately apparent to any careful observer that the uniformly white color of the polar bear and full-grown white whale is connected with the snow and ice of their polar surroundings. The arctic fox, blue hare, ermine (Plate 107) and northern least weasel take on this same coloration in winter. Certain color patterns, such as the roe deer's white rump, which is visibly displayed during flight, doubtless serve as signs of recognition or warning among members of the same species. But all this explains only why such colorations might be retained, and not how they could arise in the first place. The capacity to form a particular coloration rests on the overall constitution of each species. For countless patterns of coloration simply cannot be explained either causally, as a response to certain conditions in the environment, or as random mutations that have enabled certain forms to survive. Portmann's statement (1960) still holds true.

> We are surrounded by unaddressed phenomena that are intended neither to attract the eyes of members of the same species or of a potential mate, nor even to hide the animal from hostile eyes. Above all they represent visibly the unique character of an animal or plant species. . . . Once we have progressed to the stage of actually beginning to observe these unaddressed phenomena, they will show themselves to us even in cases that only a short while ago we believed to be narrowly circumscribed, expedient formations.

X The Shape of Time: Reproduction and Death

Most mammals withdraw the reproductive processes from the direct influence of the surrounding world to the interior of the mother's body. Embryonic development has thus been removed from the field of direct observation. Yet it has not lost its meaning for the biology of form. In preceding chapters we have observed the shape of a mouse, a cat, or a whale only in the adult animal, since it does not reveal itself fully until the animal reaches maturity. Early stages of development, however, as well as the juvenile form and that of the aging adult, are equally meaningful for the biology of form. Is a horse a horse only when fully grown? No, it is the same entity in the ovum and as an embryo, as a newborn or half-grown animal, and even in its old age and in the manner of its death. Because the shape of the adult organism makes such a strong impression on our senses, we forget all too easily that an animal is characterized fully only by *all* the stages it passes through during its lifetime. The shape of the adult is highly significant, but it is only one stage in the whole sequence of forms. If we observe this sequence carefully, it too reveals an overall shape, but one that occurs in *time.* In every organism—and none can be comprehended apart from its processes of growth and decay—the spatial and the temporal are not separate ways of being but are joined in the animal's form, in a manner specific to each species. In observing this sequence, we shall attempt to join the *spatial* shape with the corresponding *chronological* one, thus practicing a biology of the *living form in its entirety.* In this way the very processes of life and death take on meaning for the biology of form.

Plants' relationships to time and space differ from those animals. Form, which in the plant takes shape in the progression of leaves that follow one another *chronologically* along the stem, is expressed by the animal in *space.* As a plant grows and its existing leaves no longer suffice, new ones are added to the old. As a young animal grows, however, the old organs are themselves gradually transformed into new ones (Bockemühl, 1962). There is, for example, no 'adult' shoulder blade added to that of the young animal, but the original organ is itself transformed. Nearly all of an animal's organs develop in this way. The 'exceptions,' such as the crowns of the milk teeth, the antlers of deer, and the hair, have lost their connection with the blood and cannot be absorbed.

Since the animal is continuously destroying and creating anew most of its organs, its spatial organization is more constant than that of the plant. It is true, of course, that metamorphosis takes place during the earliest stages of embryonic development, but this process soon comes to an end in the spatial form characteristic of the animal. Also characteristic of each animal species is its size: while a plant, under favorable environmental conditions, may grow considerably beyond its normal size, an animal cannot do this. Particularly in mammals, the chronological development of the embryo leads quickly to a definite spatial unity.

A correct interpretation of these facts leads us to conclude that the idea of metamorphosis is expressed *spatially* in the animal as the idea of threefoldness. Metamorphosis and threefoldness, then, are not two ideas but one, namely the idea of *organism.* If this idea is expressed primarily in chronological form, metamorphoses appear; if it gives rise to a spatial shape, we find polarities and their mediation: threefoldness. Both manifestations of this idea are, of course, to be found in every organism, since each one is by its very nature both formed space and formed time. Yet, it is not only to our own consciousness that these two forms appear to be separate, for nature itself distinguishes between them. The plant, as we have observed, tends to grow in chronological form: its leaves and branches, once developed, retain their original configuration. When it requires different organs it must add new shoots and leaves, imperfectly achieving a finished spatial form only when the growth of the stem has ended and the blossoms and fruits finally appear. The form of the animal, too, undergoes metamorphosis, especially during embryonic development; but it early attains its spatial shape. It then changes as a whole while preserving its nascent form.

We are normally able to observe an animal first in its newborn state. Extraordinary variations in development are shown by the various species when they come into the world. A baby seal, for example, is at birth quite similar to its parents in shape. In other cases, however, it is impossible to predict without prior knowledge whether the tiny, helpless creature will prove to be a rabbit, a hamster, or a marmot. Portmann (1959) has compared the newborns of higher vertebrates, as well as man; the following observations are based on his findings.

The young of the various bird species also leave the last protective sheath, in their case the egg, in various stages of development. Goslings, chicks and ducklings are able to stand, see and hear soon after hatching, while song birds are born blind, naked, helpless and incompletely developed. These remain long in the nest and must be cared for intensively by their parents, until they, too, achieve some degree of independence. These polaric types have been designated since the time of Lorenz Oken (1837) as *precocial* and *altricial.* Although their use is normally restricted to the birds, Portmann (1959) has applied these terms to the mammals, dividing them according to the degree of development shown at birth.

Altricial	*Precocial*
Mice, rats and other members of the mouse group,	Beavers,
	All members of the porcupine group,
Most members of the squirrel group,	Hares,
Rabbits,	The spotted hyena,
All members of the marten group,	Seals,
Raccoons and bears,	Whales,
Cats,	Horses, tapirs and rhinoceroses,
Dogs,	Pigs and hippopotami,
Shrews,	Llamas and camels,
Moles and	Chevrotains,
Hedgehogs.	Giraffes, deer and bovine animals *i. e.* the entire ungulate group).

It is immediately apparent that this division corresponds to the contrast between sense oriented and metabolically oriented groups. All hoofed animals have precocial young, as do all metabolically dominated aquatic carnivores (including the whales); among terrestrial carnivores only the spotted hyena is precocial, and among the rodents, the beaver is, as well as members of the strongly metabolic porcupine group. All altricial animals are sense-active: the mice and squirrels among the rodents, carnivores of the marten group, as well as the closely related bears, and to a certain degree, even the cats and dogs. A mere system of classification would break down in the face of such an apparently arbitrary distribution. The threefold idea, however, shows that the distinction between the conditions shown at birth follows a definite order. What then is the relationship between the nerve-sense organization and an altricial birth condition, on the one hand, and the metabolic-limb organization and a precocial condition, on the other? And is it not reasonable to assume that a close examination of the carnivores would reveal that they occupy a 'median' position between the other two groups?

The mice, as genuinely altricial animals, are born in large litters. After a pregnancy of only three weeks, the European striped field mouse, for example, gives birth to as many as twelve offspring. Under favorable environmental conditions (low humidity and a large food supply) as many as seven litters may be born each year, and after a scant two months the young reach sexual maturity and themselves begin to reproduce. The mice seem to be in a tremendous hurry to raise their offspring; at birth these young are not even completely formed. The eyelids, nasal and aural openings are still closed, and the skin is hairless; in the spinal cord the sheaths of the pyramidal tracts are not yet present; the limbs can neither support the weight of the body nor be moved in coordination; body temperature must still be regulated from the outside; the red blood corpuscles have attained a degree of maturity comparable to those of a four month old human fetus; six weeks after birth nephrons are still being formed in the kidneys (Slijper, 1960). Literally born too early, almost embryos bearing little resemblance to their parents, the young lie helpless in the nest and must be warmed, fed and cared for by the mother (Plate 166). Most mammals with altricial young have short pregnancies (16 to 30 days), large litters (5 to 35 offspring), and incompletely developed newborns. The squirrel, for example, opens its eyes only after thirty days. All this points to the rapid and yet incomplete prenatal development of these animals.

A calf is born at a much higher stage of development. When it stands up, within an hour of its birth, it immediately tries to run and by the next day is quite able to do so. The newborn Eastern European saiga, closely related to the sheep and goats, can run so quickly on the first day of its life that a man can scarcely overtake it (Grzimek, 1968). The typically precocial mammal, then, is the ungulate. At birth it is completely covered with fur, and its shape closely resembles that of its parents (Plate 155). As it grows toward maturity its bodily proportions change only slightly. For example, the calf's forehead is at first somewhat rounded and its horns grow only later; its limbs seem to be too long in relation to its trunk. But all its sense organs are open and, like the nervous system, completely functional (the sheaths of the pyramidal tracts and the ventral nerve roots are complete; thus, while the increase in weight of a mouse's brain from birth to adulthood is ninefold, that of the cow's is only twofold). Its system of warmth regulation is complete, and its limbs are ready for use.

How does the newborn ungulate come to be so strangely 'adult'? Its mother devotes her metabolic strength almost entirely to the development of her calf. During pregnancy her metabolism is especially active. An animal such as the mouse, however, having a weak metabolism, is physiologically 'unwilling' to accept pregnancy and frees herself from this condition as quickly as possible. Yet the cow seems unwilling to part with her burden and carries her calf for 280 days. She forms and forms her calf deep within the unconscious sphere of her body, shaping it fully, until—almost too finished—it finally must be born. Other animals with precocial young have gestation periods ranging from 110 to 540 days* and give birth to one or, in rare instances, two or more offspring. Embryonic development proceeds quite slowly, but so thoroughly that the young are virtually complete at birth, and the environment has little influence on their final form.

The rodent mother, because she lacks the metabolic capacity to nurture her young fully before they are born, must provide for them after birth, through her own nervous activity in the outside world. The skillfully woven nest of the harvest mouse replaces the uterus; warmth and care are provided by the mother only from without. The calf, on the other hand, developing for such a long time in the metabolic region, itself becomes an animal dominated by the metabolism. The mouse, brought up almost from the be-

* These limits refer to the spotted hyena and the rhinoceros.

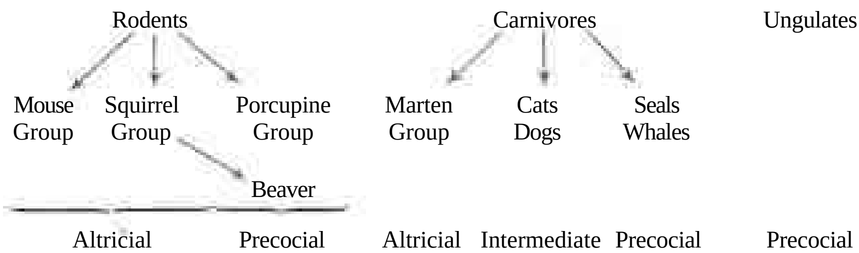
ginning by the sense oriented activity of its mother, remains throughout life a creature ruled by the sense system.

Might we not expect the carnivores to occupy a central position between these two extremes? The sense oriented small carnivores are, in fact, completely altricial; the newborn weasel opens its eyes only after four or five weeks. Metabolically oriented carnivores, as we have already indicated, are genuinely precocial. The young of central carnivores, such as dogs and cats, are usually classified as altricial, since they are blind at birth. Still, they are more completely developed than truly altricial animals: they are covered with fur and are able to crawl immediately after birth. In duration of pregnancy (fifty to seventy days), and in litter size (two to eight young), as well, they occupy a middle position. Portmann writes:

> Cats and dogs occupy an intermediate position that corresponds to their degree of specialization and organizational development (between the martens and the seals); their young are indeed altricial, yet at birth these are much more highly developed than either rats or hedgehogs. It is no accident that even the number of young lies somewhere between the above mentioned extremes (1959).

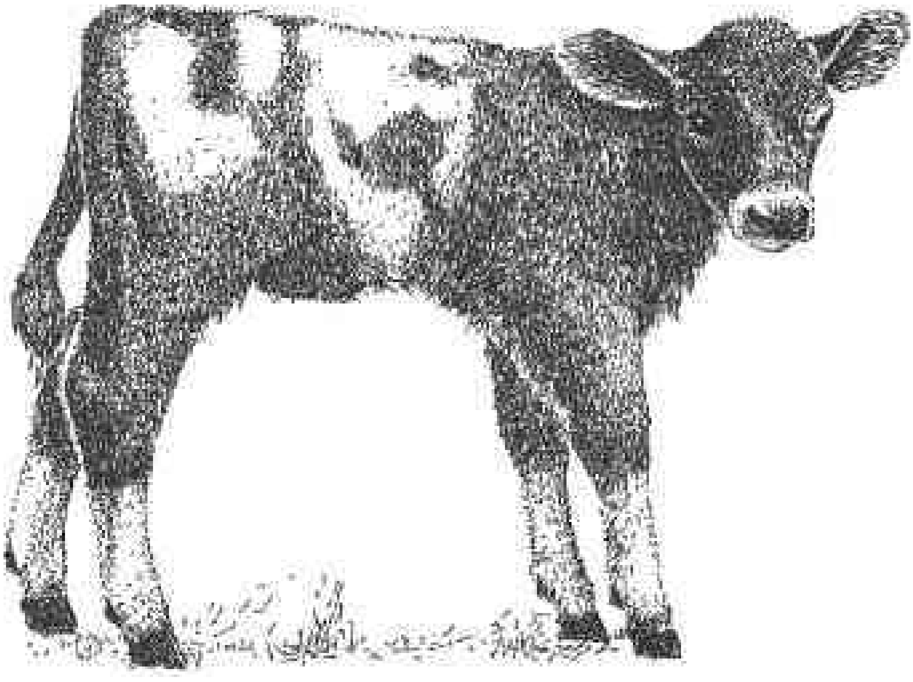
Dieter Starck, the eminent German embryologist, has come to a similar conclusion: "The carnivores, both in type of ontogeny and degree of cerebralization, stand somewhere in the middle (1955)."

Thus we find in the mammals three stages of maturity at birth, and these stages correspond to the animals' threefold classification:



For the first time the exceptions are fully comprehensible. Metabolically oriented rodents, such as beavers and members of the porcupine group *(Hystricomorpha),* have precocial young. The carnivores are subdivided into three groups. The hoofed animals are almost always precocial; only in a few central species, which tend to be somewhat primitive in development, is any hint of an altricial condition to be found. Thus swine are less completely developed at birth than other ungulates are. Their ability to regulate bodily warmth is not yet independent, and their coats are not finished; the unusually large litter (up to twelve young) is consistent with this overall picture.

85. Newborn rat *(above right),* dog, and calf (not drawn to scale).



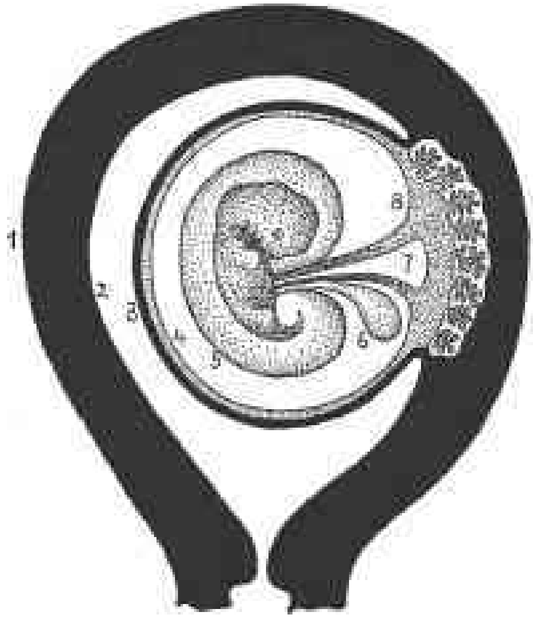
Thus each mammal tells us at birth, through its altricial or precocial condition, both the general mode of its embryonic development and the form its life will later take; altricial animals will become sense oriented, and precocial ones will be dominated by the metabolism (Plates 166 and 170).

During or shortly after the birth of a mammal, its 'afterbirth' appears, composed primarily of the now superfluous fetal membranes, which have enclosed the growing embryo and transmitted to it everything needed for its development. In order to study these embryonic membranes in terms of the biology of form we must consider them in detail.

In the lower vertebrates, such as fishes and amphibians, developmental stages similar to those undergone by the mammals are completed outside the mother's body, in the water, and thus come under the influence of the entire outside world. Among the reptiles (for example, the lizards) the embryo is surrounded by yolk and protein substances and is covered with a parchment-like shell; yet it is still directly dependent upon the humidity and warmth of the environment. In birds the solid, calcified shell, the nest, and the external incubation warmth provided by the parents replace the direct influence of the surrounding world. But it is only in the mammals that all these processes are transferred to the interior of the female organism. If the whole environment, in providing food, water, air and warmth, may be said to form the 'embryonic membranes' of the lower animals, we might also say that processes of the outer world have been transformed in the mammals and in man to a kind of 'inner environment' composed of the four embryonic membranes:

Yolk Sac
Amnion
Allantois
Chorion with Placenta.

These four structures arise out of the embryo itself; only in the formation of the placenta does the maternal uterus play some part. Plate 81 shows the position of the human fetus within its membranes. The outermost layer is the chorion. In its earliest stages its entire surface is covered with evenly distributed villi. Where these establish contact with the inner wall of the uterus they grow outward and join with maternal tissue to form the placenta. Where this contact is lacking the villi disappear and the chorion shows its simplified form (the serosa). The embryo itself is surrounded by the fluid-filled amniotic sac, in which the growing organism floats, protected from the influence of gravity and from mechanical shock. The amnion is simply a continuation of the embryonic epidermis and develops outside the embryo as a transparent sac.—In man the yolk sac and allantois are rather small; after birth, the former is sometimes found as a tiny vesicle on the surface of the placenta. Just as the amnion is a kind of extra-embryonic skin, the yolk sac is the extra-embryonic portion of the developing gut. The



86. Sheaths covering the human embryo; maternal tissues shown in black. 1) uterus, 2) mucosa of the uterus, 3) deciduate mucosa, 4) serosa, 5) amnion, 6) yolk sac, 7) allantois, 8) placenta.

allantois is an outgrowth of the hind gut. Internally, it enters into the formation of the bladder, and in some animals it is able to collect urine. Its blood vessels eventually connect the placenta with the embryo's own developing circulatory system. The umbilical cord, with its umbilical arteries and vein, also develops along the allantois, connecting the embryo with its membranes. (The embryological details that follow are based primarily upon observations published by Starck in 1955 and 1959.)

All these membranes are cast off as afterbirth and usually eaten by the mother—even in herbivorous animals. Only in a very few animals (such as the moles, dasyures and bandicoots) is the afterbirth reabsorbed by the uterus. The greater portion of the afterbirth is the placenta. As the connecting organ between the embryo and the maternal organism, it can provide us with detailed information about the nature of the connection between the two.

The placenta may adhere closely to the uterus of the mother. In this case a loss of blood precedes the placenta's discharge after birth. This type of placenta enters so deeply into the mucous membranes (the decidua) of the uterus that they are destroyed. Since the time of Huxley (1871) this placental type has been called *deciduous,* while the opposite type, in which the uterine membrane remains intact during pregnancy and the blood connection between mother and embryo is not as close, is designated as *nondeciduous.* At birth such a placenta is easily detached from the inner surface of the uterus and no loss of blood occurs.

It might seem reasonable to assume that a deciduous placental type is to be found in the ungulates, since we have already noted the close connection between the cow and her unborn calf. This close contact, however, cannot arise from an increased physical connection through the blood, for just the opposite is the case. The ungulates have nondeciduous uterine membranes, while the rodents have deciduous ones.

Rodents Carnivores — Deciduata

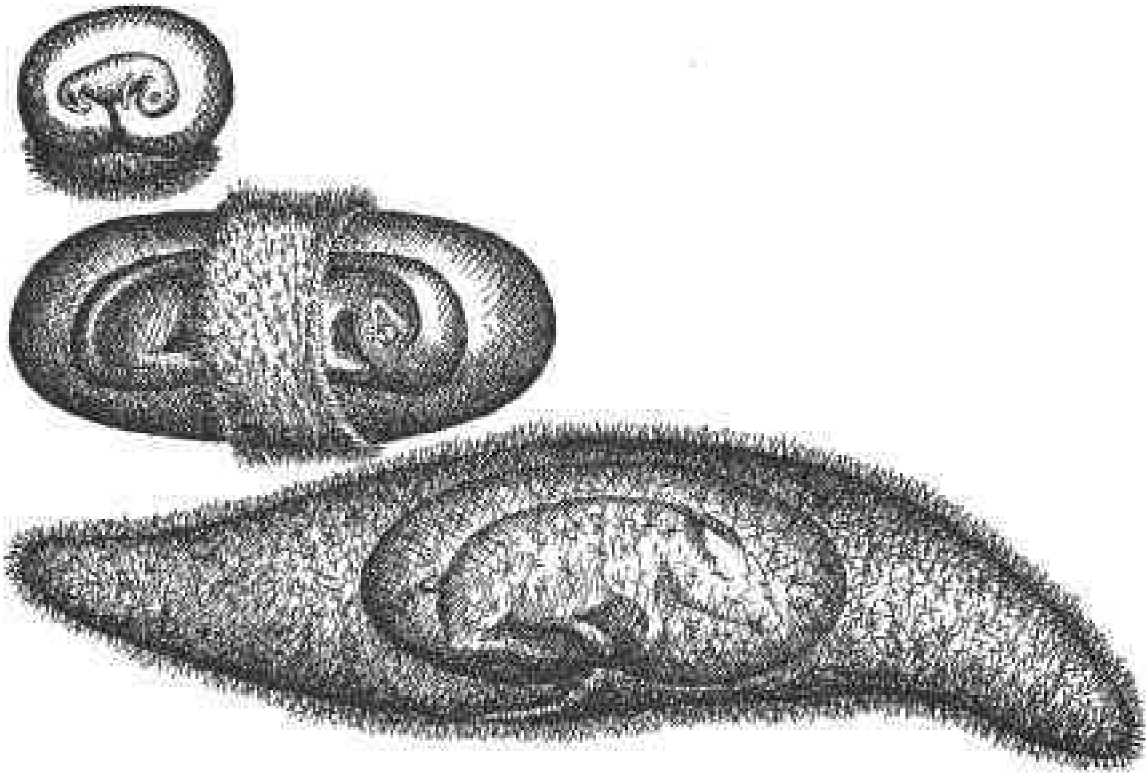
Whales Ungulates — Nondeciduata

The nondeciduous type has often been regarded as incomplete, and the deciduous one as fully developed; and this interpretation is certainly correct, because every deciduous membrane is ontogenetically at first a nondeciduous one. Yet it has led to the conclusion that the rodents must therefore be more highly evolved than the ungulates are. The results of comparative-anatomical and systematic studies, however, directly contradict this assumption; for a rodent's body is certainly far less developed than that of an ungulate. This contradiction has thus far defeated all attempts to find a systematically consistent theory of placentation (see Portmann, 1938; Starck, 1959). We shall return to this question at the end of the present chapter.

In the ungulates the placenta develops around the whole chorion, whose entire surface is covered with delicate villi that attach to the uterine epithelium without destroying it. Thus, contact with the mother is established not through a direct exchange of blood, but through a peripheral contact between the entire surface of the chorion and the uterine wall. The placenta completely encloses the embryo.

Early in its development the rodent's placenta establishes contact with the uterus, but only in the one area where the blastocyst has penetrated to the endothelium of the maternal blood vessels. Thus, although the placenta enters so deeply into maternal tissues that it reaches the blood stream, this contact is restricted from the beginning to a small part of the chorionic epithelium. What a difference in form there is between the ungulate's placenta, which completely envelops the embryo, and the centered placenta of the rodent! Significantly, the beaver, as a metabolically oriented rodent, deviates slightly from this centered form and has instead a placenta shaped like a kidney.

What form does the carnivore's placenta take? It is neither completely centered, nor does it envelop the embryo from all sides; rather, it has a form that mediates between the two extremes. It surrounds the central area of the embryo and forms a broad, closed band; this remarkable organ of the central carnivores is called the zonary placenta[40]. In extreme representatives of this group this basic form may undergo certain variations. In the raccoons, for example, the band is not completely closed (incomplete zonary placenta); in martens and polecats it divides into two discs (bidiscoidal placenta). The seals, like the cats and dogs, have a genuine zonary placenta. In the whales, however, the placenta has the same enveloping form as that of the ungulates.



87. *From the top down,* fetuses of the mouse, with discoidal placenta; the dog, with zonary placenta; and the pig, with diffuse placenta (not drawn to scale).

Thus we find the following distribution of placental types:

Rodents	*Carnivores*			*Ungulates*
	Marten Group	Most Representatives	Whales	
Discoidal Placenta	Incomplete Zonary Placenta	Zonary Placenta	Enveloping Placentas: Diffuse	Enveloping Placentas: Diffuse and Cotyledon

Portmann (1938) was the first to emphasize the importance of the differences among the various placental forms. He called these three the 'cumulate,' 'mixed type' and 'plicate' placentas, based on a differentiation established by Assheton in 1910.

The microscopic structure of the different placentas is also important. Grosser (1908-9) was among the first to attempt to establish an orderly classification of placental types on the basis of their microscopic structure. Where fetal and maternal tissues contact one another through the placenta the following layers are present between the two blood streams.

Blood stream of the mother	Endothelial wall of the maternal blood vessels	Syndesmic connective tissue surrounding the maternal blood vessels	Uterine epithelium	Chorionic epithelium	Syndesmic connective tissue of the chorion	Endothelial wall of the chorionic blood vessels	Blood stream of the embryo
Maternal Tissues				Fetal Tissues			

The chorion of the embryo remains whole throughout pregnancy. If the connection with the uterus is loose, as is the case in animals with nondeciduous placentas, the uterine epithelium also remains whole. In this case the uterine epithelium and the fetal chorion together form an *epithelio-chorial placenta.* If the uterine epithelium is destroyed by the embryo the chorion comes into contact with the connective tissues of the uterus and forms the *syndesmochorial placenta.* If the connective tissue, too, is dissolved, so that the chorion comes into direct contact with the endothelial walls of the maternal capillaries, an *endothelio-chorial placenta* is formed. The highest developmental stage is reached when the chorion dissolves even the endothelium of the maternal blood vessels and is bathed in maternal blood, so that a *hemo-chorial placenta* results. This detailed view permits us to make distinctions more exact than that made between nondeciduous and deciduous placentas. And these distinctions also enable us to examine closely the various methods of providing nourishment for the developing embryo. The major placental types, then, are distributed among the mammals as follows:

Epithelio-chorial placenta:	Ruminants, camels, pigs, whales.
Syndesmo-chorial placenta:	Ruminants, horses.
Endothelio-chorial placenta:	Carnivores.
Hemo-chorial placenta:	Rodents, hares, and most insectivores.

The rodent embryo has the most direct physical connection with the maternal blood stream. With vehemence the blastocyst penetrates the tissue of the mother; the maternal blood stream immediately supplies it with all the substance it requires. This close, concentrated blood connection permits oxygen to enter the embryo and carbon dioxide to be removed from it quite easily. The initial, oxygen-poor condition of the developing embryo's blood stream ends early, so that its blood soon arterializes. Nourishment is passed on to the embryo in a similarly direct manner. Directly from the mother's blood stream the embryo receives nourishing substances in the finished, easily assimilable, concentrated form in which they are always found in the blood. The exchange of substance takes place in the least complicated manner possible. Naturally, even in the rodents the maternal blood stream does not flow directly into the circulatory system of the embryo; rather, the chorion, whose surface area is increased by numerous villi, selects only what the growing organism requires. Nevertheless, this placental barrier is morphologically and physiologically quite thin in the rodents. Yet despite the fact that the embryo receives such rich nourishment so early in its development, only a tiny, nervous rodent will finally be born.

In the ungulates the contact between mother and child is quite different. Generally, an epithelio-chorial placenta is found. Through the fully intact uterine tissues any rapid exchange of substance is extremely difficult. Oxygen and food, carbon dioxide and waste materials are transmitted less through direct exchange than through an increased activity of the living tissue that mediates between the embryo and the mother. The embryo therefore remains in a more venous than oxygen-rich condition. This method of exchanging gases is less direct than that of the rodents, but it also demands life processes far more intensive than theirs.

Members of the swine group, for example, develop an epithelio-chorial placenta. The villi are evenly distributed over the entire surface of the chorion (diffuse placenta) and adhere closely to the uterine epithelium, which receives them into its corresponding depressions. Also distributed over the surface of the chorion are about 10,000 areolae, which form wherever the chorion is not in direct contact with the uterine epithelium. Here, glands in the maternal mucous membranes provide a special kind of nourishment, uterine milk, or histotrophe. This is the earliest form of fetal nourishment and in the pigs it is supplied throughout the entire gestation period. Two different modes of nourishment are employed simultaneously: wherever villi are formed, substances pass to and from the maternal blood stream, so that the exchange of gases and the excretion of wastes occur primarily here (in the hemotrophic areas); where the chorion is free of villi and forms areolae (in the histotrophic areas), on the other hand, the absorption of uterine milk takes place instead. In the villi, primarily arterialization and excretion occur; in the areolae, in a venous state, the processes that build up the organism take place. In the pigs both areas are equally distributed over the entire chorionic epithelium and are in close contact with one another.

This placental type, with its evenly distributed hemotrophic and histotrophic areas, clarifies the contrast between the placentas of horses and cattle. In the horses histotrophic areas are confined to large depressions in the mucous membrane and may be as much as 4 inches (or 10 centimeters) in diameter; here, the uterine epithelium disintegrates, so that the placenta actually becomes syndesmo-chorial in places. Hemotrophic areas of the horse's placenta remain diffuse and epithelio-chorial.

In the cattle and in most ruminants with frontal processes this situation is reversed; the early, histotrophic form of nourishment remains dominant throughout the entire gestation period. This remarkable uterine milk is secreted by the fully intact uterine epithelium into the gap between the two surfaces of epithelial contact; here it is slowly absorbed by the smooth walls of the chorion. Hemotrophic areas, on the other hand, are confined to regions prepared for them by the uterus (the caruncles). Only here does the chorion develop villi, which adhere closely to the depressions in the intact uterine epithelium and actively establish contact between the maternal and fetal circulatory systems. These narrowly restricted, disc-shaped regions of chorionic villi are called cotyledons and correspond to the caruncles of the uterus. Together, each pair forms a placentome. In the cow, between 50 and 150 of these centers of hemotrophic nourishment, each about 2 centimeters (3⁄4 inch) in diameter, are evenly distributed over the surface of the placenta. This type of placenta, therefore, is often called a cotyledon placenta (Plate 183). In comparison with the diffuse placenta of the pig, the cow's placenta has increased its histotrophic areas, while hemotrophic activity has been resticted to the well spaced cotyledons. Thus the placenta of the bovine animals contrasts totally with the strictly centered, completely hemotrophic, hemochorial placenta of the rodents[41].

In deer the number of cotyledons is greatly reduced (only 5-10); these lie closer together than those of the cattle, however, and may attain a diameter of up to 4 inches (10 centimeters). In the placentas of sheep and deer, unlike those of the cattle, the epithelium is often destroyed in the caruncles, so that the placenta, in its hemotrophic areas, becomes syndesmo-chorial. Like the horses and pigs, tapirs, rhinoceroses, hippopotami, camels, chevrotains, and even musk deer do not have cotyledon placentas, but diffuse ones.

The zonary placenta of the carnivores shows a distinctive form and mode of fetal nourishment. The chorion does not penetrate to the blood stream of the mother, but only as far as the endothelium (endothelio-chorial placenta). Thus, in the carnivores, even the method of exchanging substances takes on an intermediate form. Hemotrophic nourishment reaches the embryo through the uterine endothelium and chorionic villi neither so directly as it does in the rodents nor so 'complicatedly' as it does in the ungulates. Venous and arterial processes balance one another. Especially characteristic is the course taken by the histotrophic nourishment. Along both edges of the zonary placenta blood flows out from maternal blood vessels into open tissue gaps; thus natural hemorrhages called marginal hematomas develop along both edges of the placenta. This clotted blood forms the histotrophic nourishment absorbed by the adjacent chorion (Starck, 1955). In the rodents, histotrophic nourishment ceases almost entirely once the placenta has been formed, and the embryo receives only *hemotrophic nourishment;* in the ungulates a *histotrophic form of nourishment* composed chiefly of glandular secretions prevails. Yet the developing cat embryo, for example, receives *blood in the form of 'histotrophic' nourishment.*

These differences are not simply interesting curiosities, for the growing embryo receives through the placenta a form of nourishment that approximates the type of food it will later receive from the surrounding world. Mouse and squirrel embryos, for example, receive a concentrated, highly nourishing food that is absorbed through a very thin placental barrier; the carnivore embryo receives clotted blood; and the unborn calf feeds on uterine milk, an almost 'plant-like,' bloodless glandular secretion that grows, as it were, within the organism of the mother. The hemotrophic nourishment of the mouse embryo requires almost no digestion; the primarily glandular histotrophic nourishment of the developing calf embryo gently but continuously stimulates the metabolism to develop a powerful digestive system; the hemo-histotrophic food of the carnivore embryo helps it to develop a central organization. What takes place before birth outside the body of the embryo gives rise to capabilities that will be fulfilled by the digestive organs within the animal's body only after it has been weaned.

In cattle the maternal organism (through the uterine glands) is especially active in creating the internal environment. In rodents the embryo itself is the more active organism, 'eating' its way into the blood stream of the mother and taking for itself whatever it needs. Something of the cow's ability to adjust to its environment and to be satisfied with simple food is indicated even by the embryo, as is the tendency of the mouse, on the other hand, to race toward some goal, chewing and destroying everything it finds along the way. The mouse must actively search for its nourishment, while the earth freely gives to the cow all it needs. Thus the activity of embryonic development arises in the rodents from the many separate embryos, while in the hoofed animals it stems more from the activity of the mother. It is therefore not surprising that a pregnant mouse rids herself as early as possible of her incompletely developed young. Rather than providing a protective sheath for her offspring, she prefers to serve as the central figure in the world that surrounds them. We can also understand why the hoofed animals bring into the world such fully developed, precocial young. For the unborn ungulate long enjoys an enveloping, utterly devoted maternal organization and in such an inner environment can grow so strong that it is later able to bring into the outside world tranquility, health, and abundant energy.

In the carnivores these polaric processes are brought together and expressed in many different ways. As we might expect, the marginal hematomas are larger in the dogs and play a more important role than they do in the cats. The hematomas of the cats are brownish-red, while those of the dogs are greenish; apparently this extravasated blood is more hemic in the cats than it is in the dogs. The dog's placenta, unlike the cat's, may be recognized immediately by an additional glandular layer, which produces further histotrophic nourishment; this layer is especially well developed in the seals! In the latter there are no hematomas, so that a primarily glandular form of histotrophic nourishment is provided. The whale's placenta surrounds the embryo completely and is epithelio-chorial; the uterine membranes of these strongly metabolic relatives of the carnivores are therefore nondeciduous. The placentas of martens and bears have a variety of blood-filled sacs that increase hemotrophic nourishment. In the central carnivores, the cats and dogs, however, food that is at the same time hemotrophic and histotrophic reveals the balanced relationship between mother and embryo and between the adult carnivore and its surroundings. In these animals venous and arterial processes have a balanced, rhythmic relationship. Even such detailed observations attest to the validity of our threefold classification of the higher mammals.

Because the workings of the microscopic, earliest stages of embryonic development cannot be directly observed by the non-specialist, their discussion has been omitted here. Readers who are interested in pursuing this matter in terms of the biology of form should refer to the original, German edition of this book.

* * *

A true picture of the processes leading to birth can be attained only when the death of the animals is also taken into account. A few introductory remarks may be in order, since today not only our relationship with the living world of nature, but particularly our understanding of its connection with death, have been disturbed (Schad, 1970). Not only man brings death into the natural world, but nature itself is constantly reducing its own numbers. In nature the majority of individuals entering life die not of old age, but prematurely; more offspring are born than can possibly grow to maturity. Out of this surplus other animals are fed. Yet the fact that an animal kills a plant or another animal in order to preserve its own life is experienced in very different ways by different people. How diversely various people react to a cat catching a mouse (Plate 173) or a hawk seizing a sparrow! And how much more complex the problem becomes when man himself interferes with the animal world and kills.

Ortega y Gasset has written of the hunter:

> He has no final and absolute certainty that his behavior is correct. But we must understand this aright; he is also not sure of the opposite.... All this is not meant as a criticism of hunting, but this feeling of uncertainty sheds light on the universal, problematic, ambiguous nature of our relationship with the animals.

What, then, is the death of an animal? Perhaps the animals themselves can give us an explanation of their relationship with death. For the various animals not only live differently, but they also die in very different ways.

It should be emphasized at the outset that the predator lives in a genuinely symbiotic relationship with its prey. Thus, if a hunter shoots all the foxes in his preserve in order to hunt all the rabbits himself, these become weak and sick in the course of a few generations, since unfit animals are no longer weeded out by foxes. If the hunter then reintroduces foxes, they may well kill all the rabbits, since none is strong enough to escape! Then, not only the rabbits die, but the foxes as well. This rather simplistic example should indicate that in undisturbed nature there is a delicate biological balance between predator and prey. In the relationship between fox and rabbit, pine marten and squirrel, or weasel and mouse, we have before us a genuine symbiosis, for a natural numerical balance enables both predator and prey to remain healthy. Zisweiler, in a careful study of the relationship between carnivores and deer, makes the following statement:

> . . . The unhindered numerical increase of a particular species may ultimately lead to its self-destruction. In an animal preserve in Arizona all pumas, coyotes and wolves were shot in order to protect the deer. As a result, the deer increased to such an extent that they destroyed all the vegetation and this in turn led to wholesale starvation. We may therefore conclude that the pumas and wolves actually kept the deer alive.

A similar example is cited by Grzimek (1968) in his discussion of the necessary connection between moose and wolf. This relationship is so basic that it applies not only to mammals but to all organisms that live off one another, for by maintaining a symbiotic relationship they also live *for* one another.

Among the mammals, rodents and closely related species typically serve as prey. We need only call to mind the hares, rabbits, ground squirrels, and squirrels to prove this point. The mice in particular serve as the basic source of nourishment for all European carnivores. Most mice do not die of old age, but quite naturally as prey. All the rodents, particularly the mice, are actually constituted for this purpose. They die quite easily; even a severe fright may kill a mouse. Its life seems to hang by a thread. The wood mouse, with its natural life span of only ten months, has the shortest lifetime of any mammal (Slijper, 1967).

In no other mammal group do we find ways of dying so remarkable as those of the mice. Cannibalism, for example—the eating of other members of the same species—occurs in other higher animals only under abnormal circumstances. Occasionally, an animal giving birth for the first time devours stillborn, or even weak offspring together with the afterbirth; sometimes she may even eat the entire litter. Such behavior has been observed at times among carnivores and swine. In the rodents, however, this behavior is quite typical. The instinct of caring for and nursing the young often develops only after the second or third litter. Apparently, the nerve-sense system's constant drain on the rodent's own metabolism extends easily to the newborns, which are still closely connected with the body of the mother.

But cannibalism even among adult members of the same species is found among the rodents, as well as the insectivores. Edible and garden dormice, for example, hibernate in groups, congregating in burrows they have dug to protect themselves from the cold. The animals waking earliest in spring normally appease their initial hunger by eating others that are still asleep. Brown rats of different nesting communities wage fierce battles with one another, fighting until one opponent succumbs and is eaten by the other. The dormice and rats, as we recall, are central, 'carnivorous' rodent species.

Still more remarkable is the behavior of the northern European Norway lemmings[42]. These colorful relatives of the voles pass the harsh northern winters in the subalpine regions, where they live in burrows beneath the snow and feed upon lichens and moss. When the snow begins to melt in early May, they migrate to the great peat bogs where they breed; at the beginning of August they return once again to their winter home. These short migrations recur year after year, unnoticed by man. It occasionally happens, however, that these animals reproduce in numbers that are far too great. Litters are born more and more frequently and in ever larger size. When this massive increase has reached a certain point, the males in particular abandon their accustomed living places and gather in marching columns of tens of thousands. They travel during the night and when groups are very large, even by day, covering up to ten miles daily. Unswerving in their direction, they march across the countryside and swim across the rivers. Lack of food is certainly not the cause of this migration. Under normal conditions, strictly herbivorous—they eat almost nothing but moss—they turn now to cannibalism and eat those of their own number that have died of exhaustion.

Short, rapid migrations generally occur at the time of the spring thaw, while longer ones, with frequent interruptions, begin in late summer or early fall. These may even extend over two summers, so that the animals cover distances of up to 150 miles. Without apparent goal they move generally east or west in Scandinavia, north or south in Finland. Nothing but death awaits most of them. When they reach the sea they do not turn back but run into the waves, swim for a short distance, and finally drown. By this time many have already frozen to death on the glaciers. Even during the journey they lose all fear of death and offer themselves as easy prey to the innumerable owls, vultures, ravens, martens, wolverines, foxes, and others that follow them. Even reindeer eat them at this time. At the seashore they are met by seals, as well as seagulls and other shore birds. 1938, 1942, 1946, 1955, and 1959, for example, were lemming years. Every three or four years such a massive increase in population occurs but does not always reach large enough proportions to cause migrations. Even when these do take place, a small remnant always remains behind to preserve the species. The mass migrations of the Scandinavian lemmings often occur simultaneously with those of the Finnish, North Asian, Canadian, and Greenland lemmings. An entire group of related species is thus decimated at the same time. As a species, then, the

88. The Norway lemming, with its blunt snout and short tail, is obviously a member of the vole family (1/1.5 X).

greater part of the lemming population behaves in such a way that it invites death. These rodents not only serve as prey for other animals, but even behave in a manner contrary to life.

Many biologists consider this behavior of the lemmings 'atelic,' unsuited to any purpose, since it certainly represents the opposite of the struggle for existence. But is it really biologically senseless? For the individual animal at that particular moment, yes, but by no means for the entire species. For the species thus controls a population increase that could destroy the food supply as well as the biological equilibrium necessary for the survival of all the animals in its range. This biological equilibrium is restored during migrations, for at these times all carnivorous animals feed almost exclusively on lemmings and receive from them a biological impetus. The white owl of the far North, for example, breeds only in such years of plenty. During migration the individual lemming gives up all functions that would preserve its own life and in so doing preserves its entire species and the environment that supports it. A survey of animals making such mass migrations yields the following list (after Kalela, Cohrs, and Köhler):

Norway lemming Siberian lemming Brown lemming, northwestern United States	only in the spring
Wood lemming, Finland (mostly females) Arctic lemming, northern Asia Various rodents in Chile	usually in summer or fall

In rarer instances:

Social vole, northern Asia
Brown rat, Eurasia
Squirrel, northern Eurasia
Grey squirrel, North America
Red squirrel, North America

A similar, though less extreme, phenomenon takes place among the European common voles. When environmental conditions are right (in dry summers with ample food supply) their numbers increase to the point of overpopulation. Within 10 months a single pair of voles can theoretically produce up to 2550 offspring, since succeeding generations are themselves able to reproduce after only 15-20 days, gestation lasts only 21 days, and each litter consists of 4-12 young. At the height of such a massive increase (about 30,000 voles per hectare), no migration takes place; but well fed animals for no apparent physiological reason begin to tremble, become exaggeratedly nervous and quarrelsome, and are severely affected by slightly adverse environmental conditions, such as bad weather. They crouch hunch-backed, their hair bristling, and become incapable of coordinated movement. In the final stages the animals stop eating, their body temperature falls, and they die of a sudden drop in the glucose level of the blood (hypoglycemic shock). A few of the stronger individuals manage to survive by resorting to cannibalism—despite the fact that they are strictly herbivorous under normal conditions—and thus preserve the species.

This epidemic death, which occurs without illness, lack of food, or any other visible cause, is typical of many rodent species. This phenomenon is also known to occur among the following species:

Bank vole (Cohrs and Köhler)
Striped field mouse (Mohr, 1958)
Harvest mouse, primarily in Russia (Mohr, 1958)
Indian gerbil (Sanderson)
Mice and ground squirrels of the Caucasus (Cohrs and Köhler)
Greenland collared lemming (Cohrs and Köhler)
Snowshoe hare of North America (Cohrs and Köhler).

This mass death occurs in the various species in overlapping periods of three to four and five to ten years, often taking place simultaneously, particularly in the arctic regions (Cohrs and Köhler).

Such phenomena demonstrate the rodent's special relationship with death. Its natural inclination to die extends as far back as the embryonic period. Brambell has discovered that among the wild rabbits (a group closely related to the rodents) of northern Wales, sixty percent of the embryos that begin development normally die before birth and are reabsorbed. The peak of this embryonic death occurs at about the twelfth day of the thirty day gestation period. Only those embryos that have been large from the very beginning survive (see also Grzimek, 1965). It has also been discovered that twenty-five percent of water vole embryos generally dissolve when they reach a size of one millimeter (Mohr, 1958).

How different is the ungulate! Its death is hard. Naturally, the life span of such a large animal is much longer than that of a mouse; but the ungulate also possesses a much greater vitality, since the upbuilding metabolic processes predominate in it. Even an old, enfeebled animal still needs a strong blow from the outside world (in the form of disease, predators, and so forth) to force it to give up its life. Its powerful metabolism allows this animal to find contentment in the gathering and transformation of food, in growth, pregnancy, and the production of milk. It is only with reluctance that the ungulate gives up its life. It fends off predators more successfully than other animals can and therefore dies prematurely much less frequently than they do. The bison, African Cape buffalo, eland, hippopotamus, rhinoceros, and elephant, because of their great size and strength, are rarely attacked by the carnivores but are irritated instead by tiny parasites; only the young need be defended from attack.

The metabolically strong body dies hard. An extreme example is the South American sloth. This animal does not belong to any of the groups discussed so far, since it is not found in the Northern Hemisphere but belongs instead to the remarkable world of mammals typical of the Southern Hemisphere. The sloth's excessively developed metabolic organization is illustrated by its very exaggeration. It can go for days or even weeks without food and still fail to show any ill effects. Predictably, it eats only plants. About once a week urine and feces are deposited in large quantities beneath the tree in which the sloth last fed. All incisors are lacking! This animal would never suspect that nervousness or haste might exist somewhere in the outside world. For the hunter, shooting such an animal can be a very unpleasant experience; even when hit directly several times, it dies extraordinarily slowly. "Severe wounds are borne with the indifference of a corpse. Often, these animals do not even change position when hit by a shotgun blast. According to Schomburgk these of all animals have the longest resistance to the terrible curare poison of the Indians" (Brehm).

Thus, great polarities are presented to us in the exaggeratedly sense oriented animals and the excessively metabolic ones, even in their ways of dying. And it is only by perceiving these two polarities that we are able to understand the carnivore's special relationship to death. The rodent is constitutionally weak and its death is physiologically easy. The ungulate, with its enormous vitality, defies death as long as possible and dies with physiological difficulty. The typical carnivore, however, attacks. It exposes itself equally to life or death. With death as well as life it has an active relationship.

A study differentiated in this way enables us to approach in a realistic manner the many questions connected with the death of animals. We are able to see that just those animals most frequently eaten by others find it least difficult to die. The prey, through its very constitution, meets the predator halfway; their symbiotic relationship is much closer than is generally assumed.

The relationship between birth and death is also clarified. The rodents die as easily as they are born. Hurriedly and in great number, these primarily sense oriented animals enter life; and they leave it in the same way. An accelerated embryonic development, which in the early stages skips over many intermediate steps, is characteristic of these animals. The picture is complete when we realize that they are able to meet death just as precipitously.

The ungulates show opposite tendencies. In the earliest stages of embryonic development, preliminary formations, such as the first embryonic tissue and the amnion, are abandoned and reintegrated into the trophic tissue of the germ. Only after these events have taken place can embryonic development really begin (Starck, 1959). The formation of the body passes through additional intermediate stages and its development is retarded thereby. Yet the final result is a highly developed, well advanced physical organization.

Thus it is only with difficulty that the hoofed animal gives up its life. For just as it delays its entrance into life, so the metabolic animal delays giving up an existence it so enjoys. Not only the spatial shape, then, but even the chronological forms of the sense and metabolically oriented animals are polaric. *Each acceleration of development leads to a physiologically weak, sensitive constitution, while each retardation leads to a powerful constitution that is metabolically strong.*

Zoologists are correct in placing the ungulates developmentally above the rodents. Yet the placenta of the hoofed animals, as we have mentioned, is more primitive than that of any rodent. This fact led Strahl (in 1902) to call the ungulate placenta a *semi-placenta* and that of the rodents a *placenta vera*. He also assumed a corresponding evolutionary development leading up from the ungulates to the rodents, but this point of view is at variance with all findings on the morphological organizations of these animals, since a cow is clearly more highly developed than any rodent is. Today, this apparently insoluble problem is frequently avoided by assuming that the characteristics of embryonic membranes are simply adaptations to the temporary environment of the uterus, and therefore of no morphological or evolutionary significance. According to the biogenetic law[43] one might expect the more primitive stages of development to precede the more advanced ones, so that the semi-placenta would precede the placenta vera. Among the three principal groups of mammals, however, this is the case only in the carnivores. The rodents completely omit the primitive placental stage, in which the placenta surrounds the embryo, and immediately develop—at an accelerated pace—a hemo-chorial, discoidal placenta. The ungulate placenta, however, is retarded in its development and throughout gestation remains in the primitive, epithelio-chorial stage. These variations are absolutely consistent with the chronological forms of such one-sided animals and may be understood accordingly.

Ernst Haeckel, when he formulated the biogenetic law over a century ago, stated that in addition to the strict adherence to this law (palingenesis), there are also deviations (cenogenesis) from it. In this example of placentation we can trace the orderly manner in which all cenogenetic phenomena deviate from the expected biogenetic development, for they deviate in one of two directions: All highly sense oriented animals omit the usual transitional stages and accelerate their development. All strongly metabolic animals add intermediate stages and retard their development.

Despite the fact that such phenomena have prompted biologists to question the validity of the biogenetic law, the threefold method of observation opens the way to a solution to this basic problem of biology. Acceleration and retardation can be understood as ordered variations of the biogenetic law. This law should by no means be set aside, but applied in a wider sense, so that we might come to understand the shape of time, as shown in the life histories of the various animals.

XI The Shape of the Environment

One of the primary aims of our method has been to broaden our ordinary concept of space as an empty vessel containing the living world. For, as we have seen time and again since the second chapter, space encompasses not only the three dimensional system to which we are accustomed, but two other systems as well. On the basis of this premise alone can the biology of the threefold form attain a real, and not merely formal, content.

When we examine the various habitats of the mammals more closely than we have done thus far, we encounter many conceptual difficulties. For the landscape, too, is often regarded simply as a container in which this or that occurs, in which the animal is compelled to live, and to whose conditions the animal must adjust somehow, if it hopes to survive. But what do the animals themselves tell us about their surroundings?

Since we are studying the mammals, let us first compare their relationship to the surrounding world with that of the vertebrates in general. The lowest group of vertebrates (or, more accurately, chordates) has a primitive hollow nerve cord—the forerunner of the spinal cord—whose anterior pole is further developed by the fishes to form the brain. The *central nervous system* is the fishes' distinguishing innovation and separates them from the invertebrates. In the amphibians, the next higher class, the gills are replaced by lungs, so that the function of *breathing* is transferred to the interior of the body. Nevertheless, the amphibian continues to depend upon the moisture it receives from its environment. The reptiles are the first group to be freed from this dependence, since they, by means of their horny armor of scales, have attained a closed fluid system. They, too, however, are still directly dependent upon the external temperature (they are cold blooded). The birds, the next higher group, are finally independent even of the environment's warmth; their constant body temperature has given them an independent system of warmth.

Through what processes, then, do the mammals achieve a degree of independence from the environment even greater than that of the reptiles? Through the processes of *reproduction.* In birds and egg-laying mammals (monotremes), the offspring develop outside the mother's body, in a nest; in the marsupials they develop in a brood pouch that opens externally. Only in the placental mammals does the development of the young take place entirely within the uterus of the mother. Precisely because the young are so long protected from the direct influence of the outside world, the placental animals have become the most highly developed animal group. Even their first food does not come to them directly from the outside world, but from the mother's body, in the form of milk. The name 'mammal' is itself an eloquent expression of this evolutionary step forward.

The following chart summarizes the way in which the animals have gradually attained an increasing degree of independence from the outer world. Note also the *sequence* in which life functions have been internalized:

Fish	*Amphibian*	*Reptile*	*Bird*	*Mammal*
Central nervous System	Breathing System	Fluid System	Warmth System	Reproductive System
Brain	Lungs	Heart	Visceral organs	Uterus

It is apparent, then, that the nerve-sense system preceded all others in developing self-contained independence. Since this system is centered in the brain, the higher animals developed their increasing independence of the environment from the head downward. The center of breathing was developed in the *lungs* by the amphibians, and that of the fluid or circulatory system was developed by the reptiles, in the heart; the crocodile, as the most highly developed reptile, has a closed heart septum[44]. An independent warmth system first developed in the birds. The *uterus* developed as the center of the reproductive processes in the mammals. Once the nerve-sense, middle, and finally the metabolic and reproductive systems had become self-contained, the mammals had achieved the highest degree of independence from the environment possible for any animal.

What we see here—and this must be emphasized—is not the *creation* of a new organic system, so much as its *emancipation* from the direct influence of the outside world. In the fishes, too, the exchange of gases and circulation of the blood take place. These animals are able to produce warmth through muscular activity and also possess reproductive organs and even two pairs of fins as rudimentary 'limbs.' But the gradual shifting of the fluid and warmth systems, as well as embryonic development, to the interior of the body—or at least a growing independence of these functions from the outside world—generally took place only in the higher vertebrates[45].

Does the emancipation process we have observed come to an end in the mammals, or do we find among these animals, too, an organic system that limits them to a particular environment? The limbs constitute just such a system. The shovel-like claws of moles, the wings of bats, the climbing-claws of squirrels, the flippers of seals and whales, the leg and hoof specializations of ungulates, the hanging-arms and grasping-feet of apes, to name a few examples, are strictly dependent upon the particular environment of each animal species. Because of its limb-system the mammal, too, is an 'open organism.' In this sphere the environment and the mammal form an indivisible functional unit. How is this close relationship constituted? While there is no specific, predetermined environment for all carnivores or for all ungulates, we have encountered in previous chapters many isolated examples of such relationships. These we shall now compile.

Which mammals choose the water as their environment? We first discussed this question in reference to the otter (Plate 109). The masterful strength of its playful movements; its effortless speed; its self-assurance and tranquility; its size in comparison with the marten (large without seeming ungainly)—all this led us to conclude that the otter is a central animal secondarily influenced by the metabolism. This relationship we established as a rule, confirmed time and again: *If originally terrestrial members of a central group develop a strong metabolism, they secondarily seek the water as a habitat.* We have also found this 'otter motif' in the mink, and among the rodents, particularly in the beaver, as well as the water vole, muskrat, brown rat, and root vole. Among the carnivores, the group most strongly influenced by the rhythmic processes, the metabolically oriented members are best adapted to life in the water: the seals (Plate 113) and particularly the whales! A dog is by no means as shy of water as a cat, and the large cats are less so than the small ones; jaguars, for example, have been known to swim the Amazon, and tigers to cross the Ganges.

Even the ungulates are organized according to this basic rule, insofar as they include middle groups. The hippopotamus, for example, as the most metabolically oriented member of the central swine group, is the ungulate best adapted to an aquatic way of life. Among the deer, another central group, the love of water is most strongly expressed by the metabolically powerful moose (Plate 146); and even the red deer likes to wallow occasionally, while the roe deer avoids water as much as possible! The moose drinks much more frequently than the red deer does (Kramer), and the roe deer drinks hardly at all (Ognew). The musk ox, as a metabolically oriented member of the central group of horned animals, loves to wallow in the shallow pools that form during the short polar summer (Brehm) and is an excellent swimmer (Pantenburg). A similar, though not identical, relationship is shown in the opposite case, among rhythmic species within primarily metabolic groups. Thus, all central ungulates are typically swamp dwellers; the tapirs, pigs, chevrotains, and most red deer live near marshes and water.

We turn now to the animals that choose trees as their habitat. The pine marten has a well-developed rhythmic organization, yet it is secondarily more sense-active than other martens. It feels at home in the crowns of trees in the forest, where, with strength and agility, it hunts for squirrels. Here we find another rule: *Rhythmic, central animals secondarily influenced by the sense pole are climbers, and in most cases, tree-dwellers.* Among the rodents, the squirrels and flying squirrels are obvious examples. The dormice, too, can be understood according to this rule. Among members of the European mouse group the best climber is the bank vole, and the black rat climbs about as well as the brown rat swims. Among the carnivores nearly all civets, genets, and mongooses (the viverrines), as well as cats, especially the smaller ones, are excellent climbers! The rhythmic processes are so strong even among aquatic members of this central group that sense oriented species, such as eared seals and dolphins, express their love of the air by leaping joyfully out of the water.

Among the ungulates sense oriented members of central groups are less apt to climb in trees than along the steep walls of mountains. The entire group of sheep and goats (including the ibex, chamois, goral, chiru, tahr, Barbary sheep, blue sheep, serow, and Rocky Mountain goat) should be mentioned here. These horned animals, with their none too massive, but nevertheless muscular bodies, live almost without exception in high mountain regions and love the windy air high above the valleys. A few species, such as the goral of the South and East Asian mountains and the domestic dwarf goats of North Africa (Plate 137), are even given to climbing trees!

Because the deer are central bearers of frontal processes, we might expect to find similar tendencies among the small forms. The antlerless musk deer does in fact live high in the central Asian mountain ranges, particularly in the Himalayas, where it, unlike any other ungulate, climbs trees at the timberline. Krummbiegel (1953-55) reports that musk deer have been observed at heights of nearly 50 feet (or 15 meters) among the branches of trees and have been seen jumping down from heights of about 13 feet (4 meters). In light of what we have learned, such behavior no longer seems 'curious' but is completely consistent with the animal's organization.

What living space is preferred by the sense oriented animals? Turning once again to the European martens, we find that the beech marten and particularly the weasels (Plate 107) love to slink along the ground, through underbrush, rocks and fallen trees, into hidden nooks and crannies where there is always something new and unexpected to discover. Here their sensory faculties can be used to the fullest. In rodents this terrestrial way of life is quite common, especially among the long-tailed mice. *The wood mouse, racing in and out of the leaves along the forest floor, is a prototype of the completely sense oriented animal, living at the transitional area just at the earth's surface.* Among the ungulates the chevrotains, pudu, Chinese water deer, duiker, and dik-dik, rather like the rodents, love to slip through dense grass and thickets.

In the mouse group, the voles, somewhat less open to the world than the above mentioned animals, choose to live just beneath the surface of the earth. Outside their burrows, in the grass, they carefully dig out small covered runs. A stronger metabolism than theirs is shown by their distant relatives, the hamsters, mole rats and porcupines. These are all burrowing animals, and the more sensitive the group to which each species belongs, the deeper it makes its burrow. These animals close themselves off completely from the endless sensory irritation encountered above ground. *Metabolically oriented* *nerve-sense animals live in deep burrows.* Among the carnivores the polecat and particularly the badger are prime examples of this tendency, as are the bears (such as the brown and polar bears), with their long winter hibernation in weatherproof dens.

Is there a characteristic habitat for the purely metabolic animals? What kind of environment is chosen by the cattle, for example? The European bison and gaur choose the forest; the American plains buffalo, the steppe; the yak, high mountain plateaus; the anoa, swampy areas; and the water buffalo, the opportunity to wallow in water for hours at a time. Such great variety is evidently connected with the fine differentiations found among the various cattle species. Yet as a group they offer no uniform picture. Their connection with the environment is not so strong as that of the squirrel, for example, or the whale. For the cattle have achieved a greater degree of independence from their environment than other mammals have. They hold their heavy bodies high above the ground. *For the metabolic animal, the powerful body has itself become the most immediate physical environment.* The cow gazes out from her body, and into the world outside, as though from a deep hole. The mole rat and badger, as metabolically oriented nerve-sense animals, still require an external den, while the purely metabolic animal creates this den within its powerful body, where it lives absorbed in its own dreams. In this sense, rhinoceroses, hippopotami, giant whales, and large seals, too, could be called 'burrowing animals *per se.'*

Yet even in the cattle the limbs are given form by the outside world. The portions near the body are short, while those close to the ground grow long, and only two toes are accentuated. The transformation of the nail to a hoof, too, shows the strong influence of the environment.

How do the ungulates more open to the outside world, the horses, camels and giraffes, orient themselves toward their surroundings? Their limbs, through the reduction of all lateral hooves, have become completely specialized running organs. *These limb animals clearly prefer wide plains such as savannas, steppes and deserts.* A landscape that can be widely surveyed, that conceals no surprises, and that allows them to roam endlessly is the appropriate living space for these animals. Many gazelles and other antelopes, such as the gemsbok, should be included in this group. Among the carnivores the dogs (including the South American maned wolf, the East Asian wild dog, the jackal, etc.) are good runners; among the cats, only the large, long-legged cheetah runs well. Among the rodents only the South American mara (of the Argentine pampas), if any, might be considered a limb animal.—The energy stored up by the metabolism is freely available for intense physical motion. Thus a close relationship with the surrounding world is established even by the limb animals, who are best suited to a broad landscape with a limitless horizon.

The bond between a mammal and its environment, then, is so close that the environment may be predicted from the animal's constitution. The rules we

Sense and Nerve Animals		Central Animals		Limb and Metabolic Animals	
Surface of the Ground	Burrows	Trees (or Mountains)	Water	Plains	Unspecified—in the last analysis, the animal's own body

It is clear that the habitats listed on the left-hand sides of each group provide the animal with a wide field of observation, while those on the right serve to shield the organism from the outside world. In addition, the two central habitats, in which the animal is neither without protection nor completely hidden, seem to mediate between the two extremes. Nevertheless, these relationships between the animals and their environments require further clarification. We could propose a causal explanation and hold responsible the no longer verifiable 'pressures of natural selection' theoretically exerted upon these mammals, or we could assume teleologically a certain plan underlying the obvious external order. However, a third method of observation, namely that of deriving the living relationships from the principle of the organism itself, is also possible; and it is this method that we shall follow once again. Why should the organism not be capable, in this instance as in others, of explaining itself?

The mammalian organism creates its middle system from the interplay between lungs and heart. The lungs, as we described in the second chapter, are the organs more open to the outside world; while the heart, more closely bound with the metabolism, is the center of the vascular system, through which the blood, a fluid, is constantly streaming. And in the same way, central animals secondarily inclined towards the metabolic processes tend to live within the 'circulatory,' or 'fluid,' system of the landscape, in the rivers, lakes and seas. Central animals dominated secondarily by the sense processes, on the other hand, prefer a life in the airy regions of the tree tops or mountain peaks, in the 'lungs' of the landscape. The relationship with the surrounding world, then, is organically ordered.

Sense oriented rodents choose a habitat that corresponds to the position of the sense organs of the single organism: they live on the very surface of the ground, on the 'sensory layer' of the landscape. The 'digestion' of perceptual activity, on the other hand, takes place in the brain, enclosed within the encapsulating, highly ossified skull. Just as the brain leads its own life, as it were, far from the light of day, metabolically oriented nerve-sense animals live in burrows in the landscape, closed off from the abundance of outer sense impressions.

The limb animals need open, free space—a landscape with the widest periphery. The limbs, too, constitute the periphery of the individual organism. The purely metabolic animal's relationship with the landscape is more or less the same as that of the digestive organs within a single organism. They remain fairly independent of any particular environment and devote themselves entirely to their own existence.

Thus, we have discovered a completely organic relationship between the animal and the landscape it inhabits. The animal seeks as an appropriate habitat an environment similar in form to whatever system is functionally predominant within its own organism. The seal, in the rhythmic pulsation of the waves that surround it, experiences what rules within its own body as the pulsation of its circulating blood (Plate 113). The wild cat lives in the 'lung space' of the landscape, the mouse on its sensory layer. Thus, the animal's form expresses what is basic in its relationships with its surroundings. It accepts the landscape as a huge supplementary 'organism,' without which its own body would be incomplete.

Thus we learn, by the way in which the animals are incorporated into their specific environments, that the different landscapes are by no means empty 'places of habitation' but are themselves imbued with biological value. We might even suggest, therefore, that the different landscapes of the earth be taken together as the representatives of a single, vast organism.

We cannot help wondering whether the present pollution and destruction of the biosphere is not a result of our ignorance of the living organization of geographic space. If we define life merely as a complex arrangement of proteins and nucleic acids, we blind ourselves to the idea of life as a functional system in general, and in so doing are unable to stop the vast exploitation of our environment. We must learn to understand that our world is itself a living entity, worthy of respect, and that methods of agriculture, forestry, and industry must adapt themselves to fit the environment's basic requirements.

XII The Soul Life of Animals

At every stage of its life the animal leads a physical, a living, and an emotional existence. Since we have seen already, in their physical forms and chronological life processes, the threefold differentiation of many mammals, we may expect to find similar differences in the configurations of their emotional lives, or souls.

Let us take as a starting point the remarkable correlation that exists between the embryo and its membranes. The rodent hastily forms a highly differentiated placenta and a relatively simple body. The ungulate's body is more highly developed than the rodent's, but its placentation is comparatively simple. The rodent's accelerated development is especially apparent in the early embryonic stages, the time of membrane formation. The fetal membranes develop very quickly and indeed are excessively formed. (The amnion, for example, begins to form even before an intra-embryonic endoderm is present [Starck, 1959].) As a result, the rodent has not developed fully by the time it is born, and even as an adult it remains comparatively underdeveloped. The ungulate's development, on the other hand, is retarded, allowing it to retain the epithelio-chorial placenta, the earliest and simplest placental form. Consequently, an intensive formation of the embryo can take place. It is this physical overdevelopment that leads to the almost adult appearance of the precocial young at birth. The developmental energy of the rodent embryo remains stuck, as it were, in the membranes, so that these and not the embryo are over-formed. In the ungulates these formative processes are transferred almost entirely to the body of the embryo, so that the membranes remain structurally under-developed. The rodent embryo lives more actively in the environment provided by its membranes than it does in its own developing body.

What takes place physically in the embryo before birth lives on in the soul condition of the adult animal. Because of its extreme sensory activity, the rodent continues to live more in the environment than in its own small body. This animal is always more or less 'beside itself.' Whatever goes on around it is experienced intensively by the animal's soul, while its body remains unimportant, small, insignificant. How inadequately this animal seems to manage in its far too hastily formed body! An insatiable quest for food, constantly interrupted by terrified flight, fills its days. Frequent naps are required because of this constant nervous strain; yet these are of extremely short duration, and even in sleep shudders of excitement pass over the tiny, sleeping form. A rodent lives almost reluctantly, in a state of constant fear. In man, such a condition would be considered pathological and could take the form of an aversion to life, fear of death, agoraphobia, or deep pessimism; yet it is perfectly normal in the rodents. Many people fear mice. Their aversion may well be connected with the fact that in these animals they find mirrored the exaggerated vulnerability of their own nerve-sense processes.

Biologists have long recognized that the rodents constantly need to be touching something, whether under, over or next to their bodies, and seem to feel brief satisfaction when they can press close against the runway walls of their burrows (Plate 174). Perhaps they seek such outer coverings because their own bodies are insufficiently insulated. This urge to touch is nothing less than agoraphobic. It may be difficult for us to understand such a state with our ordinary consciousness, but the psychiatrist and his patient know of conditions of the soul that point in a similar direction. It is extraordinarily difficult for some people to cross an open space alone, since their highly penetrable sense system fails to protect them adequately from the outside world. They are in such close contact with the outside world, as conveyed to them through their senses, that they are in danger of being overwhelmed by the variety and intensity of their sense impressions. Small wonder that such people feel inadequately protected by their own bodies! The rodent lives perpetually with such phobias; they invade its life even more than they do that of human beings who suffer from agoraphobia, for the animal has no choice but to identify with its bodily constitution.

During gestation, as we have said, the metabolically dominated ungulate focuses its activity less on the formation of embryonic membranes than on the development of the embryo itself. Quite consistently, therefore, the soul activity of the adult animal is more deeply involved with the processes of its own internal organs than with the world outside. The cow gazes out upon the world as though through a veil of mist. What a sense of peace and contentment emanates from the cud-chewing ungulate, as it devotes itself entirely to the enjoyment of life! By its very nature the ungulate is a perennial optimist, even to its physiology. It could otherwise never be satisfied with its almost indigestible food. Such an animal is so self-sufficient that its emotional activity can be completely absorbed in the life of its own body. Much of the ungulate's soul life—despite its undoubted intensity and power—does not appear at the surface, because it is too much involved in the processes of digestion and growth to establish any close relationship with the outer world.

For the metabolic animal, then, the body itself is a self-contained world; while for the sense-oriented animal, the environment serves as an additional body. In *Faust, Part II*, Goethe gives imaginative expression to these one-sided conditions of the souls of animals.

Fear

Lamps and lights and torches smoking
Through this turmoil gleam around;
'Midst these faces, shamming, joking,
I, alas, in chains am bound.

Hence, ye throngs absurdly merry!
I mistrust your grins with right;
Every single adversary
Presses nearer in this night.

Friend turned foe would here betray me,
But his mask I know well. Stay,
Yonder's one who wished to slay me;
Now revealed, he slinks away.

Through the wide world I would wander,
Following every path that led,
But destruction threatens yonder,
Holds me fast 'twixt gloom and dread.

Hope

Hail beloved sisters, hail!
Though today and yesterday,
Ye have loved this masker's play,
Yet tomorrow ye'll unveil.
This I know of you quite surely.
If beneath the torches flaring
We can't find our special pleasure,
Yet in days of cheerful leisure,
As our will doth bid us purely,
Now in groups, now singly faring,
We'll roam over lovely leas,
Resting, doing, as we please;
In a life no cares assailing,
Naught forgoing, never failing.
Everywhere as welcome guest
Let us enter, calm in mind,
Confident that we shall find
Somewhere, certainly, the best.

Translated by
George Madison Priest

The rodent is too superficially, the ungulate, quite deeply, connected with its own body. The connection between soul life and physical organization is quite tenuous in animals open to the world. Because this bond has been established quickly and incompletely, it is easily broken once again. The metabolically oriented animal, on the other hand, develops an intimate connection between soul capacities and physical body. The body is fully developed and fully enjoyed—and therefore given up with great difficulty. The carnivore's organization, however, arises out of a unique congruence of body and soul. Its soul is neither bound too closely with the body, nor connected too little with it; the bond between the two is neither too strong nor too weak, but finds visible expression in the carnivore's powerful form and striking coloration. In the carnivores, the two ways of being coexist in a state of balanced tension, which finds expression in the many different forms of the various species.

In seeking to understand the emotional life of the animals in such a carefully differentiated way, we also gain our first real insight into the processes of animal death. What does the soul of an animal experience at death? We propose that these experiences are as diverse as the physical constitutions of the various animal species. An animal deeply tied to its own body dies with much greater difficulty than one closely connected with the outside world.

With startling directness Steiner once described what occurs, for example, between predator and prey. Between cat and mouse, according to Steiner, a surprising relationship exists. Death, he said, comes to the mouse as a welcome release from a life filled with fear. An actual feeling of well-being accompanies its separation from the inadequate body to which it has felt chained. And the cat, when it plays for a while with the half-dead mouse, actually prolongs for the 'victim' this enjoyment of death[46]! A more radical departure from all generally accepted views of the 'cruelty of nature,' the 'struggle for existence,' and so forth can scarcely be imagined. Yet such ideas, because of their emotional content, are really anthropomorphisms. For the cat, unlike the kind of human being who would act out of conscious cruelty, is incapable of enjoying its victim's fear. When we free ourselves from emotional cliches and begin to view nature in an unbiased way, the truth becomes apparent to us: the cat and mouse complement one another, not only physiologically, but even on a psychological, or soul, level. Each bestows a benefit upon the other. The cat satisfies its urge to hunt and its hunger, and the mouse is permitted to die.

The ways of dying we have found to be characteristic of many rodents are not only in complete accord with this idea, but are even clarified by it for the first time. We are now able to develop a sense for what actually occurs in the mass death of the voles, the migrations of lemmings, and the relationship between predator and prey. An animal closely bound to the environment fulfills its biological role both physically *and* psychologically by serving as the principal source of food for the higher animals. During its lifetime such an animal's soul is completely taken up in its perceptions of the outside world, so that in death its body also merges easily with its surroundings. The carnivore receives as nourishment the body of an animal that gladly surrenders its life.

A metabolic animal, on the other hand, dies not only with reluctance, but with extreme difficulty. For the ungulate, the physical organism is the most important aspect of life, and it therefore parts with its body reluctantly. Its death marks the end of a fruitful and enjoyable life. The ungulate shuns death; the nerve-sense animal actually seeks it.

Opposite worlds are thus represented by the rodents and the ungulates. In the carnivore's nature these two poles of animal existence are brought together in a state of tension. It is this inner battle of forces that makes the carnivore so aggressive in the outer world. In aggressive conflict it is equally prepared to accept either life or death.

Rodent	*Carnivore*	*Ungulate*
Lives unwillingly Dies gladly	Accepts equally the possibility of life or death	Lives gladly Dies unwillingly

Strictly speaking, of course, the emotional attitudes we have ascribed to the three mammal groups, as well as the organic systems that form the basis of these attitudes, are found in every animal. Whether rodent, carnivore, or ungulate, every animal has a nerve-sense system, a respiratory-circulatory system, and a metabolic-limb system. In the nerve-sense system of any animal, there exists a tendency toward death. Since nervous tissue cannot be regenerated, cell division does not take place here, and insufficient supply of food or oxygen can be endured for only a short time before the nervous system begins to suffer irreparable damage. The nerve-sense system therefore requires regular periods of freedom from soul functions. In sleep it participates in the regenerative bodily processes that enable it to function once again when the animal wakes. The waking state is physiologically possible only to the extent that life processes are cut off in the nerve-sense system.

In the metabolic system, the organism is completely engaged in the world of matter, which it transforms intensively but unconsciously, in order to maintain physical life. Even the completely unconscious metabolic processes lead to incarnation, or a closer connection between soul and body. All nerve-sense processes excarnate the soul of an animal; all metabolic processes incarnate it.

We may therefore propose an even more precise differentiation: even a rodent, since it has metabolic processes, may try to preserve its life and to avoid death. It cannot be denied that the urge for self-preservation comes upon a rodent when it flees an enemy. Even an ungulate, on the other hand, may experience such a profound shock when attacked by a carnivore that its soul excarnates immediately, despite the fact that its body has not yet died. The sudden shock of the carnivore's attack may simply be too much for any animal's soul life, which is bound in all cases to the sense organization; and the animal may give up all resistance. In many cases, however, an aggressive response similar to that of the carnivores may occur, since every animal possesses a middle system, which tends to assert itself in time of danger. All three modes of behavior may therefore be observed in all animals.

In most cases, however, the behavior basic to the animal's own organization prevails. Sense oriented animals tend to show fear of a struggle and submissiveness towards death. Animals with a dominant rhythmic constitution usually attack. Metabolic animals avoid disturbance whenever possible and seek to enjoy their own well-being.

Let us return now to a detailed consideration of the ungulates. In the tropics these animals often serve as prey for the large cats. Yet even here the usual victims are the sense oriented members of this group: the antelopes and the deer! The favorite prey of the lion is the zebra; of the tiger, the sensitive Indian deer; of the leopard, the gazelle and monkey; and of the jaguar, the capybara, a rodent (Plates 171 and 172).

But even when a large, deeply incarnated ungulate is killed by a carnivore, its death is not in fact accompanied by the terrible pain we humans usually ascribe to it. William Joseph Long, an accurate and subtle observer of animals, has written that

> ... the victims of the carnivores do not experience pain. The terrifying attack of a predator causes a kind of shock paralysis or stupor, which makes the animals insensitive to injury. Mice, squirrels, rabbits, woodcocks, deer and other wild creatures I have observed as they fell prey to their natural enemies, showed, with few exceptions, an amazing indifference. Apparently they did not realize what was happening to them (1924).

Grzimek (1959) has made a similar observation:

> It happens quite frequently that an apparently dead animal runs away unharmed if the lion is driven off. Recently, one of four lionesses was forced to give up a zebra foal, and the little animal ran away neighing loudly—a happy zebra child. A few weeks later the same thing happened, before Myles Turner's eyes, to a Thomson gazelle. Just as a lion cub becomes entirely motionless and does not struggle when its mother takes its neck and head between her teeth and carries it around, it is probably inborn in many animals hunted by lions to become instinctively calm when they are seized. ... I even believe that these animals experience neither pain nor terror in the jaws of the lion. In fact, I could almost say I *know* it.

At the turn of the century John Hirst collected all available accounts of people who had survived attacks by large carnivores. He described sixty-six such cases, but only two persons reported that they had experienced pain during the attack[47]. The best known case is that of David Livingstone, the great African explorer, who was once attacked by a lion. He later gave the following account of the incident:

> Growling horribly close to my ear he shook me as a terrier dog does a rat. The shock produced a stupor similar to that which seems to be felt by a mouse after the first shake of the cat. It caused a sort of dreaminess, in which there was no sense of pain nor feeling of terror, though I was quite conscious of all that was happening. It was like what patients partially under the influence of chloroform describe, who see all the operation, but feel not the knife. This singular condition was not the result of any mental process. The shake annihilated fear, and allowed no sense of horror even at the sight of the beast.

At the next moment Livingstone's companions drove off the lion.

This trancelike state, in which one is fully conscious and yet experiences no pain and is powerless to react, is caused by the fact that the nervous system, because of the excessive demands suddenly made upon it, simply loses contact with the sense impressions. Physicians see this condition frequently in cases of severe brain concussion. The patients, after returning to normal consciousness, report that they saw and heard everything that went on around them; yet they could make nothing of these sense impressions. Such exceptional cases help us to understand that animals serving as prey—even the ungulates, despite their vitality—normally experience death in a painless state of shock.

When a young carnivore first kills, however, it is still clumsy and inexperienced, and the animal attacked may well suffer a painful death

(Guggisberg). We must touch upon even this rather minor aspect of the problem of animal death, for only a balanced, objective understanding of this problem in all its aspects will enable us to gain a correct attitude toward the animals. Otherwise, we would be forced to vacillate once again between 'heartlessly cold' concepts and sentimental feelings.

What is pain? Every human being is acquainted with it. And yet, for obvious reasons, we are not generally aware of the fact that it is experienced in three distinct stages. The first is the body's immediate reaction to injury, the physiological trauma, the actual physical experience. This takes place on a virtually unconscious level and is therefore easily overlooked. Like every sense perception, it is soon transferred to the psychological plane, and the normal bodily sensation of pain sets in. This conscious experience of pain, however, need not always take place. If the soul's attention is distracted (as a physician usually tries to do for his patient when severe pain is present), only discomfort remains. As in the shock condition described above, the soul cannot grasp the impressions conveyed to it by the senses. It is certainly true that pain of this kind, which is experienced by the soul, exists in the higher animals, insofar as distractions or conditions of shock fail to intervene (Hediger). Man alone, however, knows yet a third form of pain, which is best —if indeed rather inadequately—described as 'grief.' If pain encompasses more than the body's automatic reaction to an injury, grief is certainly far deeper than the soul's experience of pain.

> It is simply not possible for us to grieve on command. For grief is a feeling that enables us to accomplish a definite purpose: Through grief we slowly overcome pain. . . . The gradual ebbing away of grief, the acceptance of the loss, is the normal course of this feeling (Mitscherlich).

The animal is well acquainted with the psychological experience of pain but does not know the deepening of pain to individual grief. And this is certainly connected with the fact that an animal never rebels as an individual against its fate. The question, "Why me?" is known only to man. Even when an animal suffers a painful death we should try to avoid anthropomorphizing its experience through our sympathy, for the comparison between man and animal must encompass far more than mere sentimentality.

A human being is not only 'Man'; he is also a physical being and therefore bears the world of matter within him. He lives and grows and thus shares certain qualities with the plants; and his emotional, or soul, life connects him with the animals. Only the fourth part of his nature, in which his soul participates in the world of spirit, forms his purely human essence. All the realms of nature are present within man and in him they coexist harmoniously. In man, therefore, we can observe in microcosm how the kingdoms of nature are related to form a whole outside man. Our method allows us to find in man the basic example from which to understand the interrelationships of the outside world, and at the same time it prevents us from lapsing into the narrow perspective of any single point of view. On the one hand, man is the only being in nature who can stand apart and perceive the natural world. On the other hand, however, since he bears within him all the kingdoms of nature in fitting relation with one another, he is himself the model from which nature can be understood. Man is not only the thinking organ of the world, but, viewed objectively, he is also the alphabet through which we learn to read the world's language.

For example, the nourishing substances taken in by the human organism are reduced to the finest possible consistency; all crystallization is avoided, and these substances are distributed throughout the body in a manner completely independent of gravity. Ultimately these substances are brought into a condition in which they can contribute to the life of the organism. The tendency characteristic of inanimate nature, to reach a state of physical and chemical equilibrium, is constantly arrested. Solids are transformed into unstable, ever changing, labile liquids. Life consists in holding in abeyance the purely inorganic condition, without, however, suppressing it entirely. Yet neither are the life processes allowed free rein in the human organism. If this were so, man would never progress beyond a state of deep sleep. When he is awake, his soul processes, aided by the nerve-sense system, actually suppress these vital forces. Soul activity can take place only when life processes as such have first been partly destroyed (Fortlage). Yet the soul must not destroy these upbuilding processes utterly—therefore it must retire at regular intervals during the time of sleep. In the waking state, however, the soul's activity subdues the growth forces of the organism.

Still another step is possible for man. His impulses, desires, sense perceptions, emotions, and other instinctive reactions to the outer world may all be repressed if he becomes spiritually productive. A sound spiritual development never seeks to eradicate such reactions entirely but only to bring them into moderation and order. Such self-development, however painful it may be to the emotional side of man, serves to liberate his most human faculties; physical body, life, soul and spirit are able to work together in balance only when each lower level partly recedes to make way for the next higher one. Each successive stage is attained only through the partial destruction of what precedes and supports it.

What takes place within the microcosm of man appears in unindividualized form throughout the whole of nature. Only when the inanimate stone has lost its mineral form through erosion and crumbled into viable earth can it be transformed into living plant substance. The animal kingdom, in turn, continually brings partial destruction to the plants, which would otherwise choke the landscapes of the earth. (This process is assisted by the activity of non-green plants, such as fungi, and particularly bacteria.) These processes of decay enable the animals, as representatives of the soul life on earth, to exist. And when an animal dies, the totality of the earth benefits, for some of the drives, emotions and desires existing in its realm have been overcome. This is true even in a spiritual sense, for the process taking place here is similar to that which occurs in man when he strengthens his ego to gain control over his emotions. And according to Steiner, the animal itself experiences something of egohood, which man does whenever he is awake, only at the moment of its death[48].

From this point of view, death in nature takes on a new meaning. The deaths of plants, of animals, and of man must be strictly differentiated (Steiner, 1912). In undisturbed nature the death of a plant is a necessary process, similar to what takes place in the body of a man when he wakes from sleep: living substance is sacrificed for the sake of soul activity. Rudolf Steiner stated as a fact of supersensible experience that a feeling of well-being comes over the earth when a field of grain is mowed or when a cow is grazing[49]. The death of an animal, even if painful, is also a natural process, necessary for the whole earth. What man knows as an individual and must himself strive to accomplish, and what for him, too, is associated with great pain of soul—namely self-discipline and the control of instinctual desires—is brought about inevitably and involuntarily in the animal world, through the actions of the carnivores. Here the process takes place in an unindividualized way, bound to the body and its instincts. Thus, even the painful death of an animal has a spiritual meaning for the world as a whole, a meaning far deeper than could be fathomed through conventional theories of natural selection.

In this way we discover for the first time our real relationship with the animals that surround us. We need not regard the death of an animal with cold indifference, because we are beginning to understand what takes place in the animal's soul life. On the other hand, we are able to avoid the sentimentality that attributes to the single animal a human individuality. The individual animal can be replaced by another of its kind, but the individual man cannot. But neither can one animal species be replaced by another. Each species is as unique as an individual man. The death of a single animal is merely the end of an unindividualized, replaceable portion of a species. Only the loss of an entire species is comparable to the death of a single man. Not the killing of a single animal, then, but the destruction of an entire species, is murder.

The truth of what is expressed here as idea is felt by many contemporary biologists. The world-wide concern for the protection of nature is a definite sign of this feeling. It is not the individual animal that must be protected but the entire species; this can never be replaced. The single animal must be carefully preserved if the numbers of its species decline; yet it must be killed if its numbers grow too large. Nature is protected when a healthy balance is maintained among all indigenous plants and animals within designated environments. In America, for example, the bison, saved at the last moment, now dwells secure in national parks established for its preservation. In Sweden, on the other hand, there are too many moose; at present, 30,000 must be shot each year. Such a procedure is morally justifiable because the yearly increase in population exceeds this number. Nevertheless, it would be more effective simply to end the persecution of the large carnivores, since these would regulate the growth of the moose population in a natural way. The only group on earth whose every individual must receive unstinted help is man. Among human beings no life is 'unworthy,' for man's destiny, unlike the animal's, is individual, and not determined by his membership in a biological species.

The death of an individual animal is often painful to us. It is the destruction of an entire species, however, that should fill us with sorrow and weigh heavily upon our consciences. Protection of nature is of the greatest importance, since it is only within the *whole* of nature that each animal and plant can become what it is meant to be.

XIII Some Additional Groups of Mammals

Let us now consider some mammalian groups far different from those already discussed. Rodents, carnivores and ungulates are indigenous to the Northern Hemisphere. Although members of these groups are found south of the equator, paleontology and zoogeography have shown that these species moved down from the north in ancient times. Remarkably different from these are the animals indigenous to the Southern Hemisphere, those found in South America, South Africa, and Australia. There we meet the egg-laying monotremes, the marsupials, pangolins, and armadillos, the sloths, anteaters, and aardvarks. Underlying these southern animals are other, to us strangely alien, formative processes, which upon closer investigation prove similar to those active in reptiles and birds (which also show extraordinary diversity in the Southern Hemisphere). A consideration of these animals would go beyond the scope of this book; we shall, however, refer briefly to a third group of mammals, which stands between the specifically northern and specifically southern groups. These are the insectivores, primates and hares (including the rabbits and pikas); as well as the dassies, sea cows and elephants.

Insectivores found in Europe are the shrews, moles and hedgehogs. These are all strongly sense oriented, small mammals. The tiniest forms actually resemble mice, though they certainly are not rodents. At a glance a shrew may be distinguished from a mouse, since the shrew has a long, pointed, mobile snout, fringed with whiskers. Unmistakable, too, are its steady, rapid, yet surprisingly supple movements. Like most of the rodents, the insectivores give birth to blind, naked, altricial young; only the whiskers, and, in the hedgehogs, a few soft quills, 3 millimeters (or about 1/8 inch) in length, protrude from the skin. The elephant shrews of Africa, transitional forms between the genuine shrews and the tree shrews (closely related to the lemurs), however, are precocial. The litters of insectivores are large: the European mole may give birth to as many as 10 young, and the common tenrec of Madagascar, up to 32 (the largest litter size of any mammal). The placenta of European species becomes hemo-chorial and discoidal after completing an early diffuse stage.

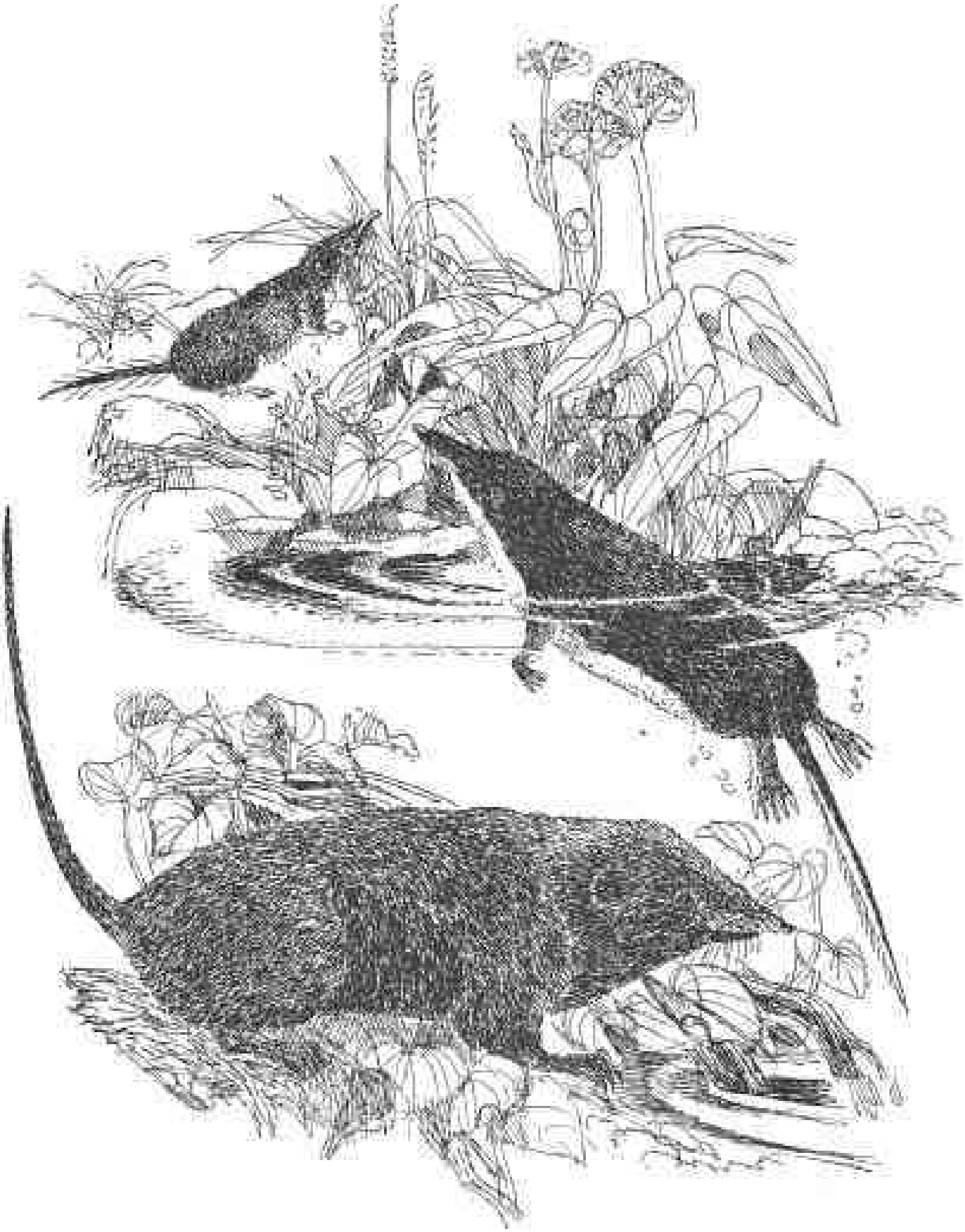
The insectivores, then, are a group strongly influenced by the sense system. It is for this reason that their formative characteristics are so similar to those of the rodents.

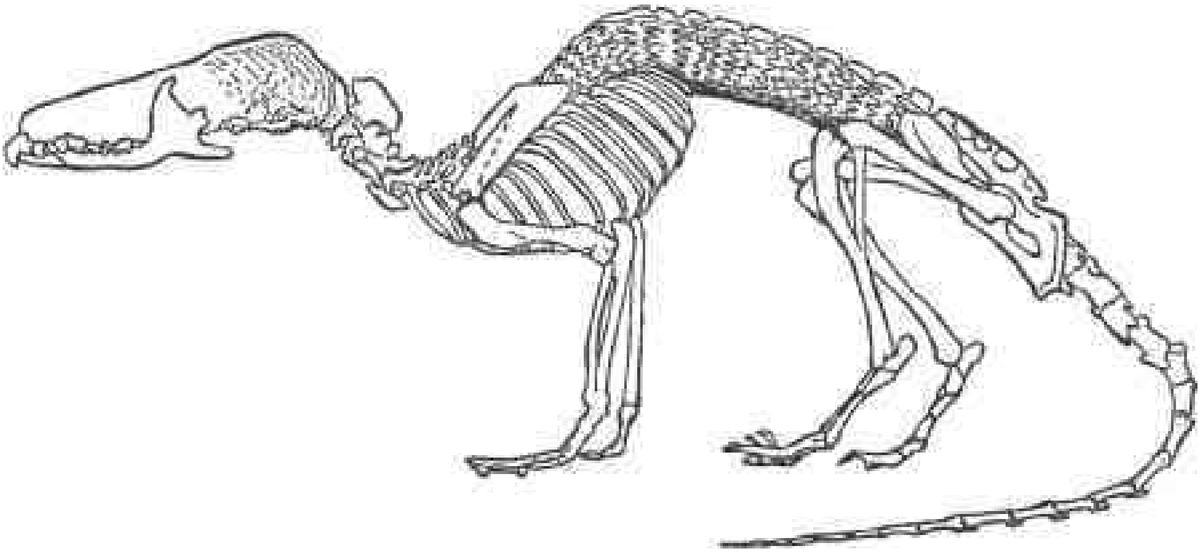
The shrews are the most obviously one-sided members of this group. Their coloration is generally dark above and light below. A typical member of this group is the European bicolored shrew. Sensory hairs, especially long at the root of its snout (Plate 175), are found over its entire body, even on its otherwise almost naked tail. It constantly seeks to establish physical contact between its entire body and the leaves and stones beneath which it finds shelter. Such fearful behavior so pervades the shrew's nature that the young, on their first outings, hold fast to one another with their teeth. The first in line grasps the mother's tail, and in this way the entire little caravan scurries and leaps together over the ground, without easily becoming separated (Plate 176). Thus we find in this animal as well as in the rodents, behavior similar to that of an agoraphobic human being, who is able to cross the largest open space so long as he holds a companion by the hand; yet his legs would give way beneath him were he to attempt to cross it alone (see Chapter XII). The shrew's hold on life is so tenuous that a severe fright is enough to cause the animal's death (Grzimek); the physiological cause of death in this case is the sudden disruption of the animal's hormonal balance. The shrew's pulse rate is 500 to 1320 beats per minute (Grauwiler); thus it lives with a constantly racing heart.

Closely related to the bicolored shrew are the white-toothed and lesser white-toothed shrews. All three species belong to the genus *Crocidura,* which, with 144 different species, is the largest mammal genus on earth. Another group of white-toothed shrews, the genus *Suncus*, which is often regarded merely as a subgenus of *Crocidura*, includes the smallest living mammal, the Etruscan shrew. The geographical area inhabited by this animal extends from the Mediterranean to Southeast Asia. Without its tail it measures less than 4 centimeters (or about 1 1/2 inches) and weighs only 2 grams! Because all the animals mentioned above have white teeth, they are often referred to simply as the 'white-toothed shrews.' Their group forms a subfamily of the shrews and includes 181 different species—an unusually large number.

Somewhat less extreme are the 'red-toothed shrews.' This subfamily is composed of 82 species, which are generally larger than members of the white-toothed group. Their short-haired tails lack the long, stiff hairs found on the tails of white-toothed shrews. As the name suggests, the tips of these animals' teeth are covered with reddish enamel. Two genera are indigenous to Europe: the common shrews *(Sorex)* and the water shrews *(Neomys).* The former (represented by the pygmy, common and Alpine shrews) prefer wooded areas and mountains; the latter (represented by the Miller's water shrew and the water shrew, the largest member of this group) have taken up an aquatic way of life, seeking even their food in the water. In this subfamily we find a definite strengthening of the rhythmic constitution.

89. *From the top down,* Etruscan shrew, water shrew, and armored shrew (each 1/1.3 X).

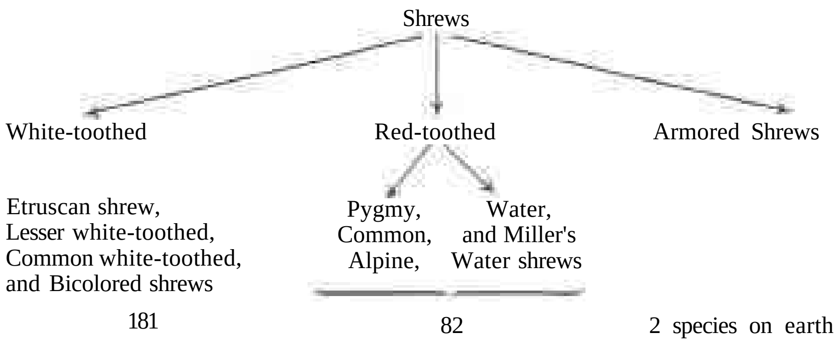




90. Skeleton of the armored shrew (natural size; Kingdon).

A third group, which includes only two species, is represented by the remarkable armored shrews of central Africa. These are relatively large animals (up to about 10 inches, or 25 centimeters in length), powerfully built; and their spinal column is so strong and protects the internal organs so well that it can support a man's weight. When the animal is released it runs away unharmed (Grzimek, 1967). The vertebrae, with their elongated bony processes, show a degree of ossification normally found only in the skull. These animals may therefore be considered the shrews most independent of the environment.

A survey of the total number of species on earth reveals the ordered relationships that prevail within this animal group:

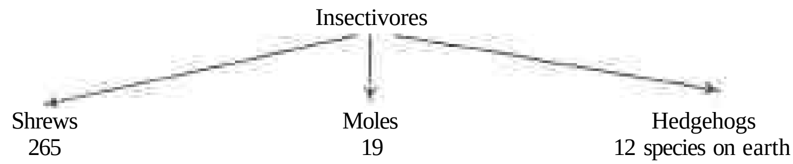


We turn now to the mole family. In Europe these animals occupy a central position between the shrews and the hedgehogs. Just as the voles, as central members of the mouse group, retreat from the surface of the earth, many mole species turn to burrowing as a way of life. Like the water vole, the European mole not only digs, but even swims quite well; this fact is little known since all we usually see of a mole is its mole hill. Some large, non-European species, such as the South Russian and Pyrenean desmans, are definitely aquatic. With tireless strength these muscular athletes of the mole family swim and dig through their domain, devouring every tiny creature they can find.

The hedgehog is the largest of the European insectivores. Its powerful metabolism enables it to eat not only insects and small animals, but even vegetable matter, such as fruit. Less violent and impulsive than the shrew, it ambles along in the dark of night, using its keen sense of smell to search for tasty morsels. Careful observation reveals the beginnings of a head pattern (Plate 91) that becomes quite pronounced in Eastern European species. The hedgehog has the most powerful metabolism of any insectivore. Evidence of this is its spiny coat of quills. We have already found quills on the most metabolic of the rodents, the porcupine. Evidently, then, the transformation of hair to thick, horny quills occurs in primarily sense oriented species that have secondarily closed themselves off from the surrounding world. The strengthening of metabolism necessitates the formation of horny substance to keep these powerful metabolic forces dammed up within the animal. This unusual formation is thus explained by the basic organization of the hedgehog itself.

Another example of this phenomenon is found among the rodents, in the spiny mouse of North Africa and the Middle East (in Europe this animal is found only on Crete). A long-tailed mouse, it is a member of the most sense oriented group of mice; yet its metabolism is so strong that it not only endures hunger and thirst better than any of its close relatives (van den Brink), but it even gives birth to precocial young (Dieterlein). The formation of quills is quite consistent with such an organization. The Australian spiny anteater and even such a distant species as the sea urchin among the echinoderms may also be understood in this way. Thus we may formulate the following rule: *When a species belonging to a group that is primarily open to the environment closes itself off from the surrounding world, it tends to develop quills*. The hedgehog provides the classic example of this tendency. Its entire mode of being contrasts utterly with that of the shrews. The latter flee from even the slightest disturbance; any leaf or stone to hide under affords them a feeling of security. The hedgehog, on the other hand, does not run from danger but rolls up into a ball and finds protection within its own body. Within its own relatively large body it finds its physiological and psychological centers. The outer world it rejects by forming quills on the surface of its body.

There are only twelve species of hedgehogs and nineteen of moles. The European insectivores, then, have a genuinely threefold relationship.

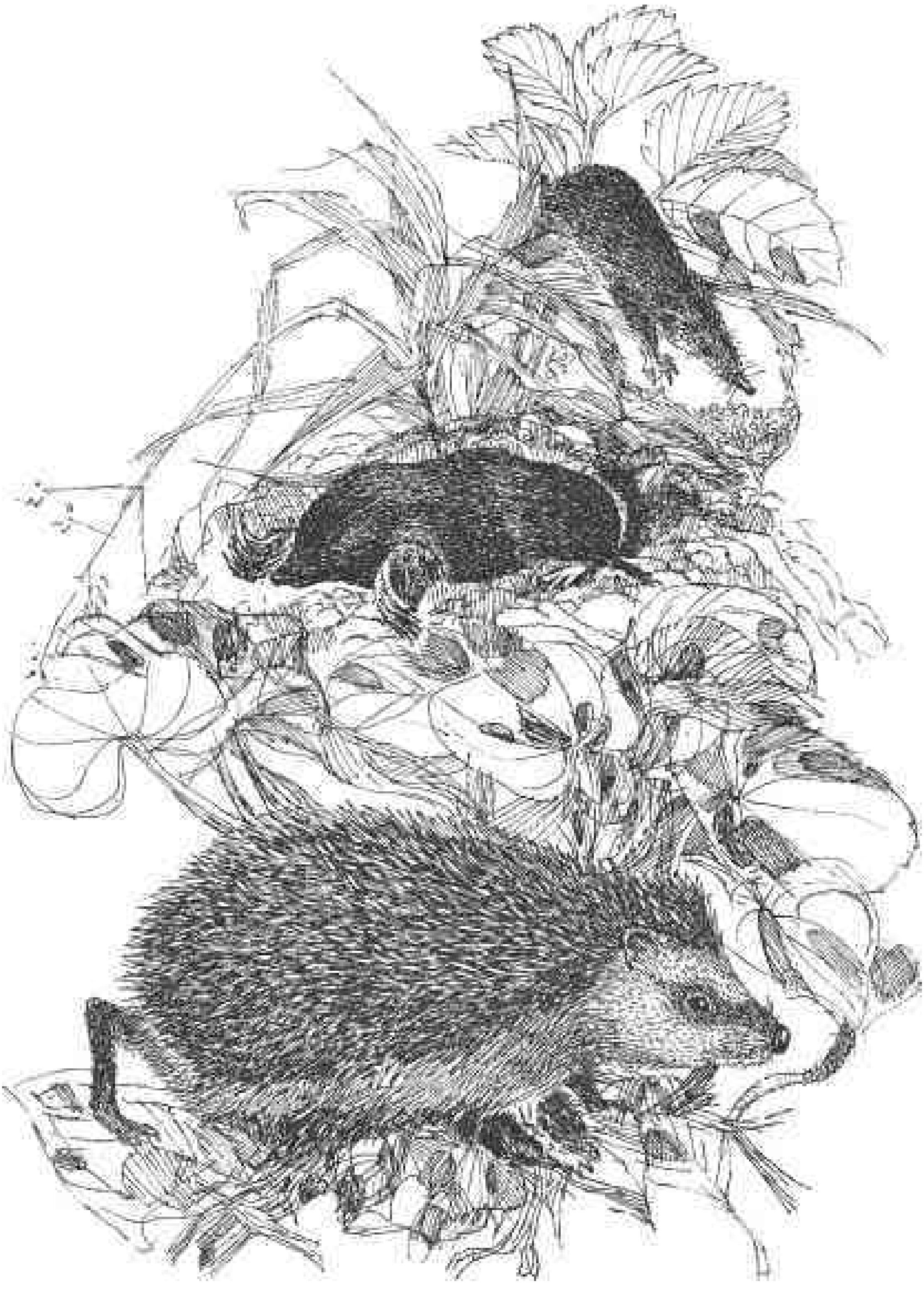


This threefold relationship is also apparent in the insectivores' dentition, which includes all three kinds of teeth and is therefore relatively uniform in structure. Still, characteristic differences may be observed. The shrews, for example, have remarkably long, ridged first incisors, which—although they do not equal the rodents' gnawing teeth—still dominate the entire dentition. The moles and desmans, in contrast with the shrews and hedgehogs, have elongated upper canines, and these, oddly enough, have two roots (as do the tiny canines of the hedgehogs). In the mole's lower jaw the elongated milk canine is replaced by a very small permanent one resembling an incisor; both its form and function, however, have been assumed by the first premolar, which is even located in the appropriate position in the jaw. As we might expect, the hedgehog's broadened molars dominate the rest of its teeth.

Periodic increases in population similar to those occurring among the mice have also been observed among the shrews. Here, too, the population expands through a general increase both in litter size and frequency of births. Unique to the shrews, however, particularly the white-toothed species, is the fact that not only the population as a whole, but even the individual animal increases in size; within a few generations its length doubles and its weight increases fivefold (Sanderson). When the population increase has come to an end, individual size also declines—an example of the connection between size and biological conditions.

As their name suggests, the insectivores eat primarily animal food, in contrast with the rodents. These tiny predators help regulate the population of the small animal world, just as the carnivores do among the higher animals. Any surplus among the tiny creatures, such as earth worms, snails, and slugs; all kinds of insects, including beetles and their larvae, caterpillars, grubs and so forth; small fishes, newts, and tadpoles, is devoured by the insectivores. Without the shrews and moles, the relationship between plant and animal worlds could easily become unbalanced. The more abundant the insectivores are, the healthier the landscape they inhabit. Each day these animals consume at least their own weight, and frequently twice as much and more. They rarely sleep, for their gnawing hunger soon wakes them (only the hedgehog hibernates!). When food is scarce they eat their own young or even the weaker adults of their own species, for the shrews in particular can easily starve to death within a few hours.

91. European insectivores. *From the top down,* bicolored shrew, mole, and hedgehog (1/1.5 X, 1/2.5 X, 1/2.5 X).

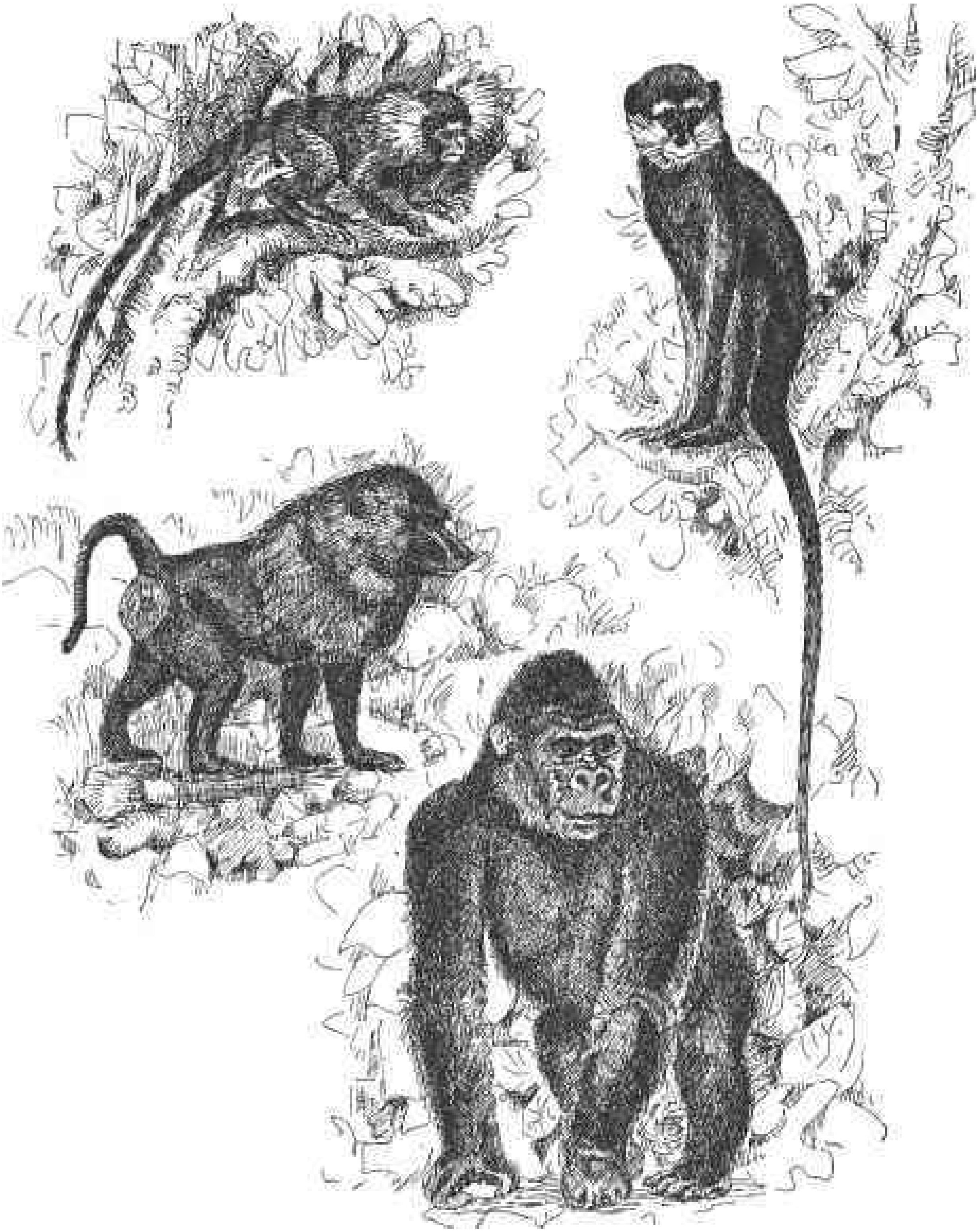


What can we learn from all this? It is remarkable that such sense-active animals have so many traits in common with the carnivores. The clear-cut divisions we have found among the higher mammal groups appear to be lacking among the insectivores. Rather it is the *intertwining* of nerve-sense and rhythmic processes that characterizes these animals. Their overall physical form is certainly not divided into the three bodily regions so distinct in the higher animals. In the ungulates, for example, any outgrowths are located at the body's anterior pole; in the rodents, particularly the porcupines, they appear at its posterior pole. Yet the hedgehog's horny growth of quills covers the surfaces of head and body alike; no clear center of organization has developed within this animal. The teeth, as we have mentioned, are similarly undifferentiated in form. All three types are present and stand small and pointed next to one another, with only slight differences in form and without gaps between them. The insectivores, then, are even more undifferentiated and primitive in form than the rodents are. Today they are regarded as the most primitive of placental mammals. Outside Europe they are found in great variety and number, distributed over almost every continent in the world.

In the first chapter we mentioned that the animals most closely related to this primitive group are the primates. Among the latter the rhythmic organization has gained dominance, though not so thoroughly as it has in the carnivores. In these animals, too, however, the canines dominate the other teeth, and at least the small species have turned to an arboreal way of life. The platyrrhine ('flat-nosed') monkeys of the New World are generally graceful, rather sensitive forms, often scarcely larger than squirrels, while the catarrhine ('narrow-nosed') monkeys of the Old World are more rhythmic in orientation. Thus the long-tailed guenons are cat-like, while the baboons resemble dogs. The largest and most metabolic forms are the anthropoid apes; the males of the Asian orangutans, and, to an even greater extent, of the African gorillas, are gigantic animals weighing several hundred pounds. Typical flat-nosed monkeys tend to eat insect food, rich in protein, while the central, narrow-nosed species prefer a mixed diet that includes fruit; the anthropoid apes, particularly the gorillas, are completely herbivorous, feeding chiefly upon leaves. In comparison with these animals, in whom metabolic activity is accentuated, man's organism appears to stress the limbs. None of the apes could compete with a trained runner in a long-distance race.

Together, then, the insectivores and apes, linked by the tree shrews, form a single group of related animals. As members of this group they preserve many primitive characteristics and therefore their three organic systems have only

92. The marmoset, *above left*, of South America, is only as large as a squirrel (1/7 X). The guenon, *above right* (1/8 X), baboon, *below left* (1/12 X), and the gorilla, weighing over 500 pounds (1/16 X), all live in Africa.



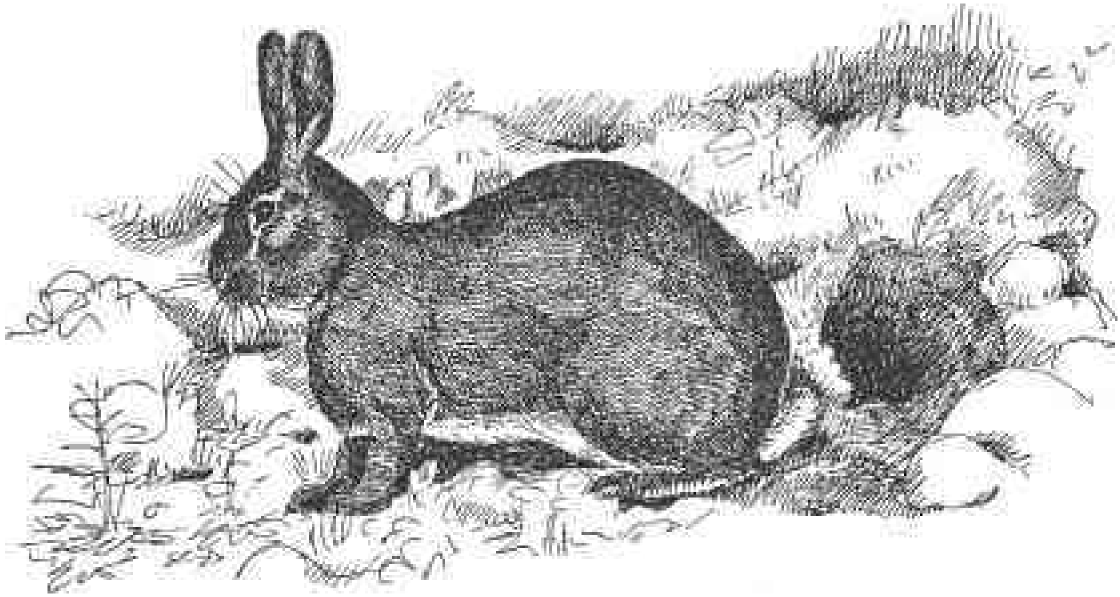
begun to differentiate. They have not achieved a threefold differentiation so complete as that of the rodents, carnivores and ungulates.

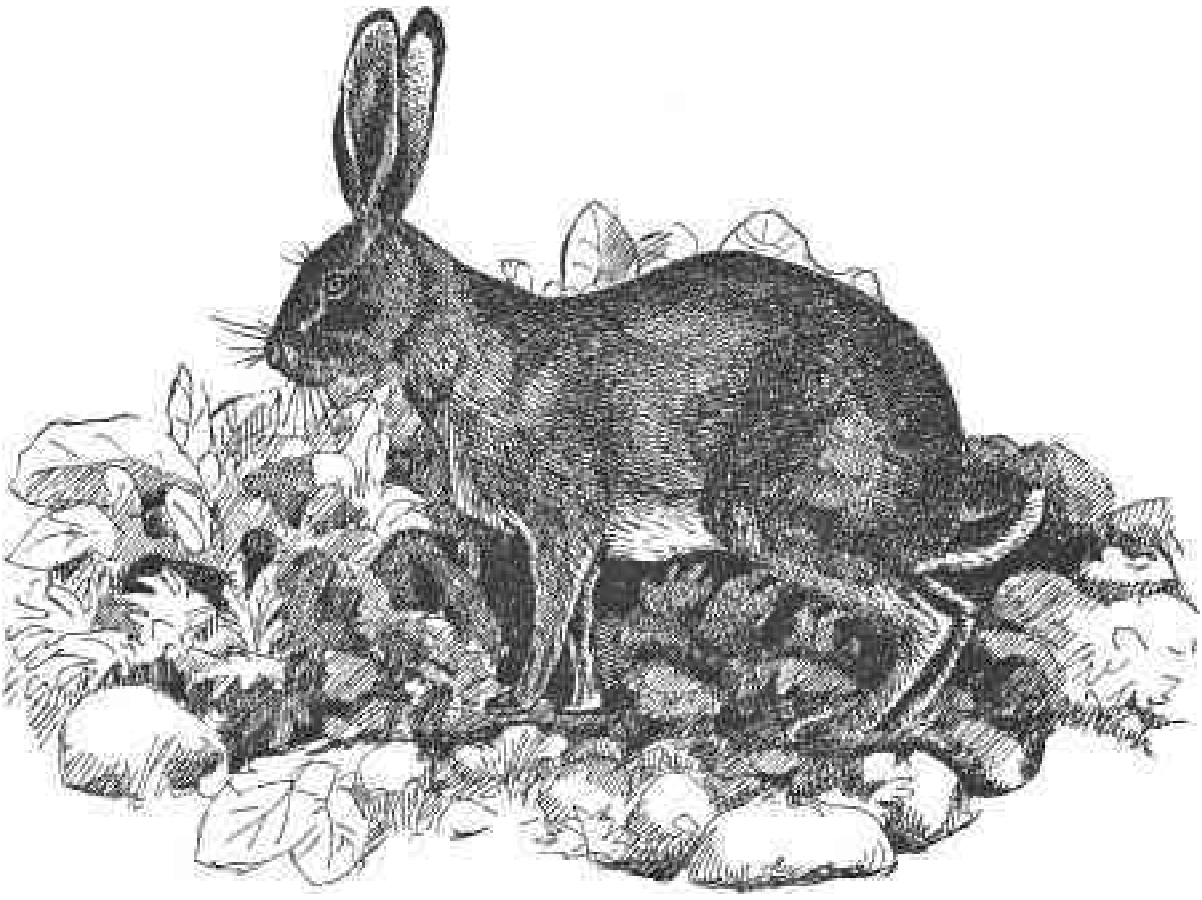
The hares and rabbits also show a 'mixed' organization. They are closely related to the rodents, whose diet, life habits, and dentition are similar to theirs. In coloration, too, the hares and rabbits show the dark dorsal and light ventral sides typical of sense oriented animals. They are too large to belong to the sense oriented rodent groups, yet they lack the ungainly figure and inverted coloration typical of the metabolically oriented rodents. And, despite their sensitivity and quick reactions, the hares and rabbits seem to be much stronger creatures, more closely connected with the body, than rodents inhabiting the same geographical area. Even their bodily posture is more expressive than the genuine rodents'.

Let us consider the teeth of these animals. The dentition, with its elongated incisors, missing canines, and rootless molars, is similar to that of the rodents; yet there is a very important distinction between the two. Directly behind the two large upper incisors stands a second pair, small and pointed. The actual number of incisors is therefore greater in these animals than in the genuine rodents. Nevertheless, the sense processes do not seem to emerge in such a one-sided manner as they do in the rodents. The enamel covering the first incisors is not confined to their front surfaces alone, as is the case in the genuine rodents, but surrounds each tooth completely. Thus, the teeth of these animals are actually less specialized in form than those of the rodents. If we consider the structure of the hare's teeth to be 'archetypal,' we may make the following statement: The hare's nerve-sense system is not completely dominant, but is held in check by the metabolic-limb system. That the bones of the head are quite porous is undoubtedly connected with this fact. The skull cap itself has not ossified to form the typical hard, thick capsule. Because of these characteristics, as well as several others, the hares and rabbits are no longer classified as rodents, but are regarded as a distinct group, closely related to them (Gidley).

The brown hare is the only member of this group truly indigenous to middle Europe. The wild rabbit was introduced, during the Middle Ages, from northern Spain. These two species are so similar that they lend themselves well to comparison. Smaller than the hare, the wild rabbit has a grey dorsal side and lacks the hare's disproportionately long ears and hind legs. The hare has long, powerful hind legs that enable it to make long jumps; its dorsal side is brown. Its ears, edged with brilliant black, are so long that they reach, when bent forward, beyond the tip of the snout. In both animals the underside of the tail as well as the rump is white, so that the upturned tail flashes visibly. These slight differences indicate that the rabbit is the more sensitive member of this group, while the hare is the more metabolic. The

93. *Above*, the wild rabbit, *below*, the larger brown hare (each 1/5 X).

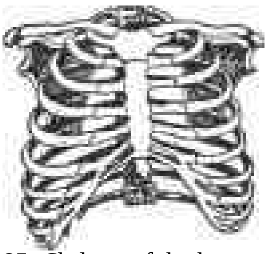




94. Newborn rabbit, *left*, and brown hare (natural size).

rabbit therefore finds it necessary to dig deep burrows, while the hare is able to live freely in the open landscape, trusting to its ability to flee from danger. The hare also swims more readily than the rabbit does (Brehm), while the latter occasionally climbs trees (van den Brink), an accomplishment that has never been observed in the hares. The conditions of these animals at birth are also consistent with their differing constitutions; the rabbits are completely altricial, while the hares are born with functioning sense organs and a full coat of hair. The basic difference between these two animals is further demonstrated by the fact that the hare, like the ungulates, lacks clavicles, while the rabbit, like almost all rodents, has them.

What is the meaning of the clavicles, or collarbone? In reviewing the form of the human skeleton, we recall that the greatest degree of ossification is found near the center of the nerve-sense system, in the head. The brain is completely encapsulated, as is the spinal cord. In the body's central region the formation of the vertebrae begins to show a rhythmic sequence, a sequence that is most clearly manifested in the formation of the ribs. The abdominal cavity, as the center of the metabolic system, has almost no bony protection. In the limb area the enclosing character of the cranial bones is completely reversed: the bones of the arms and legs form part of the internal skeleton, which is hollow and surrounded with soft tissue. The basic contrast between these bones extends even to their development. The hollow bones develop first as cartilage; next to the cartilage the bony tissue itself develops, gradually replacing the cartilaginous skeleton. These bones are therefore called 'replacement bones.' The flat, plate-like bones of the cranium, on the other hand, develop without any preliminary formation of cartilage. They are called 'membrane bones', since they develop out of the subcutaneous layer.



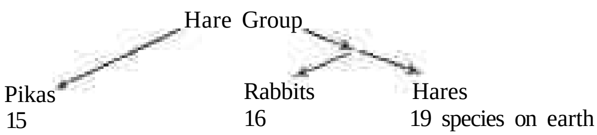
95. Skeleton of the human chest, showing the placement and function of the clavicles.

In the central area of the skeleton, the rib cage, in its rhythmic alternation of bone and intercostal space, gives spatial expression to the time rhythm shown by lungs and heart in their alternation between expansion and contraction. The chest's mediation between the poles of the body is also expressed in the difference between its own upper and lower portions. Within its own form it recapitulates the two extremes. For example, close examination reveals that no two of man's twelve pairs of ribs are exactly alike. By means of their cartilaginous ends the seven upper pairs of ribs are attached to the sternum; the five lower pairs are not attached in this way and become successively shorter. Above, the rib cage approaches the enclosing form of the skull, since the ribs are quite close to one another; below, it widens and reduces its degree of ossification, thus accomplishing a gradual transition to the soft abdominal cavity. The shape of the middle region is determined equally by the tendency of the head to form bones and that of the metabolic center to avoid their formation. The influence of the head system is so strong in the upper region of the chest that in addition to the plate-like shoulder blades in back and the upper part of the sternum in front, yet another pair of bones, the clavicles, appears. These are the only membrane bones outside the head! In them the upper middle region recapitulates the formative tendencies of the head; in man these bones are the first to become ossified (Starck, 1955).

In direct contrast, the diaphragm, at the lower end of the rib cage, is a muscular organ; here the rhythmic system takes part in the activity of the limbs. Above, the chest organization is as still as possible; below, it is highly mobile. The central region of the rib cage mediates between the two extremes. The collarbone thus forms the 'head region' of the chest. These bones are present in all higher vertebrates dominated by the nerve-sense system. Thus, insectivores and rodents, with the understandable exception of some members of the porcupine group (such as the guinea pigs, carpinchos, and porcupines), have these bones. Among the carnivores only the cats and some members of the raccoon family (such as the kinkajou) possess clavicles, and even these are incompletely formed. In dogs, seals, whales and ungulates, these bones are entirely lacking; in some species tendonous ligaments are found in their place[50].

Thus the accentuation of the nerve-sense system on the one hand and of the metabolic-limb system on the other affect even the formation of the rib cage. In the one case clavicles are present; in the other they are not. This tendency also holds true for the rabbits and hares. Thus, in the presence or absence of this one bone, the constitutional differences between these two animals are given morphological expression.

Another member of this group is the tiny pika of southern Eurasia and North America. This animal is even more strongly influenced by the sense system than the rabbit is. Its clavicles are well developed, and its young are precocial. Strangely enough, however, this highly sense oriented little animal has differentiated into slightly fewer species than the hare.



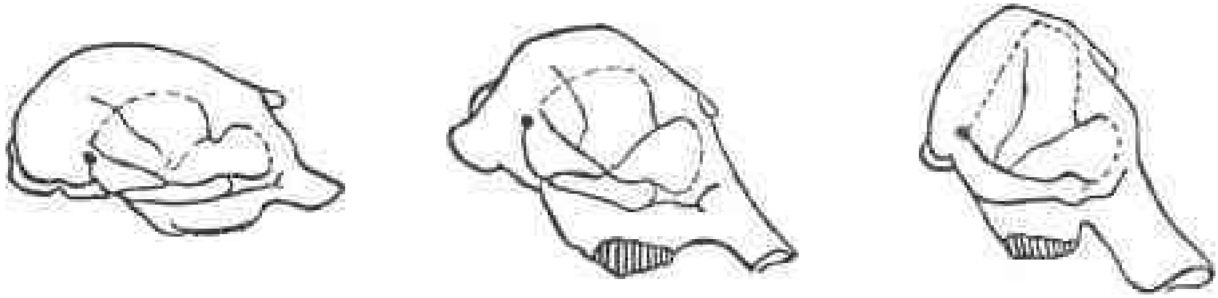
The organization of the elephants is of extraordinary interest for our threefold evaluation. These animals are closely related to the ungulates, yet they cannot be regarded as members of this group; for these largest and heaviest of all terrestrial mammals have too many characteristics that distinguish them from the genuine ungulates. Although they, too, have hoof-like, thickened nails, they do not walk on these, but on the thick, cushioned soles of their feet. Together with two other animal groups they are therefore called penungulates. The digits of both fore and hind limbs have remained short and more primitive in form than the elongated, highly specialized extremities of the genuine ungulates. The elephants retain all five toes, and the Indian elephant even has five hooves on each front foot. Near the trunk of the body the limb bones, in a development similar to that taking place in man, are slightly elongated; yet near the ends of the limbs the damming processes are so strong that fingers and toes have fused to form the elephant's 'club foot.' With an odd swaying motion that involves the entire body and invests even its massive form with a certain grace and suppleness, this animal moves through African savannahs and south Asian jungles. Only two species exist today: the Indian and African elephants (Plate 181). At the end of the Ice Age, however, man hunted the woolly mammoth, which wandered then in enormous herds across Europe and Asia.

The elephant, like all the largest mammals, is herbivorous and consumes vast quantities of leaves, twigs and even branches, thus feeding mainly upon cellulose. Can it therefore be considered a purely metabolic animal? Its large molars would seem to support this supposition. Yet the elephant is certainly no ruminant. Not its stomach, but its enlarged cecum (see page 126) serves as a fermentation chamber. As the cellulose ferments excessive quantities of gas result, and the excrement itself is discharged in the form of hard, dry pellets. Only forty percent of its food is fully digested (Benedict). Is the elephant, then, a gigantic nerve-sense animal? Its enormous tusks might suggest that it is, since these are really incisors that continue to grow throughout the animal's life! In the African elephant these tusks may attain a length of about 10 feet (or 3 meters). Yet these tusks develop from the lateral, second incisors, not the median, first ones. (Presumably it is the third pair of incisors that has developed in the unique case of the four-tusked specimen shown in Plate 180.)

But how did the elephant's incomparably long proboscis, its trunk, come into being? In order to understand this development we must first consider the universal form of the head, as seen in man. The head, as we recall, is the center of the nerve-sense system; yet, in slightly altered form, it also recapitulates the body as a whole. Opposite the rigid cranium, the head's lower jaw is limb-like in its mobility. Here, the head is covered with soft tissue, and through the mouth it is even connected with the metabolic organization. For digestion, through the action of the salivary glands, actually begins in the mouth. The larynx lies beneath the head, but is still protected by the lower jaw, and, as the upper part of the trachea, with the rhythmic system as well. In the region of the head, this organ recapitulates the reproductive system and therefore changes during puberty. Between the cranium and the region of the mouth, lower jaw and larynx, lies the middle, or respiratory area of the head, formed by the nose itself, the nasal passages, and the pneumatic cavities of the head, including those found in the upper jaw and middle ear, and in the sphenoid and frontal bones.

This threefold form of the head appears in perfect balance in the countenance of man. His forehead is influenced solely by the nervous system, the middle region of his face is dominated by the nose, and the form of his mouth and chin is determined by metabolic-limb processes. When we turn to the mammals, however, we find that this harmony is disturbed by the exaggerated development of the jaws. The snout greatly exceeds the cranium in size, so that no true forehead can develop. And even the nose alone can dominate a mammal's face. In such a case the nose lengthens to form any one of the various kinds of trunks. These trunks appear in most insectivores (especially in the desmans and elephant shrews), in the hooded seals and sea elephants, and among the ungulates in the tapirs, pigs, and, to a lesser extent, in the moose, saiga and chiru. All of these animals show the secondary influence of the rhythmic system. The most extreme development of the trunk and air-filled cavities of the head is found in the elephant, whose high-domed forehead is filled not with a highly developed brain, but with enormous pneumatic cavities. Is the elephant's general organization therefore dominated by the rhythmic system? The rib cage, with its increased number of ribs (twenty pairs), extending over the entire length of the trunk, even to the pelvis, definitely shows the influence of this system. In addition, the elephant's placenta, like that of the carnivores, is hemo-chorial and zonary! Yet it lacks any trace of canine teeth.

What are we to make of all this? A threefold analysis of the elephant's organization breaks down in the face of this animal's extraordinarily complex interweaving of the three organic systems. In its complexity the elephant's organization approaches that of man. In man the balanced interpenetration of the three organic systems serves as the instrument of his human personality; in the elephant a similar condition prevails, but in a preliminary, non-individualized form. The elephant is like an 'old Adam' of the ancient mammalian world, living on into our time. Its organization therefore shows many similarities with that of man. We have already mentioned the damming process active in the periphery of its limbs. The elephant, unlike any other mammal, does not use its mouth to pick up food, but uses its trunk instead to bring food and water to its mouth. The trunk serves as arm and hand; its tip can even be used like fingers, to pick up small objects. The elephant always holds its head well above the ground. It, like man, takes food directly into its mouth only as an infant, when it suckles at the breast of its mother (whose mammary glands, unlike those of most other

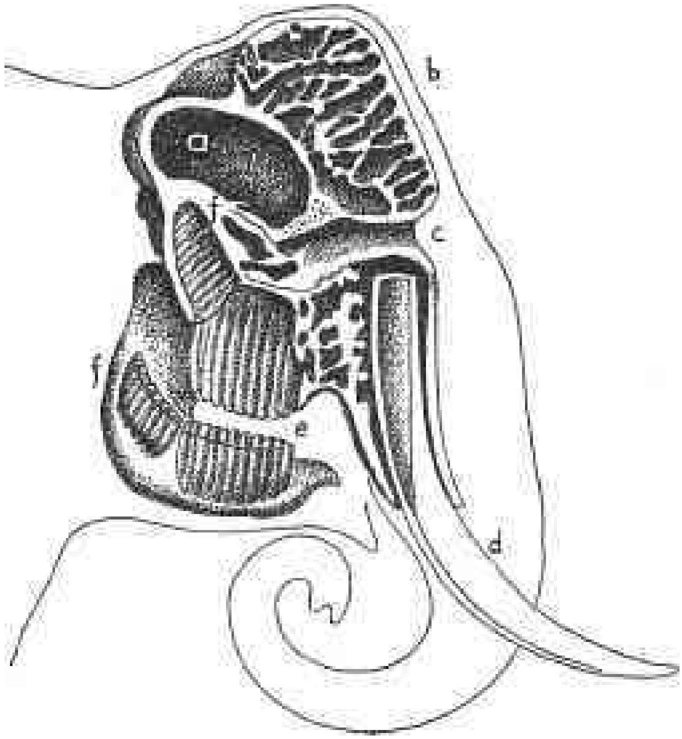


96. The skull of the elephant becomes increasingly vertical as the animal matures. *From left*, infant, half grown, and adult African elephant tuskers (after Kingdon).

mammals, are located on the chest). In later life, however, the whole jaw area ceases to function as an organ of grasping and recedes beneath the skull; we cannot speak, therefore, of the elephant's 'snout.' Large pneumatic cavities add height to the forehead; the profile of the elephant's face becomes increasingly vertical as the elephant grows older, thus gradually approaching the upright countenance of man. Sexual maturity is reached between the ages of twelve and fifteen years (in captivity at eight or nine years), and reproduction usually begins to take place when the animal is about twenty or thirty years old. The span of its life is also comparable to man's.

Of particular interest, however, is the elephant's change of teeth. This animal is born with a set of milk teeth, consisting of two upper incisors and two pairs of upper and lower grinders. After the first year, the change of teeth begins with the shedding of the incisors. During the second year these are replaced by permanent incisors, which continue to grow throughout the animal's life. But how does an herbivore manage to chew with only one pair of grinders in each half of its jaw? It is able to do so because each of these grinders is enormously enlarged and has dozens of cross ridges, so that each tooth may measure from 12-16 inches (30-40 centimeters) across. As each grinder wears down it is shed and replaced by a new, completely formed one that has developed in the back of the jaw. When the new tooth has been ground down to its roots, it, too, is replaced by another, and so forth. Throughout its life, then, the elephant is constantly changing teeth. Not only the region of the incisors, but even that of the grinders is active in forming teeth throughout the animal's lifetime, though in the latter case one tooth follows another.

Each mammal, in contrast with the lower vertebrates, normally has only two sets of teeth, the milk and permanent teeth. In its succession of molars does the elephant grow more than the two sets of teeth ordinarily possessed by a mammal? No, it does not; comparative research on the elephant's prehistoric ancestors has revealed that the first three grinders to be replaced are actually premolars from the set of milk teeth (Weber). Only the next



97. Elephant skull in cross section (after von Zittel and Weber): a) cranial cavity, b) pneumatic cavities in the frontal bone, c) nasal passage, d) incisor elongated to form tusk, e) molars, f) developing molar.

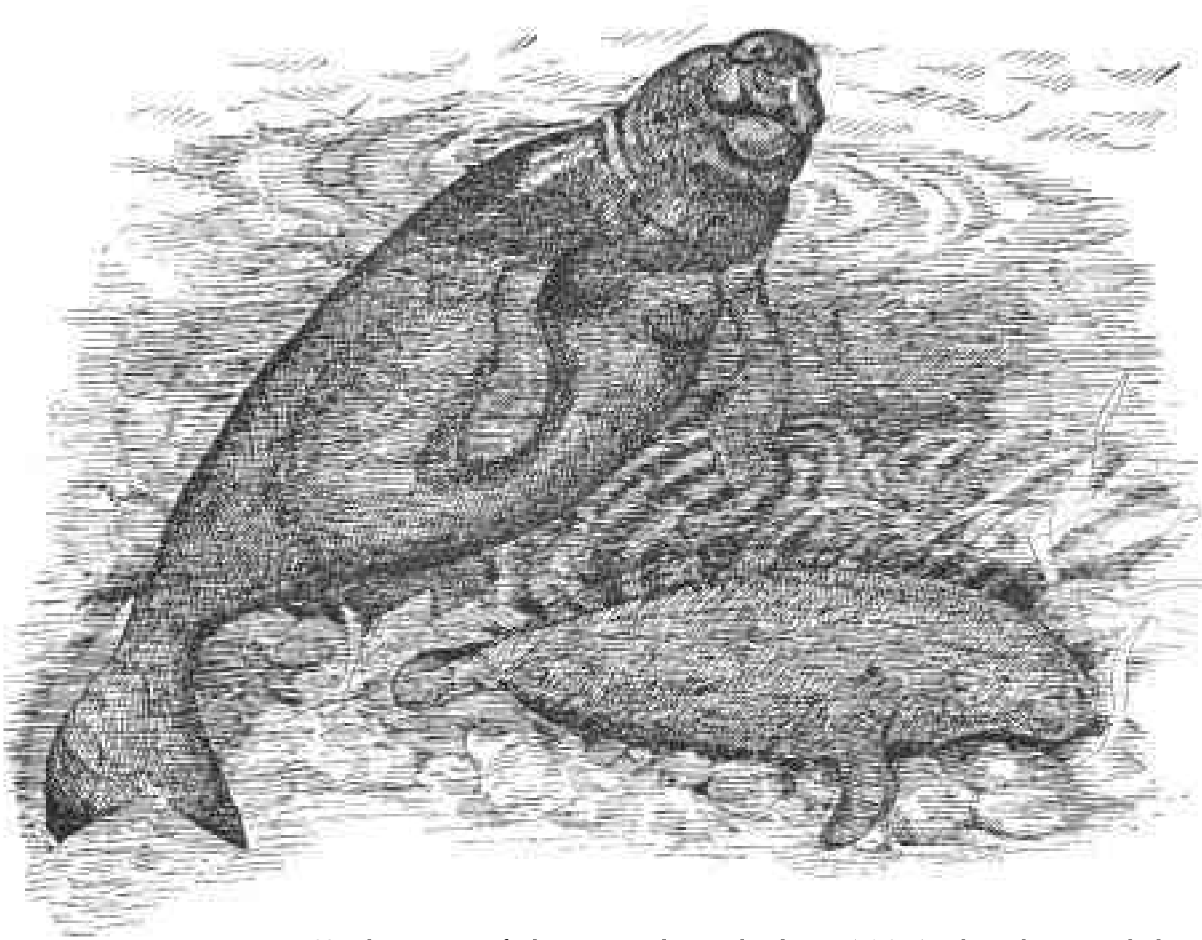
three are genuine permanent molars. Permanent premolars still appeared in the prehistoric mastodon, but these are lacking in modern species. So in the course of its lifetime, the modern elephant may grow as many as six pairs of grinders in each half of the jaws (three pairs of premolars and three pairs of molars). After the sixth pair has been shed, however, no replacements can be formed. The animal is then unable to chew its food and eventually must starve to death. Since each tooth lasts for an average of about ten years, elephants generally live to be about sixty or seventy years of age.

In most mammals the change of teeth takes place either shortly before or shortly after birth. In man this process begins only in the sixth or seventh year and lasts until the fourteenth (although the last molar, the wisdom tooth, may grow at any time up to the age of thirty). Rudolf Steiner has pointed out that the change of teeth is a sign of the child's growing capacity for intellectual learning. And the elephant? Constantly 'teething,' it is able to learn throughout the greater part of its life. An adult wild mammal usually cannot be tamed, but the Indian elephant can still be trained for work at the age of forty (Gerlach). Thus the elephant remains at the level of a 'school child' during most of its life.

In the tropics there is a second group of animals, closely related to the elephants, and having an ongoing change of teeth similar to theirs; these are the sea cows (sirenians). They are completely aquatic, and their hind legs have become as stunted as those of the whales. Neither whales nor seals, they are genuine herbivores and feed on seaweed at the sea coast or on water plants along the banks of great rivers. Four species are recognized today:

The African manatee	Coasts and rivers of tropical West Africa
The American manatee	Coasts and rivers of the tropical eastern Americas
The dugong	Coasts of the Indian Ocean
The Steller's sea cow	Off the Behring and Copper Islands of the northern Pacific (extinct as of 1768).

These medium-sized, good-natured animals venture neither onto the high seas nor upon land. As they graze in small herds along ocean bays or the lower



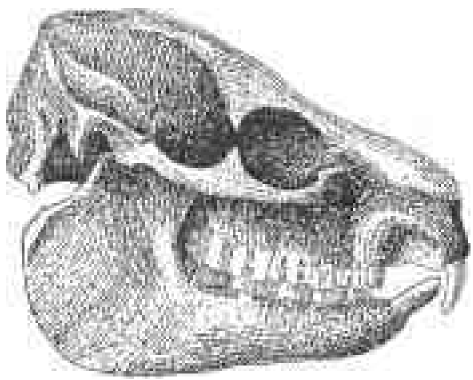
98. The sea cows feed on water plants. The dugong (1/20 X), *above*, has a notched tail, while the West African manatee, *below*, has a rounded one (1/30 X).

courses of great rivers, they periodically rise to the surface for air. Although they are not ruminants, they have a four-chambered stomach, which, along with the small cecum, serves to ferment cellulose. The dugong's placenta is at first diffuse and later zonary. With the exception of this animal, which has in its upper jaw a pair of small tusks similar to those of the elephants, the sea cows lack incisors in the permanent set of teeth. Canines are lacking in the permanent teeth of all species, but they are sometimes present in the embryo's milk teeth. The grinder teeth are replaced according to a sequence similar to that of the elephants; as each molar wears down it is shed and replaced from behind. As each new tooth moves forward its socket is displaced, so that the bone in front of the tooth is continuously dissolved, while new bony substance is built up from behind. Throughout the animal's life the teeth and bones of the jaw are continually formed anew. We suggest, therefore, that the sea cows possess a life-long capacity to learn, though I have been unable as yet to discover any evidence to that effect. The grinders are of course not so oversized as those of the elephants and are therefore more numerous; as many as six may be present simultaneously in each half of the jaw. In the manatees, in fact, the number of molars is limitless; the tooth-forming tissue remains active until the animal's death. Tooth after tooth is worn away, discarded, and replaced. What these aquatic animals express chronologically in the sequential replacement of teeth is given spatial expression by the dolphins, and, in a preliminary way, by the seals, in their increased number of teeth (see page 58). The additional finger bones typical of the toothed whales (see page 63-64) are occasionally found in the sea cows as well (Mohr, 1957). Many aquatic animals have an increased number of teeth; this phenomenon is not limited to any single group.

The hyraxes, or dassies, make up a third group of animals, closely related to the elephants. These animals are no larger than rabbits, and the name 'cony,' by which they are designated in the Old Testament,* is actually an Old English word meaning 'rabbit' (Romer). Even today the northernmost species of this group lives in the mountains of Syria and Israel. In small family colonies, members of this group play like marmots among the rocks and immediately disappear into hidden crevices when disturbed (rock dassies). Distributed over Arabia and the entire continent of Africa, these animals inhabit deserts, plains, bush country and forests. Zoologists distinguish three genera and eight species within this group. The external appearance of these remarkable animals would seem to indicate that they should be classified with the rodents rather than the elephants. Yet they share far too many characteristics with the sea cows and elephants to permit such a classification: the large number of ribs (about 20 pairs); the location of the milk glands, on the chest; the placenta, which is at first diffuse and later zonary and cotyledonary; the unusually long gestation

* Proverbs: 30, 26; Psalm 104:18

99. The dassies, though smaller than the hares, are closely related to the elephant (1/8 X).



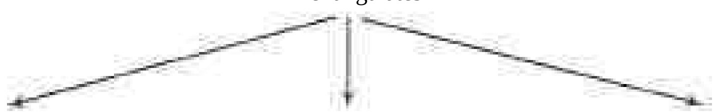
100. In the skull of the dassie the elongated incisors are quite conspicuous (1/2.5 X; after Weber).

period (225 days in so small an animal!); the precocial young; and the absence of clavicles.

The original home common to all three groups is Africa. Even today the dassies are restricted almost entirely to Africa, while the sea cows have spread from the African coasts throughout the oceans adjacent to this continent. In addition, the earliest prehistoric ancestor of the proboscidians (the moeritherium) lived in what is now Egypt during the early Eocene epoch; only later did the proboscidians spread from Africa to all continents except Australia; on the American continent, however, they soon died out.

This penungulate group, composed of the elephants, sea cows and dassies, is quite remarkable. These three families are so dissimilar in shape that their relationship was long unsuspected by taxonomists. The threefold method, however, reveals that they form a single group of their own, in which the dassies are dominated primarily by the senses, the sea cows by the rhythmic system, and the elephants by the metabolism. It is therefore not surprising that the dassies remain quite small and have 'gnawing teeth' similar to those of the rodents. Our method also shows why the sea cows, as rhythmically oriented members of a basically metabolic group, are aquatic animals. And because the elephants form the group most similar to the hoofed animals, they too accentuate the head, by forming huge protuberances such as tusks, trunk, and, in the African elephant, very large ears. Even in their visible forms, then, these three families, despite their obvious differences, represent a single related group. The number of species existing today also supports this conclusion.

Penungulates



Dassies 8 | Sea cows 5 | Elephants 2 species on earth

The penungulates are thus as similar to the genuine ungulates as the hares and rabbits are to the rodents and the primates are to the carnivores. These animals show formative processes similar to those of the rodents, carnivores and ungulates, and yet fail to attain the extreme specializations shown by these three groups. The many primitive, unspecialized characteristics of the penungulates indicate that in them the three organic systems have remained quite closely connected. In his perfectly balanced union of the three systems, we find man's physical organism at the center of these three groups.

Hares and Rabbits — Insectivores, Primates — Penungulates

Man

XIV The Threefoldness of Man

All organisms, including man's, share a common evolutionary development and are therefore related to one another with varying degrees of closeness. This significant idea, which has gained general acceptance since the nineteenth century, is fundamental not only to conventional methods of biology, but also to the Goethean, anthroposophical method presented here (Hemleben). That all organisms stem from common ancestral forms can no longer be held in doubt.

Yet it is still necessary to ask *how* this evolutionary development took place. Did the animals in fact descend from plants, the vertebrates from invertebrates, the mammals from reptiles, and man from the apes? We are accustomed to asking this question in just such a simplistic form. Yet nothing could be more certain than the fact that no modern invertebrate is ancestor to any living vertebrate, and it is equally evident that no mammal existing today has descended from a contemporary lower vertebrate, nor man from any modern ape. These facts are self-evident; yet we still must strive to understand the basic principle underlying them. Man, apes, mammals, and so forth have evolved from common, extinct ancestors. This common ancestry is the basis for the relationships that obviously exist among them.

The sequence of ancestral forms is often presented as a 'genealogical tree,' in which the animals of today represent the peripheral twigs, while fossil forms from earlier geological epochs form the central branches, boughs and trunk. We come closer to reality, however, when we take as the image of evolution not the tree, which puts forth the same leaf form each year, but the annual plant, whose every leaf is different. The seed leaves (cotyledons) of the latter are followed by primary leaves and foliage leaves, the bracts lead to the leaves of the calyx and corolla, and even the filaments and pistil are transformed leaves. The succession of these lateral forms may take place in many small steps or in a few dramatic leaps. And yet, as various as the leaves are in their sequential development, they form together a complete and finished whole, as does each organism during the normal course of its life.

Every leaf thus takes part in two metamorphic processes (Bockemühl, 1967). On the one hand it develops out of a lateral budding of the growing shoot, spreading out, flattening, developing lobes, and finally attaining its finished form. This transformation takes place with perfect continuity. Yet each finished leaf also stands within a second developmental sequence, between the leaves previously formed and those that follow. Particularly in annual plants, these sequential stages of growth are by no means chaotic but follow a strict, living order, described by Goethe (1790) as a "threefold expansion and contraction." At any given moment, however, only a minute segment of this second metamorphosis is visible to us. Obviously, no finished leaf alters its own shape to conform with that of the leaf that follows. It is not the visible, finished leaf that undergoes this second metamorphosis, but the ability of the shoot to develop different forms, as the diverse kinds of finished leaves bear witness. They bring to visible manifestation the evolutionary steps that take place within the tip of the shoot, within the vegetative cone that constantly renews itself. Thus each leaf takes part in both a visibly continuous, quickly finished metamorphosis and one that, to our sight, is discontinuous.

The image of a 'genealogical tree' is therefore hardly appropriate, for in the evolution of organisms we see this second kind of metamorphosis. The same is true of fossilized organisms of earlier geological epochs. Paleontologists have discovered many series of animal species; and the greater the resemblance among the single forms, the more evident their common ancestry. Yet even such tangible evidence as this does not prove that the organisms discovered have actually descended from one another through procreative connections. For in general, each animal represents a completed stage within evolution, just as the single leaf is itself complete within the metamorphosis of the entire plant. Even as each new discovery in the geological strata of the earth brings important evidence for the course of evolution, so, too, we are pleased to find in the blossom of the water lily many intermediary stages between the leaves of the corolla and the filaments. Yet no single leaf has been transformed into another! And it is in this metamorphosis of the plant, discontinuous to our perception, that answers to the riddles of evolution must be found.

All the fossil and contemporary organisms we can observe are related to one another through ancestors that actually existed. We can imagine, however, that these omnipotential forms, like the vegetative cone of the plant, which remains in an embryonic state, could not be preserved as fossils because of their tentative plasticity and lack of firm substance. Yet they must have existed, or there could not be the obvious relationships we now see among their descendants. Such an idea is not without precedent. Schrammen, for example, has already demonstrated that the decisive transitionary stages in the evolution of the Cretaceous period's siliceous sponges must have been of a kind that could not be petrified, else they would have been incapable of carrying out the necessary steps of evolution[51].

But what develops from the formative centers of evolution visible to us today? When the plant ceases to put forth leaves, the formative tissue itself appears—and ends its growth—as fruit. Might this process be taken as an image of evolution's goal? Göbel (1968) has stated that in the fruit, as nowhere else in the plant's metamorphosis, stem and leaf become one. The hitherto hidden formative center, together with all the organisms that have previously developed from it, at last makes its appearance in the evolution of the living world. The *fruit* of the whole evolutionary process is the fossil found last: it is man. Man's ancestors, who, like the vegetative cone of the plant, could not be preserved in all their continuous transformations, are the original form of all the living creatures that have ensued (Tittmann). It was from the ever-developing ancestor of man that the profusion of the kingdoms of nature gradually split off; their fossil and present forms testify indirectly to the course of his evolution. Every newborn mammal, with its relatively rounded forehead and as yet undeveloped snout, suggests such human origins[52].

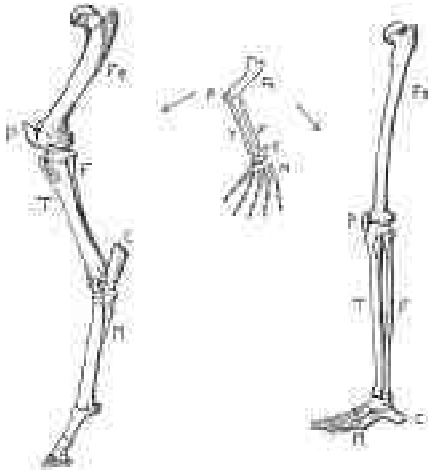
Though this theory of the evolutionary relationship between the animals and man goes beyond conventional ways of thought, it is nevertheless based solely upon developmental phenomena to be seen in the living world. No existing scientific observation contradicts it. Such an interpretation of the events of evolution is certainly unusual, yet it allows us to rediscover the real meaning of the various animals that surround us. It presents an image that grants us insights into stages of man's evolution no longer available to our senses. For on the basis of their degree of relationship to man the animals are divided into the various taxonomic groups (such as classes, orders, families, and so forth). The vertebrates are closest to man, since it is they who received from his ancestor the vertebral form.

The fishes, as we mentioned in Chapter XI, were the first to develop a fully centralized nervous system. The amphibians, in acquiring the lungs as a new organ of breathing, added an inner breathing surface that made it possible for them to live on land. The reptiles' dry skin, reinforced with scales or horny sheaths, has freed them from an aquatic environment. Because their body heat remains constant, the birds have become independent of the outer temperature. In the mammals the entire development of the embryo has been transferred to the interior of the body. In this way the mammals have attained an especially high degree of independence from their surroundings; yet, since their limb system must still adapt to it, even they remain closely bound to the environment.

The final step to be made in this process of emancipation is taken by man's organization, through the special form of his limbs. His hand, in its balanced five-fingered structure, is not limited to any one activity. In this sense, we could say that man's hand is perfected. Yet, biologically speaking, it must be called underdeveloped, for it needs tools in order to compete with abilities the animals naturally possess. Man has no shovel-shaped limbs like those of the mole; he must use a spade. Neither are his hands shaped like paddles, as are those of the seals, but he requires oars. He has no hooves but needs shoes. It is nature that provides the tools necessary for an animal's existence. In this respect most mammals are morphologically superior to man. However, since the human hand has not adapted to any single element or purpose, it is also not limited to one capability: man can use one tool and put it down again so as to take up a second and a third. It is just the imperfection of man's hand that permits him a choice, a choice that no animal can make to the same extent. Man's perfection is his imperfection: he can learn to choose freely what nature has not decided for him. In most cases the animal is permanently tied to the tool its limbs have become and thus remains dependent on a certain environment[53]. The high degree of emancipation achieved by man's limbs is illustrated by his flat, delicate nails, which are of little mechanical use. By contrast, what a diversity of practical tools is shown in animal claws and hooves! It is also significant that man's upper limbs have been relieved of the task of moving the body. A few animals (such as the jerboas, kangaroos, penguins, and the curious King's lizard of Australia) also have upper limbs that need not be used for locomotion; in their case the transformation has never gone so far as to allow the entire spinal column to be held erect.

Even more interesting, however, is the construction of the lower limbs of man, where his organization *is* forced to undertake the function of locomotion, and thus to come to terms with gravity. The lower limbs of man *are* specially adapted: namely, they must adjust themselves fully to the force of gravity. In the animals the necessary adaptive processes always take place in the peripheral parts of the limbs, the parts closest to the environment. Thus the thigh bones and shanks of horses are relatively short, while the metatarsus and toe, and the nail that meets the ground, are powerfully developed, the lateral toes being stunted and serving only to reinforce the central digit. The legs and feet of man adapt in the opposite manner. Here, the peripheral parts of the limbs remain relatively short; all five digits are retained; the foreshortened toes are held back in their development; claws or hooves are totally absent; the toe nails are deeply imbedded in the matrix; and the first toe, in contrast with the thumb on the hand, is closely connected with the sole of the foot. The portions closest to the body, however, are elongated: the femur is the longest bone in the entire body. *In the animals those portions of the limbs nearest the surrounding world are best developed; in man, however, it is just these portions that are held back in their formation, while the weight-bearing parts of the limbs develop out from the area of the trunk.* The stable efficiency of man's legs develops not from the periphery, in adaptation to the demands of the environment, but out of his organism itself. In the animal those portions of the limbs nearest the trunk are withdrawn from the environment, while the peripheral parts join with it in order to perform a specific function. Man's legs grow out towards the environment, while his feet withdraw from it. Short legs and long feet would seem inappropriate for man, not on esthetic grounds alone, but for reasons of real significance.

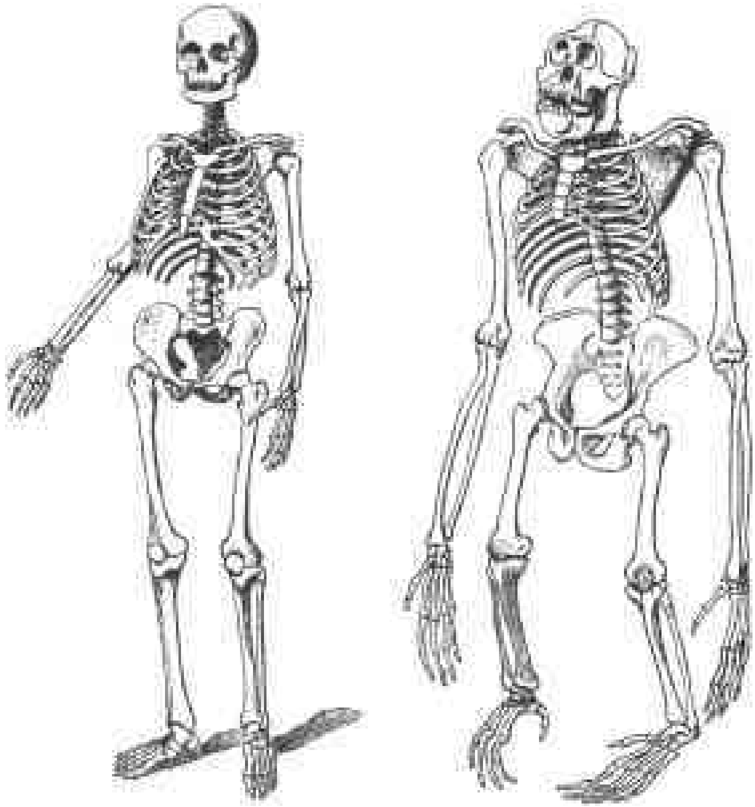
 Man's limbs, because of the damming process active at their periphery, are



101. Skeletal structure of the leg and foot, as found in embryonic form *(center)*, the adult horse *(left)*, and the adult human being *(right)*. Note that those bones nearest the ground have elongated in the horse, while in man those bones nearest the body are longest.
Fe Femur, P Patella, T Tibia, F Fibula, C Calcaneus, M Metatarsus.

freed of any too direct dependence upon the surrounding world. His lower limbs play a special role in this process of emancipation. When we observe the movements of a newborn child, we are amazed by the strength of his mouth. While arms and legs are still incapable of organized, voluntary movement, the jaws, through their own powerful activity, suck the milk that nourishes the growing infant. Suckling is the first 'limb' activity of man. We may therefore assert, with Goethe, that the jaws are the limbs of the head[54]. During the second quarter of his first year the infant gradually gains mastery over his arms and hands; he is able to grasp things. But how many things he still puts into his mouth and grasps with his jaws! Gradually, however, the feet come into their own, developing more and more independent activity, until the capability of coordinated movement has reached even the lower extremities; and the child at the end of his first year can stand and walk unaided. Thus, man's limb activity is gradually transferred from the region of the head, through the arms and hands, to the legs and feet (see also König, 1963).

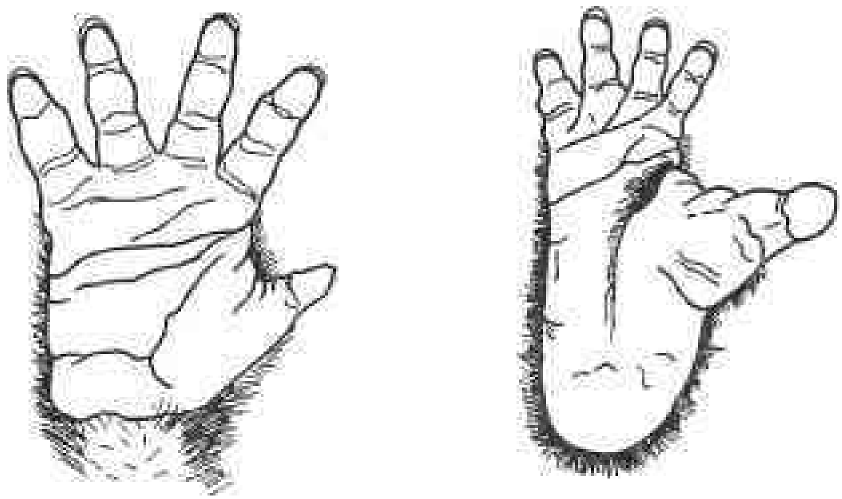
Since the locomotive function has been taken over completely by his legs, man's arms are freed, so that he can manipulate, or handle things. This decisive transformation of the limb function is what determines the special nature of the human body. Man's ability to stand erect and walk is made possible by the fact that his lower limbs have taken over the activity of locomotion, leaving his upper organization free. Since the jaws are liberated early from the function of grasping, their development is held in check, and they may



102. The bone structure of man and that of the gorilla (from Brehm).

then be used in the service of speech (see also Kipp, 1955). Because his arms are relieved in infancy of their locomotive function, they remain unspecialized throughout life and can perform man's infinitely variable deeds in the world. And since his legs, in taking over the function of movement, have nevertheless also withdrawn from the direct influence of the outer world, man has the biological capacity to choose freely the direction of his own steps. Even as early as the Ice Age, man, unlike any of the higher animals, was distributed over every continent on earth. "Never has a higher animal taken possession of the earth to the extent that man has," states Teilhard de Chardin.

Even the anthropoid apes, the animals most closely related to man, have failed to attain his complete emancipation of the limbs. The protruding teeth and jaws and the mobile, grimacing lips of the adult, in particular, are frequently used for the grasping and picking up of food. The limbs of the chest region, with their elongated forearms and hands, are clearly modified



103. *Left*, the hand, *right*, the foot of a gorilla. Compared with the large palm, both fingers and thumb are foreshortened. The heel of the foot is secondarily undeveloped (Westenhöfer); and the big toe, like the thumb, is apposable (after Pocock and Weber).

for the swinging motion with which the animal propels itself through the treetops. At their extremities, then, the ape's limbs have come under the influence of the environment. In comparison with the arms, the legs have remained short. They are neither elongated near the trunk nor shortened to form genuine feet at the extremity. Instead, the foot remains hand-like, with an apposable great toe that resembles a thumb.

Man's special relationship with gravity does not exist for the ape (Schad, 1965). Yet in the immature ape—and this is important for the concept of evolution—certain echoes of the human limb organization are found. The jaws do not yet protrude beneath the arched, well-rounded forehead; forearms and fingers are not yet elongated; and the bones of the foot (particularly the tarsus) resemble those of man (Westhöfer). In the adult ape, however, the limb activity has not been withdrawn from the head and arms and brought entirely into the legs and feet. Only man has taken this evolutionary step.

The above statements, based on direct observation of external phenomena, are confirmed by Rudolf Steiner's description of man. When Steiner discussed the teaching of zoology with the teachers of the first Waldorf School, he characterized man's body as a limb organism (1919 b). "We must bring before the children the feeling that the outward form of man is the most perfect in all creation. This perfection is attained in the limbs. … With respect to the organization of the limbs no animal is as perfectly formed as man."

We are now able to make our first complete survey of the progressive emancipation of the organic systems:

Invertebrates	*Fishes*	*Amphibians*	*Reptiles*	*Birds*	*Mammals*	*Man*
Sense System	Central Nervous System	Respiratory System	Fluid System	Warmth System	Reproductive System	Limb System
Body Surface	Brain	Lungs	Heart	Visceral Organs	Uterus	Legs and particularly the feet

In this sequential order today's living world presents an indirect picture of the true course of evolution, which consists in the progressive emancipation of life processes from the direct influence of the outside world. The biological prerequisites for all that man enjoys as freedom of the soul and spirit have been given him by the whole course of this evolutionary development (see also Kipp, 1949, and Hassenstein).

Of particular interest is the order in which the organic systems were emancipated from the environment. Going beyond the plant nature, the lowest, invertebrate animals were the first to develop genuine sensory cells and organs, which have attained their highest degree of specialization in the insects. The fishes added a fully centralized nervous system. Only then were the processes of the rhythmic organization (first the respiratory, then the circulatory systems!) freed from the environment. Finally, the metabolic system, reproductive organs, and limbs were transformed towards freedom. A form developing sequentially through time becomes apparent: the sense and nervous systems began the emancipation process, being the first to become independent of their surroundings; the emancipation of the metabolism and the limbs was retarded, thus making possible the development of the higher animals. Because man's biological independence from the outside world began in the head and gradually extended to include all organic systems, even that of the limbs, he developed not the most specialized, but the most harmonious and perfect physical organization. Man's body, because of its high degree of biological independence, has become the dwelling place of his self-conscious life of soul.

It was the formation of the feet that permitted the ancestor of man to become man himself. This statement may sound strange in light of the prevailing opinion that man owes his individuality to the extraordinary development of his brain. His cerebrum in particular is well developed in comparison with those of the animals. The whole structure of his head is determined by the fact that the cerebral skull, with its high forehead, dominates the sensory part of the head and allows man's full countenance to appear. Is man then characterized by the limbs or by the brain? It could in truth be said that the two characteristics are correlated and mutually condition one another. For in man alone the activity of the limbs has been withdrawn entirely from the region of the head, which has in turn become free to develop the upright face and arched forehead so characteristic of him. Thus, the formations of the limbs and of the brain are inseparably connected in man's evolution[55].

We have now the basis for a closer examination of man's threefoldness. What is it that distinguishes the threefold nature of man from that of the mammals? In the animal's nerve-sense system, the sensory capacity is especially well developed. The auditory perceptions of mice and bats, for example, or even of cats and dogs, far surpass those of man; and the sense of smell possessed by many animals is superior to his. Yet this abundance of sensory perceptions can be transformed into an active conceptual life only with the aid of a highly developed nervous system, while the animal's simple brain functions only within the framework of the meaningful, yet non-individual, behavior of its species. In metabolic efficiency, as well, the mammalian organization surpasses that of man. The cellulose an herbivore consumes, or even the food a polar bear is forced to eat in winter, would far exceed the capacities of the human digestive tract. Thus, in some respects the animals have reached a state of biological independence greater than that achieved by man.

In the animal sense processes dominate the nerve-sense system and the metabolism dominates the metabolic-limb system. In man, however, the central nervous system has reached a degree of perfection equal to that of his sense organs, and in his lower organism the special formation of the limbs is equal to the development of his metabolic capacities. Since the limb and metabolic organizations balance one another in development, a certain harmony prevails even within this lower system. Similarly, the extreme receptiveness of his senses is balanced by a well-developed nervous system, so that the upper system, too, has internal harmony. Man's central organization is therefore in the unique position of mediating between polarities that are themselves internally harmonious. Unhampered by extreme, one-sided conditions, the rhythmic processes of man are free to work according to their own inherent nature. The three systems of the human body are therefore able to remain completely autonomous.

We must now confront the question of man's threefoldness in all its implications. How can three relatively independent systems cooperate so closely? Is it not true that the human organism above all others represents a unified biological whole? How can it be one and yet threefold?

Once again, it is the organism itself that provides the clearest answer to its 'open secret.' In the third chapter we mentioned that the teeth show in miniature the interrelationships of the three organic systems. There we discovered the balance and homogeneity of the incisors, canines and grinders (premolars and molars) of man. The teeth of modern man, however—and it is essential that we understand this correctly—do not appear in their original, complete number. Only a comparative study of all the dentitions possessed by the mammals can reveal this original structure. The original dentition contained, in each ramus of the upper and lower jaws, three incisors, one canine, four premolars and, after the change of teeth, three molars: a total of forty-four teeth. These numbers are usually expressed according the following dental formula:

Incisors
Canines
Premolars
Molars

$$\left.\begin{array}{ll} 3143 & \text{upper jaw} = 11 \\ 3143 & \text{lower jaw} = 11 \end{array}\right\} \times 2 = 44$$

The pig, a rather primitive ungulate, retains this complete set of teeth; yet all three types are exaggerated in form. The incisors are elongated and protrude from the mouth, the canines have become large tusks, and the molars are conical in shape and covered with numerous cusps. No animal has a complete set of teeth in balanced form. The uniquely harmonious completeness of the human dentition is possible only because *each of the three types of teeth is held back in its development.* Man therefore has two rather than three incisors in each half of both jaws; the canines, unlike those of the closely related apes, protrude no more than any of his other teeth; only two premolars develop; and the last molar, the wisdom tooth, is often stunted.

A reduced number of incisors is also found in many insectivores, as well as primates. Without exception the lemurs have only two incisors in each half of the jaw, but in some species (such as the aye-aye of Madagascar) these may be as elongated as rodent teeth. The genuine apes limit the number of premolars, as well. The rather primitive flat-nosed monkeys have three premolars, while the more highly developed narrow-nosed species have only two. The latter group includes the man-like apes, whose dental formula is identical to man's.

$$\left.\begin{array}{l} 2123 \\ 2123 \end{array}\right\} \times 2 = 32$$

Yet the canines of the apes resemble those of carnivores in their exaggerated size and length (Plates 178 and 179). The apes are so thoroughly dominated by the middle system that they have lengthened canines despite the fact that they are mostly omnivorous or even entirely herbivorous (as are the African guereza and gorilla). In man even the canines are allowed to recede, so completely has he overcome the one-sided dominance of any one of his organic systems. This limited development of the canines is so characteristic of man that it provides definitive evidence for the identification of fossils. A fossil is classified as human if no elongated canines or corresponding gaps between the other teeth are found; this is considered a positive morphological identification.

In man *all three* types of teeth are restrained in their development, and it is this restraint that makes possible the extraordinary harmony of his three dental structures. When the formation of the teeth is recognized as basic to the form of man's organization as a whole, it presents the threefold, yet indivisible nature of man as clearly as the upper, middle and lower systems themselves do: in man all three biological potentialities are held in check.

These and similar phenomena (we are reminded here of the human intermaxillary bone, so long undiscovered) moved Goethe (1795) to remark, "We cannot regard man as the archetype of the animals, nor the animals as the archetype of man." Our threefold method, however, enables us to move towards an understanding of the real nature of the relationship between man and the animals. Man, of course, does not provide the archetype for any single animal; he is instead the archetype that reveals how all the animal species, in their abundant diversity, form a coherent whole.

Yet another dimension of man's threefoldness is revealed by his embryological development. A description of this development, which is naturally hidden from our eyes, may be found in the German edition of this book; here we shall limit our discussion to visible phenomena: the form of man's placenta and the stage of development attained by the newborn child. The placenta of man is at first diffuse, and its entire surface is covered with villi. A histotrophic, oxygen-poor form of nourishment is thus predominant at this time. Gradually this enveloping, preliminary form gives way to a narrowed discoidal placenta, whose hemochorial structure provides the fetus with hemotrophic nourishment that continues until birth. Thus, at first, the human placenta resembles the simple, enveloping form maintained throughout gestation by the ungulates; only later does it assume the discoidal form developed so hastily by the rodents. Through retardation, the ungulate develops only the early type of placenta, while the rodent, through acceleration, skips almost every stage but the last. Although the carnivore's placenta, like man's, is diffuse at first, it develops only as far as the endothelio-chorial stage and thus remains incomplete. Only man's placenta passes through the entire spectrum of possible forms, from the one pole to the other, thus taking part in them all[56].

At the moment of birth man's physical form appears in the outside world. This moment is quite significant for the biology of form. Portmann (1959), in describing the physical characteristics of the human child at birth, tried to determine whether man should be considered precocial, like the small mammals, or altricial, like the large ones. The helpless condition of the newborn child and his undeveloped powers of locomotion would seem to indicate that he is only altricial. Yet his distance receptors—his eyes, ears and nose—are as complete in their development as those of the precocial animals. Man, remarkably enough, is both altricial and precocial.

Precocial characteristics

The eyelids open before birth, in the fifth month of gestation;

Distance receptors are functional at birth;

The sheaths of the pyramidal tracts (like those of the ungulates) are complete;

The full number of nerve fibers in the ventral roots of the spinal cord are present for both arms and legs (in altricial animals these are present only for the arms).

Altricial characteristics

Bones are still partly cartilaginous and the fontanelle remains open for one year;

Body proportions, especially of the trunk and legs, are markedly different from those of the adult form;

The limbs, like those of precocial animals, are non-functional.

The above survey presents in summary the characteristics cited by Portmann. Its results are rather surprising in light of our threefold method of observation, for it is the nerve-sense system whose development at birth is comparable to that of the precocial animals. The lower system, particularly in the limbs, appears to be underdeveloped. In the one system the human infant is precocial; in the other he is altricial. Thus he is neither one nor the other. Neither the one-sidedness of the altricial rodent nor that of the precocial ungulate characterizes the newborn human child. It might therefore seem reasonable to assume that the child's condition at birth would prove similar to that of the mammals who are dominated by the rhythmic system, the carnivores. Yet his condition at birth is in no way comparable to theirs; and it is this observation that leads us to a proper comparison.

Cats and dogs are born in a medium state of maturity. Both their nerve-sense and metabolic-limb systems are slightly more mature than those of typically altricial animals, yet without being precocial. In man, however, no uniform level of development exists; rather, he is at once *fully* altricial in his limbs and *fully* precocial in his senses. The polaric opposites are unmixed, existing simultaneously within his organism. No comparable differentiation between the levels of development attained at birth by the upper and lower systems exists in any animal. All three systems of the body are highly developed in the newborn ungulate, in a state of medium development in the carnivore, and underdeveloped in the rodent. Only the totality of all three mammalian groups reveals the full range of development found within a single newborn child.

Genuinely premature at birth are the altricial young of the sense oriented animals (the mice, squirrels, weasels, and martens). Because they are born in a far too embryonic condition, they are unable to digest fully all the stimuli of the outside world and therefore remain small and sensitive even as adults. The young of metabolic animals (the ungulates, whales, seals, and porcupines), on the other hand, are born late[57]. They are too complete at birth to permit the environment to take part in their further development[58]. The carnivore is born at the normal stage of development. In man, by comparison, only the rhythmic system is born at the normal time. With the first breath the lungs are inflated, thus becoming morphologically and functionally 'adult'; simultaneously, certain structural changes occur in the heart so that a mixing of arterial and venous blood no longer takes place, as it does in fetal circulation. At the same time, man's head is born late, and his limb organization prematurely.

The unique condition of the human infant is further clarified when we compare with him the newborn of man's closest relatives, the primates. The lemurs and monkeys enter life in a more finished condition than the human child does, while the newborn anthropoid apes possess a degree of maturity midway between man and the monkeys. The infant gorilla, for example, is so weak during its first few weeks of life that it cannot even cling to its mother's fur (Lang). Yet the disparity between its upper and lower systems is not nearly so great as that found in man, for the gorilla becomes capable of independent movement far earlier than the human child does.

The anthropoid apes are smaller at birth than the human infant, yet their gestation period is roughly comparable to his, being only slightly shorter[59].

Man	274 days
Chimpanzee	240 days
Gorilla	255 days
Orangutan	270 days

Nevertheless, these animals are more advanced at birth than man is; evidently, their prenatal development is slightly accelerated in comparison with his. This accelerated rate of development increases after birth, so that the anthropoid apes take each step in postnatal development in about half the time necessary for man.

	First standing with support	Eruption of first and last Milk tooth	Permanent tooth	First menstruation	Life expectancy
Man	9 months	7.5-28.8 months	6.2-20.5 years	13.7 years	75 years
Chimpanzee	1.5 months	2.5-12.3 months	2.9-10.2 years	8.8 years	35 years

(after Schulz and Steinbacher)

Thus, at a time when man is fully engaged in active life, the anthropoid ape dies of old age. Every aspect of this animal's life is influenced by the acceleration of its biological development.

In summary, newborn non-human primates resemble the human infant slightly at birth, but the gap between the two widens rapidly. The newborn ape soon comes to resemble the genuine altricial animals, though it never becomes as independent as an infant ungulate of comparable age.

All primates are distinguished from other mammals by the close connection between mother and child, a connection that culminates in man. Man's childhood is longer than that of any animal, and it is this period of protection and dependence that makes it physically possible for man to grow up in a manner that is unique in the natural world. For man alone is protected long enough to enable his three organic systems to mature at very different rates. Since he realizes all three stages of development simultaneously, he unites within himself all three potentialities for one-sided development, bringing them into harmony without reducing them to a common level. Physiologically, his condition at birth is 'universal.'

The very appearance of a newborn child thus guides us to an understanding of man's physical organization as a whole. Not one, but three different, relatively autonomous, chronological processes give form to man. The autonomy of man's three systems is therefore even greater than we had previously assumed. His nerve-sense organization attains physical maturity quite early. Characteristic of the human infant is the large head, with a precociously developed brain and active sense organs. It is best to allow this organic system to develop gradually during early childhood. Any excessive demands made either upon the senses by unharmonious surroundings or upon the brain by premature intellectual instruction may cause irreversible damage (Moore). The rhythmic system reaches maturity during the second seven years, between the change of teeth and puberty. Steiner (1919 b) pointed out to the teachers of the first Waldorf School that the child should be helped during these years to establish a proper coordination of rhythmic functions, particularly of breathing and heartbeat. The aim of education during these years should be to bring about a healthy development of the child's rhythmic system. Only during the third cycle of seven years does the metabolic-limb region attain maturity, along with the organs of procreation. All that is childlike now falls away from the adolescent, who, with the development of his lower system, is for the first time completely at home on earth. What we see in the mature human form is the spatial manifestation of the three developmental processes that were so clearly differentiated even in the newborn child. *The threefoldness of man is based upon three organic systems differentiated in time.*

What we have observed on a biological level distinguishes man from the animals on the soul level as well. He does not enter completely into the present but experiences in his soul far more than the present moment can provide. To a greater degree than any animal, he can learn from past experiences and apply them fruitfully to the present. And he can plan for the future, thus gaining some mastery over it. Past, present and future are realized simultaneously in the soul of man. Is it not possible that these capacities are directly connected with the fact that his three organic systems develop at different times?

Let us now examine the variations that can occur within the human organization itself. During the past sixty years many scientists have studied the various physiological constitutions of man. On the basis of research conducted by Challou, MacAuliffe, Sigaud and Bauer, Ernst Kretschmer identified the following constitutional types among adult males:

Leptosome (slender-bodied type)
Athletic (competitive type)
Pyknic (corpulent type)
Dysplastic (underdeveloped type).

This classification has since been refined by W. H. Sheldon (1940), who describes the following three types:

Ectomorph
Mesomorph
Endomorph.

The ectomorph is generally tall, slender, and rather delicate in build. He has a long neck, drooping shoulders, and a slender trunk. Long, weakly-muscled limbs show his limited vitality. According to Karl König (1962), a psychiatrist who was active in applying the ideas of Rudolf Steiner to the education and care of mentally handicapped children and adults, the chief characteristic of the ectomorph is his restraint, his inhibition.

> Such a person has the greatest difficulty in speaking loudly or melodiously. He often begins a sentence only to stop and say, "Oh, I can't express myself!" In sitting, he not only crosses one leg over the other, but even wraps it around a second time. This is the kind of person who, when he comes for an interview, never takes off his coat. Such a person, who is dominated, as it were, by his cerebrum, his brain, is as enclosed within his own private world as the brain is within the skull.

The ectomorph often tends to formulate rigid concepts and abstract thoughts and is in danger of becoming dogmatic. His thoughts and feelings are often able to carry on separate existences within him, so that he may be designated 'schizothymic' (psychologically divided). In abnormal cases this one-sidedness may lead to schizophrenia. The majority of schizophrenic patients do in fact have an ectomorphic physical constitution.

The endomorphic, pyknic type is characterized by a round head and broad face, a short massive neck, and a squat figure with large body cavities and weak limbs. A tendency toward obesity is typical. According to König the endomorph is characteristically relaxed.

> This is a man who loves comfort. He prefers not to sit on a hard chair, but to relax in an easy chair. He is generally quite sociable, sometimes without discrimination, being friendly to everyone. Food plays an important role in the endomorph's daily life. He loves to eat, and he appreciates a good meal. He delights in sitting down in comfort to his meal, with company. He also enjoys the period following the meal—in short, the whole digestive process. He therefore tries to shape his surroundings as comfortably as possible. He likes to be surrounded by nice things and he needs the praise and admiration of others. He often requires their comfort and support, as well. He is definitely opposed to physical exercise of any kind—climbing, hiking, skiing or skating—he does his best to avoid them all!

Such a man is usually congenial, with a sense of humor and a tendency to keep his own practical ends in view. Since his mood typically fluctuates between depression and euphoric happiness, the endomorph is often cyclothymic. In severe cases he may even become manic-depressive.

A third, very different physiological type is the mesomorph. Strong in stature, muscular and athletic, he has a rectangular face, broad chest and rather well-proportioned build. According to König his principal activity is motor.

When he enters a room he finds it impossible to sit down and be still. Instead he walks around and shakes hands with everyone, approaching each person quite directly. He tells everyone who he is and why he is, what he thinks and what he does. For him, activity is an absolute necessity. Fatigue overtakes him only suddenly, so he falls asleep for a few hours—and rises early in the morning. This is a man who looks for trouble; he loves to get himself into dangerous situations. He constantly seeks activities in which danger lurks just ahead of him. But the one thing he cannot stand is loneliness. He suffers greatly from claustrophobia and cannot bear to be shut up in a room by himself; at least a window must be open. If he and another mesomorph are in the same room with thirty or forty other people, it will be just these two who make most of the necessary, and unnecessary, noise. Such a person always speaks, and even coughs, loudly.

He often seems to be unconcerned with the existence or needs of other people. The energetic nature of such a man can alternate between cool composure and explosive rage. Epileptics often have a constitution of this type (Bleuler, Treichler).

It must be emphasized, of course, that not all individuals fit into these categories. They cannot be applied at all to women or children. Yet Kretschmer (1944) reports that Saza found 60 percent of the male population of Japan to be clearly divided into these three categories.

We must regard these constitutional types not as merely accidental but as concrete manifestations of man's threefold organization. The ectomorph has a physical constitution governed largely by his head, particularly the cerebrum; psychologically, then, he is 'cerebrotonic.' The endomorph is dominated principally by his digestive processes and is psychologically 'viscerotonic.' The mesomorph is psychologically 'somatotonic' and has a strongly developed circulatory system, robust heart, and strong muscles.

The existing research on constitutional types is in most cases quite tentative with regard to the physio-psychological constitutions of women. The female constitution does appear to have more generalized features than the male, and it is less likely to develop extremes. Yet Karl König (1962) has made a remarkable first attempt to delineate the feminine constitutional types, which do not coincide with those of men.

The first type he found to be rather tall, with a relatively small head, and long neck, legs and arms. Women of this physical type are often fairly muscular; they seem to be dominated by the limb system. A second, contrasting type seems to be dominated by the senses. Members of this group tend to be rather delicate and small, with a comparatively big head, large eyes and ears, a high forehead, and a small nose. Such women tend to be hypersensitive, talking rapidly and at length about the many different subjects that interest them. Members of the third, or central, group tend to have round faces and medium-sized, rather sturdy bodies. Their traits are not easily described, since their bodily constitution is based primarily upon the harmonious respiratory system and does not tend to extremes.

König concludes his description by pointing out that every human being, irrespective of sex or constitutional type, bears within him all these constitutional tendencies. Figuratively speaking, the nervous system could be called masculine and the senses, feminine; so that the two together form a unified nerve-sense system that is both male and female. The metabolic-limb and respiratory-circulatory systems could likewise be designated both male and female. In this sense, the two sexes may be seen as nothing more than one-sided manifestations of what is universally human, and present within every individual. Even the derivation of the word 'sex' (from the Latin *secare,* 'to cut through') is an indication of this division of the human whole.

It is also instructive to consider the forms of the teeth, as related to the constitutions discussed above. Hörauf has discovered empirically that the leptosome (or ectomorph), despite his slight figure and narrow face, generally has large, broad incisors, of which the two front teeth are largest. The opposite is true of the pyknik (or endomorph), who, despite his broad face, has short, narrow incisors. In the athletic (or mesomorph), the canines are larger than those of most others. Hörauf's conclusions thus confirm our own observations of the threefold structure of the teeth. Unfortunately, he has concerned himself only with the frontally visible teeth, and not with the molars. We may wonder whether a study of the molars of the pyknic in comparison with those of the leptosome would show them to be broad and strong.

Let us take this line of reasoning one step further. Man's first teeth are incisors; thus the sense pole of the teeth is accelerated in its development. The molars, on the other hand, appear only at the change of teeth. The last molar, the wisdom tooth, usually appears long after the change of teeth, and frequently not at all. On the basis of the above observations, we may venture to predict that this relatively frequent anomaly may prove to occur more frequently in the leptosome than in the pyknic.

Any such attempt to formalize the physical and psychological traits of man can only be of limited value. For it describes merely what is typical in him, and non-individual. But insofar as man, in his inherited, physical organization, does in fact have certain traits that may be designated according to type, such a theory is valuable. In these three different constitutions of man we can find hints of the thoroughly one-sided developments that dominate the mammals. And conversely, in the animals we can study in bold outline developments that appear in man only as mild tendencies.

Man alone is in a position to recognize his own one-sided constitutional tendencies. In becoming aware of them he realizes that he, as a thinking being, cannot be identical with his inherited nature (Eccles). If he were so, he could not remove himself from it in the act of cognition.

Der Mensch ein chemischer Prozeb.	Man, a chemical process.
Ein Wahrwort. Doch was wiegt's?	A word of truth, but does it count?
Gewib „Prozeb"—doch dab er des	"Process," no doubt—but that he
selbst inne wird, da liegt's.	*knows* it, that counts.

Thus the poet Christian Morgenstern describes this cognitive experience. But what is man? Is he, as an individual, nothing more than the representative of his biological type, or is each of us a unique, irreplaceable individuality? The experience of both aspects of our existence is what makes us human. It is only in the continuous struggle with the discrepancy between the two that man exists.

How can man exist as both individual spirit and typical organism? Is there some connection between the inherited nature of man and the personality that conceives of itself as unique spirit? How does man's essential individuality come to terms with the more or less one-sided biological constitution given him at birth?

We cannot answer such questions without making reference to what we consider a fact of the greatest possible biological significance. The individuality of man, unlike the physical body he comes to inhabit, lives not only between birth and death, but also before birth and after death. And we believe that its life on earth is repeated many times. The concept of repeated earth-lives was taken for granted in most cultures of earlier times, and it still prevails in certain non-Western cultures today. It was the claim of Rudolf Steiner that methods appropriate to the scientific consciousness of our time could afford a solid basis for the renewal of this ancient knowledge. He presented the theory of reincarnation in an entirely new way. We must refer now to his explanations of the facts he investigated (see, for example, 1904, 1907 a, 1903-8) in order to understand the consequences such an idea has for the questions we have raised.

According to Steiner, man takes on a particular, one-sided constitution for the duration of one earth-life only. He balances this one condition in another earth-life, when he takes up another constitution that will be complementary to the first. A life as a man, for example, is quite generally—though not always by any means—followed by an incarnation as a woman. The specifically human, which cannot be identified with one sex only, thus achieves physical realization; the one-sided characteristics of the two sexes are balanced in this chronological alternation. The same holds true for a man's membership within a particular race, constitutional type, and so forth. It is only because he lives many times that man is able to accept the one-sided life condition he inherits at birth. Because he feels the need of balancing the one-sidedness of a former life, he is instinctively willing to accept the limitations of his present condition, at least in part. Yet he cannot identify fully with this single condition, because he seeks not only to experience the consequences of a former incarnation, but at the same time to prepare a new one. Thus man always aspires to far more than he can accomplish in any one lifetime. As senseless as the never-ending hope of man may seem to one who sees him only between birth and death, this hope is felt and understood as profoundly justified by one who knows of his repeated lives on earth.

Reincarnation is a spiritual process, not a physical one; it is man's spiritual essence and not his physical body that endures throughout his incarnations. The validity of this concept can therefore be established only on the basis of an exact science of the spirit, and not by natural science alone. But is it not possible that the reincarnating individuality could choose, before birth, whatever biological conditions it will need, thus providing indirect, but physically perceptible, evidence of its existence?

Every newborn child demonstrates to our very eyes the reality of reincarnation. We have seen already that his physical body matures at three different rates. Three organisms of different ages might be said to dwell within him. In his head he is born late and is precocial; in his limbs he is born prematurely and is altricial. Only in his rhythmic system is he born at the normal time. This extraordinary biological condition is consistent with Rudolf Steiner's contention that the head organization brings with it from a previous incarnation most of its formative tendencies (1918 b, 1916). The brain, already large at birth, reaches the end of its physiological development as quickly as it does because its organization—insofar as it is not merely physical—is based on the individual's past. The limbs, on the other hand, are so unfinished because they carry within them abilities that will develop not only in the life just begun but also in the one that follows. Only in his rhythmic organization does man belong completely to the present. "We can thus experience a new sense of reverence in the presence of a newborn child; for his very appearance shows us that he has lived before, is ready for his present life, and will live again. The metaphysical secret of man, normally hidden from our perception, namely that in some sense he experiences three incarnations at once, is revealed to our physical senses by the appearance of every newborn child.

The idea that the specific formation of the brain is determined by a previous lifetime and that the limbs are the source of a future one is fully consistent with a way of thinking that takes into account the soul and spirit of man, thus allowing us to understand the whole of his nature. Every man, not only in his soul but also in his spirit and physical body, bears within him at every present moment both past and future; thus his existence in *time* is threefold. And this threefold existence in time is the real source and basis of his tripartite physical organism. In it man's life in time is given physical form. The wellsprings of human existence lie in the individual's passage through repeated lives on earth. His physical organization, determined by the course of his lifetimes, shows that what is truly human is determined not by the dominance of his upper, lower, or even rhythmic systems, but by the harmonious balance of all three. Thus, the idea of threefoldness takes on social implications. For true social life can arise only when we understand that the differences among men have meaning; and this meaning is found in the fact that they complement one another.

In closing, we refer to the words of Rudolf Steiner, which give clear, succinct expression to the wholeness and interdependence of the three main systems and functions of man.

Ecce Homo
In dem Herzen webet Fühlen,
In dem Haupte leuchtet Denken,
In den Gliedern kraftet Wollen.

Webendes Leuchten,
Kraftendes Weben,
Leuchtendes Kraften:

Das ist der Mensch.

Ecce Homo
In the heart weaves feeling,
In the head shines thinking,
In the limbs lives strengthening will.

Light that is weaving,
Weaving that strengthens,
Strength that gives light:

That is man.

Notes

1 The causal-analytical method of physiological research is well aware—insofar as it reflects upon itself—that it is in no position to study Life itself. Bünning has pointed this out: "Once we have understood what it is we mean by life in its physiological sense it becomes clear that Life in its real sense, as it was known before the time of biological science, is not what is meant by biologists."

Therefore, chiefly that part of nature that can be isolated and quantified is considered important by today's scientists. And the method itself interferes with the phenomena observed. Heisenberg has formulated this fact and its consequences as follows:

"The scientific method of isolation, explanation, and classification is aware of its own strict limitations, namely that the application of the method itself alters and reshapes the object of study, so that method and object can no longer be separated. The world picture formulated by natural science ceases at this point to be truly scientific."

2 We know today that the activity of the single elementary particle is undetermined and can therefore be predicted only according to statistical probability. Yet the average behaviors of many such particles do not vary according to any regular pattern, so that even in the visible dimensions the universal applicability of these causal laws may be called into question.

3 Aristotle, and afterwards scholars of late antiquity and the Middle Ages, designated these animals as live-bearing, four-footed animals. The young Linnaeus (1735) was the first to name them for their mammary glands: *Mammalia*. Oken (1838) suggested the name 'Haartiere' (hairy animals); this term has never been widely used, though it is equally appropriate.

4 An exception is provided by the most primitive of the mammals, the monotremes of Australia. In these animals, as in reptiles and birds, wastes from the bladder and intestine empty first into a cloaca and are then excreted together.

5 These non-placental mammals are found principally in Australia. Only the opossums and opossum-rats are found outside Australia, in North and South America, respectively.

6 Man has often been described from a biological point of view as 'incomplete' (Gehlen) and, as unsatisfactory as such a designation may be, it is nevertheless a valid attempt to describe something true. Eibl-Eibesfeldt, basing his argument on observations made by Conrad Lorenz (1959) has opposed this point of view:

"Even in terms of physical capacity alone, no animal, after running a hundred meter dash, could plunge head first into the water, dive to a depth of a few meters in order to retrieve three objects, swim to the other shore, climb a rope, and then begin a long march."

But Lorenz and Eibl-Eibesfeldt are unaware of the fact that they have provided concrete evidence in support of the very theory they had hoped to refute! For an antelope can run faster than a man, a sea lion dives more elegantly, a dolphin dives and swims better than he does and can retrieve one or more objects from a greater depth, a guenon can climb a rope more rapidly, and a camel can march longer. But precisely because man cannot perform any one of these feats as well as a particular animal can, he—unlike the animal—can perform them in far greater variety. Since his particular physical capacities are underdeveloped compared with those of the animal specialists, he is extraordinarily versatile. The term 'incomplete' can have no other meaning than this. Lorenz (1959) himself describes man as a "specialist in non-specialization." See also the works of Poppelbaum (1928), Kipp (1948), and the literature cited therein.

7 In 1917, fifteen years after the beginning of his anthroposophical activity, Rudolf Steiner first presented his ideas on the threefoldness of man's physical organism. The history of this idea is given by Steiner in a lecture of March 22, 1917 a.

"In the last two lectures, which concern the relationship between the soul and the nerve-sense man, breathing man, and metabolic man, I have attempted to express, in complete accord with natural science, an idea I believe to be of extraordinary significance for the understanding of the world's coherent working. I have never before expressed in this way the matters I have discussed in these last two lectures, but it was thirty-five years ago that I, as a very young man, began the investigations that ultimately enabled me to speak as I have done in these lectures."

Going back thirty-five years we find, in March of 1882, the twenty-one year old student of natural science at the Vienna Technical High School. Shortly before his death, Steiner (1925) described some of the questions that led him to his discovery of threefoldness.

"I now felt compelled afresh to press forward toward a knowledge of the natural sciences from the most diverse directions. I was led again to the study of anatomy and physiology. I observed the members of the human, animal, and plant organisms in their formations. In this study I came in my own way upon Goethe's theory of metamorphosis. I became more and more aware that the picture of nature which is attainable through the senses penetrates through to that which was visible to me in a spiritual way ....

"I came upon the *sensible-supersensible* form of which Goethe speaks, which is interposed, both for the true natural perception and also for spiritual perception, between what the senses grasp and what the spirit perceives.

"Anatomy and physiology struggled through, step by step, to this sensible-supersensible form. In this struggling my eye fell, at first in a very imperfect way, upon the threefold organization of the human being ....

"At the beginning, it became clear to me that, in the portion of the human organization in which the formation is directed chiefly to the nerves and senses, the sensible-supersensible form also stamps itself most strongly upon the sense-perceptible. The head organization appeared to me as that in which the sensible-supersensible also becomes most strongly manifest in the sensible form. On the other hand, I was forced to look upon the organization consisting of the limbs as that in which the sensible-supersensible most completely conceals itself, so that in this organization the forces active in nature external to man continue their work in the shaping of the human body. Between these two poles of the human organization everything seemed to me to exist which expresses itself in a rhythmic way, the processes of breathing, circulation, and the like."

Steiner was well aware of the scope of this idea, yet he did not reveal it for many decades, preferring instead to work on it further. In 1917 he finally described the physical threefoldness of man, in his book *Von Seelenrätseln.* A year later, at the end of the First World War, Steiner used the idea of threefoldness as the basis for his thinking about a new, more humane social order (Steiner, 1919 c).

8 This argument is based neither upon pure sensationalism nor a Kantian agnosticism, but, with Steiner, upon a critical realism and empirical idealism.

"Cognizing would certainly be a useless process if sense-experience provided us with something complete. Every combining, arranging, grouping of sense-perceptible facts would have no sort of objective value. Cognizing has a meaning only if we do not admit the completeness of the form of knowledge given to the senses, if it is for us a partial truth concealing within it a higher element, which, however, is not perceptible to the senses. Here the mind enters. It perceives that higher element. For this reason, thinking must not be so conceived as if it added something to the content of reality. It is neither more nor less an organ of perception than are eye and ear. Just as that perceives colors and this tones, so does thinking perceive ideas. Idealism is, therefore, perfectly compatible with the principle of empirical research. The idea is not the content of subjective thinking, but the result of research." (From *Goethe The Scientist;* see also *Goethe's Conception of the World.)*

9 References to Portmann's discovery, so significant for the biology of form, appear throughout his works (1948, 1953, 1957, 1958, 1965). One such reference is quoted here:

"The skin of higher animals is opaque; regular patterns of color enclose an internal form quite different from their own, disclosing nothing of the specific arrangement of the organs at work within.—Nothing of the kind exists in the diaphonous organisms of the high seas. Here, the structure of the entire body is and remains subject to a single law of symmetry, which determines the structure of the internal organs as well. —Even among the absolutely transparent aquatic forms, however, there are higher and lower degrees of organization. And precisely these life-forms show that transparency is no arbitrary phenomenon but is strictly limited by formative laws. In animals whose form is more complicated, such as snails and cuttlefish, as well as vertebrates and their relatives, this transparency is confined strictly to those parts of the head that are symmetrical—any non-symmetrical formations are clustered together and concealed beneath opaque sheaths. Whatever is not symmetrical is hidden from sight; even within the transparent body there is another covering, which, like the skin of the higher animals, hides whatever is not formed according to simple geometrical rules. The older zoology ... took into account such groupings of organs, giving to them the name '*nucleus vegetativus* (visceral cluster)'.

"The sea-snail *Pterotrachea* shows this structure—its inner covering is a silver, shimmering sheath. A similar structure appears in the salps, close relatives of the vertebrates, and this cluster is covered by a red, gold-brown, or bright blue sheath; ... transparent cuttlefish show the dark cluster and snails from entirely different groups show the identical structure. Even the immature, transparent stage of fish belong to this group; silver sheaths are the rule for them all (1958)."

Even adult fish such as the glassfish and the Asiatic glass catfish provide impressive examples of this phenomenon. The head, the entire nerve-sense system, the skeleton, the skeletal musculature, and the air bladder are either translucent or completely transparent. The organs of the abdominal cavity, however, are protected from the light by a silvery, opaque layer, beneath which the asymmetrical organs are hidden. These metabolic organs must not be allowed to become sense-active.

Portmann sees this asymmetry as a "significant, space conserving adaptation," in which, for example the intestine, through its lengthening and its highly compressed, twisted orientation within the abdominal cavity, is economically formed." Recent research in developmental physiology has shown, however, that these structures cannot be traced back to any mechanical cause (von Kraft). Neither causal nor teleological significance can be ascribed to the relationship between the living organism and space.

Later, in his book *Die Tiergestalt* (1948), Portmann returned to this problem of symmetry and asymmetry and made the following discovery within the mollusks: as the influence of the nerve-sense system increases, the shell and the animal become more and more symmetrical.

10 We discuss the structures of muscle fibers here in order to show how the threefold idea may be applied to the entire organism, even in its microscopic details. To this discussion the following information may be added:

The three muscle types show significant differences in cytological structure. The striated muscle fiber is a multinucleate plasmodium; in man and in the mammals the nuclei are almost always close to the surface of the plasmodium, so that in cross section they appear to be lined up along its edges. The smooth muscle fiber, on the other hand, is uninucleate and therefore a true cell; the nucleus always lies deep within the fibrils. The fibers of cardiac muscles consist of true cells, since each nucleus and its plasma are surrounded by a cell membrane (Leonhardt); the fibrils, however, pass through these cellular membranes (the 'seams' characteristic of the cardiac muscle fibers) into the neighboring cells, so that all the fibers together function as a plasmodium, without actually becoming one. An extraordinarily significant central condition! These fibers are striated, but to a lesser degree than those of the voluntary muscles. Their nuclei, like those of the smooth muscles, lie inside the fibrils. In size, too, the single heart muscle fiber is midway between the longer, voluntary muscle fiber and the shorter, involuntary one. Uniquely characteristic of the cardiac muscle is this *branching out* of each fiber to form networks of muscle fibers. Similar networks exist in smooth muscles, in the uterus, for example, or in the bladder; here, however, the branching arises out of the placement of the cells, and not out of a branching within the cell itself. The axial structure of most skeletal muscles and the spiral structure of smooth ones are the polar opposites between which the branching form of the cardiac muscles mediates.

We should also mention the few exceptions to this otherwise strictly threefold muscle structure. These exceptions arise particularly where the musculature of the digestive tract meets with the skeletal muscles, and voluntary and involuntary processes intertwine. The muscles at the front of the mouth are moved consciously and are striated. Some, however, are also circular muscles, and are not attached to bones, but spiral back upon themselves or are inserted into skin (mimetic muscles). In such transitional regions the striated muscles may so completely adapt to the qualities of the metabolism that they no longer come under the influence of the conscious mind, as in the upper esophagus and in the cremaster, lower rectum and anus.

Similar transformations occur in the eye. The skeletal muscles that move the eyeball are the only striated muscles in the human body whose nuclei are not completely superficial but, like those of some lower vertebrates, are scattered throughout the muscle fiber. The most extreme development is thus avoided. Significantly, this outer musculature of the eye, like that of the heart, develops neither from the somatic nor the visceral musculature of the coelom (Starck 1955, p. 585). Inside the eye, the muscles that control the pupil and lens are circular and smooth. The lens (or ciliary) muscles are the only smooth muscles that can be moved at will. With these we adjust the curvature of the lens, in order to focus upon near or distant objects. These internal muscles of the eye, like the involuntary, smooth muscles of the skin (which raise the hair, excrete sweat, cause 'gooseflesh' to appear, and so forth) originate from the ectodermal epidermis, and not from the coelom.

Thus, the process of equalization between skeletal and visceral musculature begins at the border of the metabolic realm, takes place also in the eye, and reaches its highest development in the heart.

11 Kolisko, basing his conclusions on the discoveries of Rudolf Steiner, was in 1926 the first to apply the threefold idea to the study of mammals. Poppelbaum (1937) and Kipp (1952) have done further work on this subject.

12 The otters have often been separated from the *Mustelinae* (all other *Mustelidae)* as a subfamily, the *Lutrinae.* But their divergent morphological features are simply a result of their aquatic habits, which mask their close relationship with the terrestrial members of the mustelid group. We shall find the same motif in the seals and whales.

13 The uniform, beautiful coat of the European mink was at one time more highly prized than that of the ermine, so that this animal has become extinct in central Europe. The only similar animal found in Europe today is the feral American mink, introduced from North America as a fur bearing animal. The American mink lacks the European mink's white marking on the upper lip.

14 The honey badger gets its name from its predilection for the honey stored by wild African bees. The honey-guide, which leads the badger to the hives by means of its lively chattering, is a graceful, agile bird related to the woodpeckers; its beak is not strong enough to break open the hives in hollow trees. This the honey badger does with ease, lapping up the honey and leaving the larvae and honeycombs for the bird. Here one animal contributes what the other lacks; the combined 'organism,' consisting of a representative of the sensory organization and a metabolic-limb oriented animal, then functions as a whole. It is also typical of the honey badger that it likes to dig burrows in the ground and live there, so that it withdraws from the general environment even in its way of life.

15 To a large extent, the sable can sustain itself on a vegetarian diet. Thus, in the Siberian forests it prefers to eat berries and cembran pine nuts (Kozhantschikow, Ognew).

The sea otter feeds primarily upon sea urchins. In addition to its well-developed carnivore's canines this animal has remarkably broad molars, and only four incisors in the lower jaw(!), as opposed to the six incisors typical of fissiped carnivores.

16 We are generally accustomed to thinking of the aquatic life-habits shared by many different mammal groups as accidental convergencies that are unworthy of further consideration and have in common only the fact that they take place in the water. Adaptation, however, is ultimately comprehensible only on the basis of physiology. It is also evident that the higher animals do not adapt passively, but take an *active* part in their adaptation (Hensel), for the animal's own, basic constitution determines how it will adapt to the environment.

17 The fossilized skeletons of aquatic saurians from the Jurassic period (*Ichthyosaurus, Eurhinosaurus, Tylosaurus, Peloneutes,* etc.) show an exaggerated development of a similar increase in the number of teeth and digital bones.

18 In the birds we find similar compensations. Ostriches and fowl take little trouble in building nests and merely hollow out depressions in the ground, since their young are born in a well-developed, precocial state. The songbirds, on the other hand, weave intricate nests, lined with soft materials, where their blind and naked young hatch from the eggs. In the predatory birds a central condition prevails: covered with thick down, the young enter the world, but they cannot immediately abandon the coarsely constructed nest. Thus the sense oriented small birds, the songbirds, provide their young from without—in the structure of the nest—with all the care and protection the space within the egg has been incapable of giving. Indeed, the birds demonstrate these tendencies even more dramatically than the rodents do, since they, as birds, are formed chiefly out of the sense system.

In some bird species the males, in contrast with the females, are brilliant in form and coloration and indulge in extravagant courtship behavior. Significantly, males of such species take little or no part in nest building, incubation of the eggs, or care of the young. All the formative capacities that the homely female devotes to her young are diverted by the male to the formation of its own body (pheasants, peacocks, ducks, birds of paradise, and ruffs). Kipp (1942) and Suchantke (1964) have made reference to this phenomenon. Similar behavior has been observed among the insects (Arrow).

19 c. f. Julius, page 97.

20 In North America there are many animals closely related to the European marmot. In shape and biology the prairie dogs, as well as many varieties of ground squirrels (susliks), are the nerve-sense oriented members of this group; more metabolic are the three marmot species, of which the largest, the hoary marmot, shows the beginnings of black and white head markings and inverted coloration (see Burt).

21 The beaver, which still ranged throughout central Europe during medieval times, has been virtually exterminated in many places because of its valuable pelt. In many parts of this region, however, efforts are now being made to reintroduce colonies of this animal.—The interesting private life of this remarkable animal has been described by William Russell Long and by Waescha-Kwonnesin.

22 The classification of the rodents offered here is identical in most respects with that made by conventional taxonomists. The first indications of a

similar tripartite classification are found in the work of de Blainville. In 1834 he divided the rodents into the *fuisseurs* (burrowers), *grimpeurs* (climbers), and *marcheurs* (runners), groupings that closely approximate the mice (myomorphs), squirrels (sciuromorphs), and porcupines (histricomorphs) recognized today. These designations originated with Brandt (1855), who also added the hares as a fourth rodent group. He considered the mouse to be the typical rodent. "Under careful scrutiny the mice are seen to form their own group, which is revealed as the morphological midpoint and basis of the entire rodent group." Tullberg, in 1899, was the first to take note of the significant differences between the rodents and the hares and to question whether the latter were genuine members of the rodent group. In 1912 Gidley brought conclusive evidence for their separation from this group. Thus, three main groups of genuine rodents remained, without anyone's recognizing the threefold principle underlying their classification.

Simpson (1945) reopened the question of the rodent's classification. Wood (1955) substituted seven groups for the three designated by Brandt; for example, he separated the American porcupines and their relatives (hystricomorphs) from the Old World species and denied any close relationship between them. Landry (1957) compiled a list of their similarities and refuted Wood's argument, saying, "I believe it must be recognized that the Old and New World hystricomorph rodents are closely related. The morphological evidence against the opposite point of view is simply too obvious." Hofstetter and Lavocat (1970), as well as Thenius (1972), have recently corroborated the morphological and paleontological homogeneity of all hystricomorphs.

Since the time of Brandt the dormice have been grouped with the mice. Schaub (1953) contested any such close relationship; Wood brought them together again, but still designated the dormice as '*incertae sedis*.' We have classified them with the squirrel group, as we have the beaver, which, despite the fact that its bodily structure also deviates in many respects from that of the squirrels, is nevertheless considered by many modern authorities to be closely related to them (Simpson).

23 In the camels the omasum has few of the parallel swellings of the internal mucosa that normally typify this organ, and the rennet stomach is without internal folds. See Chapter VII for a detailed description of the ruminant digestive system.

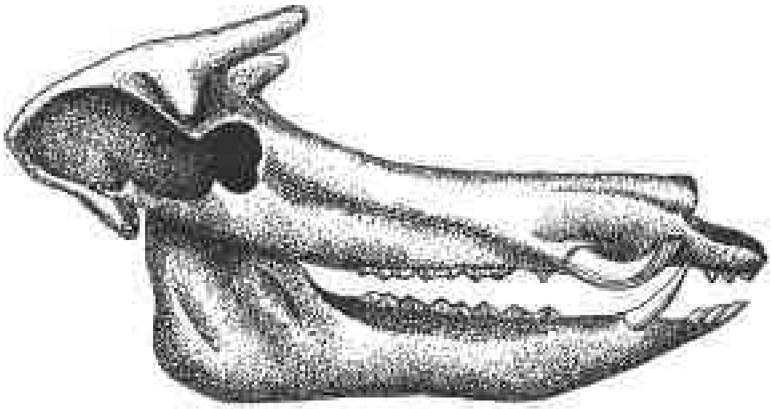
24 Among the 131 species alive today we find only 2 exceptions in which head processes are lacking: the musk deer and Chinese water deer. See also Chapter VIII.

25 This ninefold classification of the ungulates is almost identical to that presented by conventional taxonomists (Simpson; see also Müller-Using and Haltenorth). Yet they, out of a practical inclination toward simplification, have reduced this to a basically twofold system. Since the time of Owen the entire ungulate group has been divided into two orders: the odd-toed ungulates (*Perissodactyla, Mesaxonia*) and even-toed ungulates (*Artiodactyla, Paraxonia)*, a classification based primarily upon the structure of the limbs. On the same basis the tapirs and rhinoceroses have been grouped together as *Ceratomorpha*, in contrast to the single-hoofed horses, and the water chevrotains and bearers of head processes have all been classified as *Ruminantia*, in contradistinction to the thick-soled camels.

To be consistent, however, one must then group the swine and hippopotami together in contrast to the peccaries, since these have fewer hooves than the former. Modern taxonomists nevertheless base their classification of these animals on the structure of the digestive tract, which is simpler in the peccary and swine than in the hippopotamus, with its multi-chambered stomach (Plate 34). Even the generally accepted grouping of animals with head processes (the deer, giraffes and bovine animals) is not based on limb structure, for the giraffes, in contrast to the deer and cattle, have no dew claws (see Chapter IX). We have attempted to base our classification of these animals both upon the structure of the limbs and upon the formation of the digestive tract, evaluating them equally according to both criteria, in order to arrive at a classification of the ungulates that is truly consistent with their nature.

26 In the Tertiary epoch, which preceded the Ice Age, the mammals blossomed in a variety of forms far exceeding those on earth today. At that time an even stronger tendency toward the formation of head appendages prevailed and was not governed by the same formative laws that are active today. And yet, formations arose that are quite significant for the biology of form. In the Miocene and Pliocene epochs of the late Tertiary period, there were horned rodents *(Myogaulidae)* in North America (see Abel). These plump, hare-sized rodents grew their paired, bony processes *far forward,* on the bridge of the nose.

A horned swine, dating from the Miocene epoch, has been found in the Caucasus (Gabunia). The skull of this animal bears three processes, growing on the frontal bones! The location of these outgrowths offers further evidence of the centrality of the swine, between the ruminants, whose processes are paired, and the rhinoceroses, whose horns grow along the median line of the face.



104. The horned skull of a swine *(Kubanochoerus robustus)* from the Tertiary period (1/10 x).

27 "Denn so hat kein Tier, dem sämtliche Zähne den obern
Kiefer umzäumen, ein Horn auf seiner Nase getragen,
und daher ist den Löwen gehörnt der ewigen Mutter
ganz unmöglich zu bilden, und böte sie alle Gewalt auf.
Denn sie hat nicht Masse genug, die Reihen der Zähne
völlig zu pflanzen und auch Geweih und Hörner zu treiben...."

28 In the cow the cecum is about 24 inches (60 centimeters) in length and in the horse it is fully twice as long! And while part of the horse's esophagus is in fact incorporated into the stomach, this still remains single-chambered, and the esophageal portion makes up less than half of the entire stomach. The development of the cecum is similarly restricted in members of the swine family: the pigs have a short cecum; the hippopotami have none, but instead a multi-chambered stomach (Plate 34).

29 It is said that a female aurochs, killed in 1627 in the East Prussian Lake District, was the last of the species, though another aurochs (or urus, as it is also called) is reported to have lived in the Königsberg Zoo until 1669 (von Lengerken).

30 See also Julius, page 96.

31 The collared pig *(Sus vittatus)*, of the Malayan archipelago, remains spotted even as an adult. In some of the domesticated races, as for example in Hungary (Mangalica pig) and Southeast Asia, the young animals are striped.

32 König (1967) has also noticed that a spotted coloration is connected with the processes of the central organization. "We should not be wrong in thinking that the power of the rhythmic streaming of the blood and breath is the artist that creates this coloration."

33 The antler anomalies described here are rare in the roe deer and moose. Nitsche cites only five such cases in the moose; I was able to find only two more examples in the literature on this subject (Brohmée). In the roe deer only twenty cases had been described by the turn of the century (Nitsche, Brandt, Scheler). More cases must, of course, have been found since that time, but the numbers are still small enough to indicate that such antler anomalies are much less common than the crown formation is in the red deer. The European red deer can develop this formation from the time its antlers reach ten to twelve points. Occasionally, the American red deer (the wapiti, or elk) also has crowned antlers. This formation is rare, however, and found only in the Columbia Basin (Links).

There are many different antler formations. The cup-shaped crown has always been considered typical. Yet Beninde (1940) found that of all the deer reported in the Berlin summary of 1936, only 15 % had genuinely cup-shaped crowns. The other 85 % had forked crowns, in which the points forming the crown did not come together to form a cup; instead they divided into two sections. In these forked antlers we find all the transitional stages between crownless antlers and those that have developed completely cup-shaped crowns. The spaces enclosed by the main antlers and the newly added crowns still interpenetrate, since they have not yet separated completely.

Because of the numerical frequency of their occurence, the forked crowns were regarded by Beninde as the typical formation. Yet his meticulous quantitative analysis does not constitute a conclusive argument. If it did, all formative significance would necessarily be denied the single-beamed antlers of the roe deer, as well as the double palmations of the moose's antlers. And the diaphysis of some of the blossoms on a plant would bring as little proof of the leaf-nature underlying the organs of the blossom. Only an overview of all possible antler forms can reveal the meaning of the single form. Not the numerical frequency, but the morphological significance should be the determining factor in their evaluation. Thus, the crown formation of the red deer's antlers must be regarded primarily as an anomaly in comparison with the basic antler formation of the species. The new, paired formation of antler space may be traced through its transitional stages in the forked antlers to its completion in the finished, cup-shaped crowns.

34 See also Oloff.

35 Haltenorth (1963) and Oloff also mention the inadequacy of the twofold division of the deer family.

36 The fact that these phenomena, so directly visible to the eye, have almost never been seen as meaningful for the organization of the animal as a whole shows once again the extent to which the wholesale application of the theory of natural selection, particularly the application of the idea of random mutation to general evolutionary events, has made us blind to the manifest shape of the animal. It is to Portmann's credit that he has consistently avoided this pitfall (1948 a, b), unlike Rensch (1947) and Haltenorth/Trense (1956) who, for example, consider the horns and antlers to represent an accidental, arbitrary multiplicity of forms, whose individual manifestations must remain utterly incomprehensible.

37 We could also consider the different formations of the whale's spiracles: in the toothed whales, which are more sense oriented, these are unpaired; in the metabolically powerful baleen whales, however, they are paired.

38 Information on carnivorous pygmy antelopes, particularly the duikers, is given by Kurt in Grzimek's *Tierleben* (vol. 13, page 344) and by Stoneham. Dekeyser and Derivot have given accounts of the appearance of canines.

39 Recent studies on the blood serum of the panda indicate a close relationship with the bears (Sarich). But the use of serum reactions is not always reliable. On the basis of this evidence alone we would have to assume that the whales are not related to the carnivores, but to the ungulates. We must take into account the probality that the protein structures of the various animals, as well as their macroscopic features, may have some convergent elements.

40 König (1966) also saw the formative significance of the zonary placenta: "The carnivores have a so-called zonary placenta since they are central animals."

41 One often reads in the professional literature that the typical form of the ungulate placenta is syndesmo-chorial. This is true of the atypical forms, such as sheep, deer, and so forth, but not of cattle. Starck (1959, p. 230 and 233), basing his information on the research of Lederman, Grosser, and especially Björkmann, has stated that the bovine placenta is strictly epithelio-chorial.

42 See Cohrs and Köhler; Gorgas; Kalela; Mohr, 1958; and Sanderson.

43 The Biogenetic Law is generally understood to refer to the similarity between the embryonic and immature postnatal states of the single organism and the developmental history of its ancestors, a history the individual organism recapitulates in abbreviated form. Kielmeyer (1793), Meckel (1811), and Fritz Müller (1864) were the first to discover this similarity. Haeckel (1866, 1874) expressed this phenomenon, observable in so many instances, in the form that has since become famous: "Ontogeny is a shortened recapitulation of phylogeny." This rule, of course, is not a law in the sense of physics.

44 Thus in the crocodile, arterial and venous blood are separated from one another inside the heart; outside, however, this separation is not complete. Left and right aortas are already present in this animal and

venous blood flows through one while arterial blood flows through the other. Yet these large vessels anastomose directly above the heart (at the *foramen pannizae)* and again just below it.

45 In the sharks, a special group among the cartilaginous fishes, which have retained a certain formative plasticity, not only internal fertilization occurs, but in many cases embryonic development takes place inside the mother's body. In a few species (such as *Mustelus* and *Carcharias*) a primitive yolk sac placenta is even present. This organ, which was known and described by Aristotle, was rediscovered in 1840 by Johannes Müller, in the stellate smooth-hound *(Mustelus punctulatus).* Such 'exceptions' are not at all typical of the fish in general.

46 I have been unable to find written reference to this idea of Steiner's; I know it only by word of mouth. I would be grateful for a reference.

47 Hirst's informative book, *Is Nature Cruel?,* which appeared in 1899 and 1926, is available today only in the Library of the British Museum. Long cites many of the accounts given by Hirst.

48 "Anything like the beginning of an ego-consciousness comes upon the animal only at the moment of its death. Yesterday I pointed out that whoever is able to see what actually occurs when an animal dies has some idea of the fact that, properly speaking, what runs through the entire course of a man's life—the consciousness of his own ego—is present in the animal only at the moment of its death" (Steiner, 1918 b; see also 1918 a).

49 "Whoever is able to observe these things knows that when a plant is broken—especially when its upper parts are affected—this injury is not experienced as pain by the organism of the earth. It gives to the earth a feeling of pleasure. This is similar to what takes place when the calf suckles at its mother's breast, a feeling that is also associated with pleasure. For what sprouts forth from the earth in the plants, despite the fact that it is solid—this sprouting green is for the earth's organism similar to the milk given by the animal's body. And when in autumn the reaper cuts through the stalks with his scythe, this is no abstract event to one who has understood the ideas of Spiritual Science and experienced them deeply in his soul; rather the stroke of the scythe means a breath of pleasure that goes out over the field, and the harvesting of the grain sows the field with feelings of pleasure" (Steiner, 1907 b).

50 The lack of clavicles is often attributed to some mechanical advantage. Thus, it is argued, animals with limbs adapted to swimming or running are better able to move these limbs if they are unencumbered by the close connection with the sternum that the collarbone creates. An analysis based on the threefold idea, however, explains even those cases in which there is no obvious functional advantage. For example, among the anteaters only the two-toed anteater (the smallest of the group) has clavicles, while, in both the middle-sized and largest species, these remain rudimentary. Both the two-toed and middle sized species are climbing animals and thus put their forelimbs to the same use. While the armadillos of today possess clavicles, their extinct gigantic ancestors (the glyptodonts), despite the fact that they, too, were ground dwellers, did not. All flying birds *(Carinatae)* have fused collarbones (the 'wish bone'); the enormous ostriches lack them, though their forelimbs are obviously not used for running. Also, the fact that among the amphibians only the sense-active frog, in contrast with the sluggish newts and salamanders, develops collarbones, can be explained easily by our method of direct observation of the animals themselves.

51 "Consequently, we may divide the development of all animals with mineralized or otherwise preservable hard parts into two main stages: an ancient period, which is revealed only to logical thought, can never be observed directly, and during which no bodily parts capable of fossilization (such as bones, teeth, shells, etc.) were yet present, and a more recent one, from which the animals themselves are actually visible in their fossil remains.

"This realization has broad significance; namely, it shows why all beginnings and all transitional stages in the development of the animals must remain forever unknown. Furthermore, it shows why deep and far-reaching processes of cleavage and separation, which could only have occurred in the earliest stages of development, can never be directly accessible to our perception" (Schrammen, 1930; see also 1924 and 1927).

52 See also Poppelbaum (1928), Kipp (1948), and Suchantke (1966).

53 Only a few wild animals have been found to use tools, and these only to a limited extent. The chimpanzee uses grass stalks to catch termites, while the sea otter uses a stone to crack sea urchins. Three birds are also known to make use of tools. The Egyptian vulture cracks ostrich eggs with stones; a Darwin's finch of the Galapagos Islands uses cactus thorns to catch wood worms; and the satin bower bird of New Guinea uses twigs to paint its nest blue (Grzimek)!

54 It is also interesting to note that the earliest vertebrate remains are those of fish that lacked not only paired limbs, but also jaw bones (the *Agnatha* of the Ordovician period). Modern lampreys and hagfishes show just the same peculiarities.

55 Anthropologists of the first half of this century conjectured that the starting point for man was his increased brain size. Yet Thenius has stated (in Grzimek's *Tierleben*, Vol. 11), "We know today that man came into existence not when the size of his brain increased, but when he began to walk upright." Recent paleontological discoveries made in Africa support his point of view; the fossils discovered show all signs of an upright posture, while the brain cases measure only 450—800 cubic centimeters (compared with the gorilla's brain case of 650 cm^3). Only later did the enlargement of the brain take place (in modern man, 1500 cm^3).

56 Among the primates, only the anthropoid apes show a similar transition from a diffuse to a centered placenta, though the latter has a reniform rather than discoidal shape. In all monkeys placental development is accelerated, and their placenta, like the rodents', has a centered form from the beginning. It eventually becomes so asymmetrical that it divides into two sections, one of which is larger than the other (bidiscoidal placenta).

The main difference between man's embryological development and the anthropoid ape's is the fact that man's embryo, unlike the ape's, shows a high degree of individual variability during the earliest stages of development (Starck, 1956 b).

57 Peiper himself noticed this fact: "In comparison with the altricial animal the newborn precocial one must be considered to have been carried too long by its mother."

58 "Among the precocial animals ossification is so advanced at birth that it has reached a stage of development attained by man only at puberty" (Pflugfelder).

59 The following figures are approximate averages, based on the works of Grzimek (1967), Harms, Schultz, and Starck **(1955).**

Original drawings by: Christian Brügger, Zurich, 1 d, 4, 6, 7, 9, 10, 11, 14, 15, 17, 19, 21, 22, 23, 25, 27, 28, 29, 33, 41, 42, 48, 53, 56, 59, 60, 62, 66, 79, 80, 81, 92, 93, 94, 98, 99, 103. Ursula Jellinek-Köhler, Bochum, 5, 10, 14, 16, 82, 88. Wolfgang Schad, Stuttgart, 1 c, 12, 13, 44, 46, 51, 55, 61, 68, 75, 78, 87, 95, 103. Andreas Suchantke, Zurich, 74. Ulrich Winkler, Stuttgart, 2, 3, 7, 8, 18, 20, 24, 27, 28, 30, 32, 35, 36, 37, 38, 39, 40, 43, 45, 47, 49, 50, 52, 54, 55, 57, 58, 63, 64, 65, 67, 69, 70, 71, 72, 76, 77, 83, 85, 86, 89, 91, 97, 100, 101, 104.

Drawings from the publications of: Brehm, 31, 102. Dandelot, 36. Gaffrey, 26. Kingdon, 90, 96. Lemozi, 84. Matthes-Kükenthal, 1 b. Oloff, 73. Portmann, 1 a. Verheyen, 34. Weber, 1 d, 12, 13.

Photographs: T. Angermayer, Munich, 113. W. Baier, Munich, 182, 183. D. Bartlett, Armand Denis Productions, Nairobi, 120, 164, 180. C. Bartmann, Rinsecke/Kirchhundem, 126. J. Behnke, Wetzlar, 139. G. Budich, Berlin, 127. U. Demmer, Vienna, 152. L. Dorfmüller-Laubmann, Munich, 166, 167, 168. R. Eben-Ebenau, 147. O. von Frisch, Braunschweig, 134. Th. Göbel, Niefern/Pforzheim, 177. P. S. Hahn, Ingelheim, 181. R. Herzog, Wiesbaden, 156. International Press Photo Service, 118. J. Klages, Zurich, 109, 155. E. Knöll-Siegrist, Basel, 128, 153. L. Koch-Isenburg, Neu-Isenburg, 106. G. Krienke 174. A. Niestle, Bielefeld, 121, 142. J. von Oertzen, Dommelstadt/Niederbayern, 163. Okapia, Frankfurt/Main, 141, 178. H. Orth, Worms, 125. E. Parbst, 129. Paris Match No. 796, 1964, 172. Photo Rene, Rasac-sur-l'Isle, France, 132. P. Popper, London, 119, 157, 169, 170, 179. Probst, Anthony-Verlag, Starnberg, 137. G. Quedens, Norddorf/Amrum, 110. J. Roedle, Tubingen, 140, 143. W. Rohdich, 145. K. S. Sankhala, New Delhi, 171. Sauer, Düsseldorf, 108. W. Schad, Stuttgart, 107, 114 a, b, 115, 116, 117, 136, 154, 162. E. Schiele, Dornap, 124. O. Schmid, Amriswil, Switzerland, 144. G. Schuh, Küsnacht, Switzerland, 130. E. Schulthess, Zurich, 131. Simon, Munich, 175. W. Sittig, Hannov.-Münden,138. S.M. Stapinski, 173. A. Suchantke, Zurich, 135. W. Suschitzky, 161. G. Tönnies, Lüneburg, 159. C. A. von Treuenfels, Neu-Horst, 148. Ullstein-Bilderdienst, Berlin, 146. V-Dia-Verlag, Heidelberg, 122, 123. E. Wadewitz, 149. Zippelius, Leu Sirman Press, Genf, 176.

Bibliography

Abel, O. 1914. *Die vorzeitlichen Säugetiere.* Jena.

Accordi, B. *1974.* Zwergelefanten auf Sizilien. *Die Drei,* vol. 44, no. 11: 547-59. Stuttgart.

Alpers, A. 1962. *Delphine, Wunderkinder des Meeres.* Bern and Stuttgart.

Arrow, G. J. 1951. *Horned beetles.* p. 54. The Hague.

Assheton, R. 1910. Professor Hubrecht's paper on early ontogenetic phenomena in mammals, an appreciation and a criticism. *Quarterly Journal of Microscopical Science,* n. s. 54. London.

Backhaus, D. 1959. Experimentelle Prüfung des Farbsehvermögens einer Massai-Giraffe. *Zeitschrift für Tierpsychologie,* vol. 16: 468-77. Berlin.

Baer, C. E. von. 1827. *De ovi mammalium et hominis genesi epistola.* Leipzig.

Baier, W. 1964. Gefährdungen des frühembryonalen Lebens. *Veterinärmedizinische Nachrichten,* no. 3: 155-70. Marburg.

Bauer, J. 1921. *Die konstitutionelle Disposition zu inneren Krankheiten.* 2nd ed. Berlin.

Benedict, F. G. 1936. *The physiology of the elephant.* Washington.

Beninde, J. 1937 a. *Zur Naturgeschichte des Rothirsches.* Leipzig.

——• 1937 b. Über die Edelhirschformen von Mosbach, Mauer und Steinheim a. d. Murr. *Palaentologische Zeitschrift,* vol. 19, no. 1/2: 79—116. Berlin.

——1940. Die Krone des Rothirschgeweihes. *Zeitschrift für Säugetierkunde,* vol. 15. Hamburg and Berlin.

Björkmann, N. and Bloom, G. 1957. On the fine structure of the foetal-maternal junction in the bovine placentome. *Zeitschrift für Zellforschung und mikroskopische Anatomie,* vol. 45: 649-59. Berlin.

Blainville, H. M. D. de. 1834. *Cours de Ia faculte des sciences.*

Bleuler, E. 1966. *Lehrbuch der Psychiatrie,* p. 507. lOth ed. Berlin, Heidelberg, and New York.

Bockemühl, J. 1962. Lebensrhythmen im Pflanzen- und Tierreich. *Sternkalendar 1962/63,* p. 66-71. Dornach.

——1967. Äußerungen des Zeitleibes in den Bildebewegungen der Pflanzen. *Elemente der Naturwissenschaft,* no. 7: 25-30. Dornach.

Boetticher, H. von. 1941. Somatolyse, insbesondere bei Zebras. *Zeitschrift für Säugetierkunde,* vol. 16. Hamburg and Berlin.

Bogoljubsky, S. 1930. Morphogenese der Schädel der Bovidae. *Revue Zoologique russe,* vol. 10, no. 1: 3-57. Moscow.

Bolk, L. 1926. *Das Problem der Menschwerdung.* Jena.

Bourliere, F. 1951. *Vie et Moeurs des Mammiferes.* Paris.

Brambell, F. W. R. 1942. Intra-uterine mortality of the wild rabbit *Oryctolagus cuniculus. Proceedings of the Royal Society,* vol. 130: 462 ff. London.

——1944. The reproduction of the wild rabbit. *Proceedings of the Zoological Society of London,* vol. 114: 1-45. London.

Brandt, J. F. 1855. Untersuchungen über die craniologischen Entwicklungsstufen und die davon herzuleitenden Verwandtschaften und Classifikationen der Nager der Jetztzeit, mit besonderer Beziehung auf die Gattung *Castor. Beiträge zur näheren Kenntnis der Säugetiere Rußlands. Memoires de l'Academie Imperiale des Sciences,* vol. 7: 125-336. Petersburg.

Brandt, K. 1897. Rehbockgehörne mit verwachsenen Stangen. *Zwinger und Feld, Illustrierte Wochenschrift für Jägerei:* 584-93. Stuttgart.

Brehm, 1890. *Tierleben,* 10 volumes, 3rd ed. Leipzig and Vienna.

Brink, F. H. van den. 1957. *Die Säugetiere Europas.* (Trans. 1968. *A field guide to the mammals of Britain and Europe.* Cambridge) Hamburg and Berlin.

Brohmee, F. 1949. *Das Elchwild.* Neudamm.

Broman, I. 1938-39. Einige Erfahrungen aus einer Giraffenjagd. *Der Zoologische Garten,* n. s. 10: 84-94. Leipzig.

———1941. Notiz über die Gesichtswarzenanlagen bei drei 19-22 cm langen Warzenschweinfeten. *Anatomischer Anzeiger,* vol. 90: 243-48. Jena.

Brooke, V. 1878. On the Classification of the *Cervidae. Proceedings of the Zoological Society of London,* p. 883. London.

Bruhin, H. 1953. Zur Biologie der Stirnaufsätze bei Huftieren. *Physiologia comparata et Oecologia,* vol. 3. The Hague.

Bubenik, A. and Pavlansky, R. 1955-56. Von welchem Gewebe geht der eigentliche Reiz zur Geweihentwicklung aus? */. und II. Säugetierkundliche Mitteilungen,* vol. 3: 49 ff. and vol. 4: 97 ff. Stuttgart.

Bünning, E. 1952. Ein Blick in die Lebensforschung. Rector's Speech in *Universität Tübingen,* no. 41, p. 33. Tübingen.

Burt, W. H. and Grossenheider, R. P. 1964. *A field guide to the mammals.* Cambridge, Mass.

Caesar, C. J. *De hello Gallico,* vol. 6, book 28.

Challou, A. and MacAuliffe, L. 1912. *Morphologie medicale, Etüde des quatre types humains.* Paris.

Cohrs, P. and Köhler, H. 1959. Tod und Todesursachen bei Säugetieren. *Handbuch der Zoologie,* vol. 8, no. 20, 11 (5): 1-36. Berlin.

Danzer, A. 1966. *Tortpflanzung, Entwicklung, Entwicklungsphysiologie.* p. 69-70. Heidelberg.

Dekeyser, P. and Derivot, J. 1956. Sur la presence des canines superieures chez les Bovides. *Bulletin de l'Institut francais d'Afrique Noire Dakar,* vol. 18, ser. A: 1272-81. Paris.

Delacato, C. H. 1970. *Diagnose und Behandlung der Sprach- und Lesestörungen.* Freiburg.

Dieterlein, F. 1963. Stachelmäuse sind gute Hebammen. *Das Tier,* vol. 3, no. 10: 42-43. Stuttgart and Bern.

Dorst, J. and Dandelot, P. 1970. *A field ,guide to the larger mammals of Africa.* London.

Duerst, U. 1926. Das Hörn der *Cavicornia. Denkschriften der Schweizerischen Naturforschenden Gesellschaft,* vol. 63, sec. 1: 1-180. Zürich.

Dyk, V. 1959. Fleckung bei Karpatenhirschen. *Zeitschrift für Jagdwissenschaft,* vol. 5, no. 1: 67-69. Hamburg and Berlin.

Eccles, J. C. 1970. Facing reality—philosophical adventures by a brain scientist. New York.

———1973. The understanding of the brain. New York.

Eibl-Eibesfeldt, I. 1969. *Grundriss der vergleichenden Verhaltensforschung, Ethologie.* 2nd ed. p. 474. Munich.

Fortlage, C. 1869. Über die Natur der Seele. In *Acht psychologische Vorträge.* Jena.

Freund, F. 1892. Beiträge zur Entwicklung der Zahnanlagen bei Nagetieren. *Archiv für mikroskopische Anatomie*, vol. 39. Berlin.

Gabunia, L. K. 1958. Über den Schädel eines ausgegrabenen gehörnten Schweines aus dem mittleren Miozän des Kaukasus. *Berichte der Akademie der Wissenschaften der USSR*, vol. 118, no. 6: 1187-90 [in Russian]. Moscow.

Gaffrey, G. 1961. *Merkmale der wildlebenden Säugetiere Mitteleuropas.* Leipzig.

Gebser, J. 1956. *Abendländische Wandlung. Abriß der Ergebnisse moderner Forschung in Physik, Biologie und Psychologie, ihre Bedeutung für Gegenwart und Zukunft.* Frankfort.

Gehlen, A. 1966. *Der Mensch.* 8th ed. Frankfort.

Gerlach, R. 1951. *Die Vierfüßler.* Hamburg.

Geyer, H. 1940. Über Hirnwindungen bei Zwillingen. *Zeitschrift für Morphologie und Anthropologie*, vol. 8. Stuttgart.

Gidley, J.W. 1912. The *Lagomorpha*, an independent order. *Science*, n. s. vol. 36, no. 922: 285-86. Washington.

Göbel, T. 1968a. Das Fruchtblatt in der Pflanzenmetamorphose. *Elemente der Naturwissenschaft*, no. 8: 44—54. Dornach.

———1968b. Die Metamorphose des Fruchtblattes. *Die Drei*, vol. 38, no. 5: 289-305. Stuttgart.

Goethe, J. W. 1784. Dem Menschen wie den Tieren ist ein Zwischenknochen der oberen Kinnlade zuzuschreiben. First printed in *Zur Morphologie*, vol. 1, no. 2, 1820. Reprinted in dtv-Gesamtausgabe, vol. 37, p. 7 ff. Munich, 1962.

———1790. /. *W. von Goethes Herzoglich Sachsen-Weimarischen Geheimenraths Versuch, die Metamorphose der Pflanzen zu erklären.* Gotha.

•———1795. Erster Entwurf einer allgemeinen Einleitung in die Vergleichende Anatomie ausgehend von der Osteologie. Reprinted in dtv-Gesamtausgabe, vol. 37, p. 88. Munich, 1962.

———1824. Die Skelette der Nagetiere. First printed in *Zur Morphologie*, vol. 2, no. 2, 1824. Reprinted in dtv-Gesamtausgabe vol. 37, p. 136 ff. Munich, 1962.

———1829. *Wilhelm Meisters Wander jähre, 2. Teil.* Reprinted in dtv-Gesamtausgabe, vol. 18, p. 57. Munich, 1962.

———*Faust, 2. Teil,* lines 5405-38.

Gorgas, M. 1962. Das Rätsel der Lemmingwanderung. *Freunde des Kölner Zoo, Mitteilungen der AG Zoologischer Garten Köln*, vol. 5, no. 2: 58-59. Cologne.

Graf, W., Porje, I. G., and Allgoth, A. M. 1955. Observations on the temperature of human liver parenehyma. *Gastroenterologia*, vol. 83: 233-43.

Grauwiler, J. 1965. *Herz und Kreislauf der Säugetiere, vergleichend-funktionelle Daten.* Basel and Stuttgart.

Grayson, J. and Kinnear, T. 1963. The temperature of the human liver. *Federation Proceedings*, vol. 22: 775-76.

Grohmann, G. 1961. Kurzgefasster Abriß von der Lehre der Dreigliederung des Menschen. *Erziehungskunst*, vol. 25, no. 7: 193-96. Stuttgart.

Grosser, O. 1909. *Vergleichende Anatomie und Entwicklungsgeschichte der Eihäute und der Plazenta.* Vienna and Leipzig.

Grzimek, B. 1956. *Thulo aus Frankfurt, rund um die Giraffe.* Stuttgart.

———1959. *Serengeti darf nicht sterben*, p. 70-72. Berlin.

———1965. Die Hälfte der Kaninchenkinder wird nie geboren. *Das Tier*, vol. 5, no. 11: 4-10. Bern and Stuttgart.

———1967 ff. *Tierleben.* (Trans. 1974, *Grzimek's animal life encyclopedia.* New York: Van Nostrand Reinhold Company.) Zürich.

Guggisberg, C. A. W. 1960. Ein Bild, das Hunderttausende erschütterte. Sind Löwen wirklich so grausam? *Das Tier,* vol. 1, no. 1: 18-21. Stuttgart and Bern.

Haeckel, E. 1866. *Generelle Morphologie der Organismen,* 2 vols. Berlin.

———1874. *Anthropogenie oder Entwicklungsgeschichte des Menschen.* Leipzig.

Hahn, H. 1959. *Von Baum-, Busch- und Klippschliefern, den kleinen Verwandten der Seekühe und Elephanten.* Die Neue Brehm-Bücherei, no. 246. Wittenberg Lutherstadt.

Haltenorth, T. 1953—55. Säugetiere. In *Kosmoslexikon der Naturwissenschaften mit besonderer Berücksichtigung der Biologie. 2* vols. Stuttgart.

———1957. *Die Wildkatze.* Die Neue Brehm-Bücherei, no. 189. Wittenberg Lutherstadt.

———1963. Klassifikation der Säugetiere: *Artiodactyla* I (18). *Handbuch der Zoologie,* vol. 8 *(Mammalia),* no. 32: 1-167. Berlin.

Haltenorth, T. and Trense, W. 1956. *Das Großwild der Erde und seine Trophäen.* Munich.

Hassenstein, B. 1969. Aspekte der „Freiheit" im Verhalten von Tieren. *Universitas,* vol. 24, no. 12: 1325-30. Stuttgart.

Hautmann, F. 1924. Über die Nektarhefe *Anthomyces reukaufii. Archiv für Protistenkunde,* vol. 48: 213-44. Jena.

Hediger, H. 1976. Das Leiden der Tiere in zoologischer Sicht. *Universitas,* vol. 31, no. 1: 79-90. Stuttgart.

Heisenberg, W. 1958. Das Naturbild der heutigen Physik. In *Rowohlts Deutsche Enzyklopädie.* 6th ed. no. 8: 21. Reinbek.

Hemleben, J. 1965. *Rudolf Steiner und Ernst Haeckel.* Stuttgart.

Hensel, H. 1972. Anpassung in der Physiologie des Menschen, Erkenntnisse medizinischer Forschung. *Universitas,* vol. 27, no. 11: 1163-72. Stuttgart.

Herre, W. 1951. Tierwelt und Eiszeit. *Biologia generalis,* vol. 19. Vienna and New York.

Herre, W. and Kesper, K. D. 1953. Zur Verbreitungsgeschichte von *Ovis ammon* in Europa. *Zoologischer Anzeiger,* vol. 151: 204-9. Leipzig.

Herre, W. and Rohrs, M. 1955. Über die Mannigfaltigkeit des Gehörnes der *Caprini* Simpson 1945. *Der Zoologische Garten,* n. s. 22, no. 1: 85-110. Leipzig.

Herter, K. 1940. Psychologische Untersuchungen an einem Mauswiesel *(Mustela nivalis L.). Zeitschrift für Tierpsychologie,* vol. 3, no. 3: 249-63. Hamburg and Berlin.

Heyerdahl, T. 1950. *Kon-Tiki: Across the Pacific by raft.* Chicago.

Hildebrandt, G. 1967a. Störungen der biologischen Rhythmik. *Die Heilkunst,* vol. 80, no. 9: 1—10.

———1967 b. Rhythmusprobleme der unstimmenden Therapie. *Allgemeine Therapeutik,* vol. 7, no. 6: 202-14.

Hirst, J. C. 1926. *Is nature cruel? A partial answer to the question. Experiences of big game hunters and others while under the attack of wild beasts.* 2nd ed. London.

Hörauf, K. 1958. *Form und Stellung der Frontzähne in ihrer Beziehung zu Körperbautypen.* 2nd ed. Munich.

Hofstetter, R. and Lavocat, R. 1970. Decouverte dans les Deseadien de Bolivie des genres *Pentalophodontes* appuyant les affinites africaines des rongeurs caviomorphes. *Comptes Rendus Hebdomadaires des Seances de l'Academie des Sciences,* ser. D, vol. 271: 172-75.

Holmberg, L. 1966. Wie klug ist der Biber? *Das Tier,* vol. 6, no. 10: 4-9. Stuttgart and Bern.

Howell, A. B. 1930. *Aquatic mammals.* Springfield, Illinois and London.

Husemann, F. 1921. Beiträge zur Entwicklungsgeschichte des menschlichen Bewußtseins. *Die Drei*, vol. 1, no. 5/6: 556-64. Stuttgart.

Huxley, T. H. 1971. *A manual of the anatomy of vertebrated animah.* p. 281-2. London.

Julius, F. H. 1970. *Das Tier zwischen Mensch und Kosmos, neue Wege zu einer Charakteristik der Tiere.* Stuttgart.

Kakies, M. 1965. *Elche am Meer,* Leer, East Frisia.

Kalela, O. 1961. Wanderungen. In *Handbuch der Zoologie*, vol. 8 *(Mammalia),* no. 27. Part 11: 1-40. Berlin.

Kesper, K. D. 1953. Phylogenetische und entwicklungsgeschichtliche Studien an den Gattungen *Capra* und *Ovis.* Dissertation. Kiel.

Kielmeyer, K. F. 1793. Über die Verhältnisse der organischen Kräfte untereinander in der Reihe der verschiedenen Organisationen, die Gesetze und Folgen dieser Verhältnisse. Speech given in 1793. First printed 1793. Reprinted 1814, Tübingen.

Kingdon, J. 1971. *East African mammals.* vol. 1. London.

Kipp, F. 1942. Das Kompensationsprinzip in der Brutbiologie der Vögel. In *Beiträge zur Fortpflanzungsbiologie der Vögel,* vol. 18: 52—59.

———1948. *Höherentwicklung und Menschwerdung.* Stuttgart.

———1949. Arterhaltung und Individualisierung in der Tierreihe. *Verhandlungen der Deutschen Zoologen in Mainz,* p. 23-27. Mainz.

———1952. Bezahnung und Bildungsidee des Organismus. *Der Beitrag der Geisteswissenschaft zur Erweiterung der Heilkunst—ein anthroposophisch-medizinisches Jahrbuch,* vol. 3, p. 203-17. Stuttgart.

———1955. Die Entstehung der menschlichen Lautbildungsfähigkeit als Evolutionsproblem. *Experientia,* vol. 11, no. 3: 89-94. Basel.

Kirchshofer, R. 1961. Hirschferkel und andere primitive Hirsche. *Kosmos,* vol. 52, no. 2: 76-81. Stuttgart.

Klein, W. and Müller, R. 1941. Das Eiweißminimum, die zymogene Symbiose und die Erzeugung von Mikrobeneiweiß im Pansen aus Stickstoffverbindungen nichteiweißartiger Natur. *Zeitschrift für Tierzüchtung und Züchtungsbiologie,* vol. 48: 255-76. Berlin.

Klingel. In Grzimek's *Tierleben,* vol. XIII, p. 59.

König, K. 1927-28. Über die Grundkräfte, welche den menschlichen Embryo gestalten. *Natura,* vol. 2: 108-18. Dornach.

———1962. The image of man—as it pertains to our villagers. Unpublished lecture, recorded by C. A. Lindenberg. Bieldside/Aberdeen (Scotland): The Camphill-Rudolf Steiner Schools.

———1963. *Die ersten drei Jahre des Kindes.* (Trans. 1969. *The first three years of the child.* New York.) Stuttgart.

———1966. *Embryologie und Weltentstehung.* 6 lectures. Freiburg.

———1967. *Bruder Tier.* pp. 197 and 217. Stuttgart.

Kolisko, E. 1921. Die Dreigliederung des menschlichen Organismus. *Die Drei,* vol. 1, no. 5/6: 541-55. Stuttgart.

———1926. Gedanken zur anthroposophischen Tierkunde. *Gäa-Sophia Jahrbuch,* vol. 1: 254-62. Dornach.

Kosmos-Lexikon der Naturwissenschaften. Stuttgart, 1953.

Kozhantschikov, I. 1930. Ein Beitrag zur Kenntnis der Ökologie, Biologie und Geographie des Zobels. *Zeitschrift für Morphologie und Ökologie der Tiere,* vol. 19, no. 2/3: 291-320. Berlin.

Kraft, A. von. 1963. Larvengestalt und Eingeweidesitus beim Alpenmolch nach halbseitiger UV-Bestrahlung von Neurula- und Nachneurulakeimen. In *Wilhelm Roux' Archiv für Entwicklungsmechanik der Organismen,* vol. 160, p. 259-97. Berlin.

Kramer, H. 1963. *Elchwald.* Munich, Basel and Vienna.

Kretschmer, E. 1967. *Körperbau und Charakter.* 25th ed. (First printed 1944). Berlin, Heidelberg and New York.

Krölling, O. 1942. Zur Frühentwicklung der Extremitäten beim Pferd. *Zeitschrift für Anatomie und Entwicklungsgeschichte,* vol. 111: 490-507. Berlin.

Krott, P. 1962. Dichtung und Wahrheit über die Alpenbären. *Kosmos,* vol. 58, no. 4: 137-43. Stuttgart.

Krummbiegel, I. 1952. *Lamas.* Die Neue Brehm-Bücherei, no. 54. Leipzig.

———1953-55, *Biologie der Säugetiere.* 2 vols. Krefeld.

———1958. *Einhufer.* Die Neue Brehm-Bücherei, no. 208. Wittenberg Lutherstadt.

Kuntze, 0.1891. InBrehm's *Tierlehen.* 3rd ed., vol. 3, p. 305. Leipzig and Vienna.

Landry, S. O. 1957. *The interrelationship of the New and Old World histriocomorph rodents.* University of California Publications in Zoology, vol. 56, no. 1: 1-118. Berkeley and Los Angeles.

Lang, E. M. 1959. Goma, das Basler Gorillakind. *Documenta Geigy,* Bulletin 1. Basel.

Lechner, S. 1970. Bären haben in den Alpen ein Heimatrecht. *Das Tier,* vol. 10, no. 12: 36-39. Stuttgart and Bern.

Lemozi, A. 1929. *La Grotte-Temple du Pech-Merle.* Paris.

Lengerken, H. von. 1953. *Der Ur und seine Beziehungen zum Menschen.* Die Neue Brehm-Bücherei, no. 105. Wittenberg Lutherstadt.

Leonhardt, H. 1967. *Histologie und Zytologie des Menschen, eine Einführung für Ärzte und Studenten.* Stuttgart.

Linke, W. 1955. *Der Rothirsch.* Die Neue Brehm-Bücherei, no. 145. Wittenberg Lutherstadt.

Linne, C. von. 1735. *Systema naturae.* First printed 1735. lOth ed. 1758. Stockholm.

Livingstone, D. 1858. *Missionary travels in South Africa.* New York.

Long, W. J. 1956. *The spirit of the wild.* Garden City.

———1958. *Mother Nature, a study of animal life and death.* Garden City.

Lorenz, K. 1959. Psychologie und Stammesgeschichte. In *Evolution der Organismen,* ed. G. Heberer. Stuttgart.

———1963. Die Erfindung von Flugmaschinen in der Evolution der Wirbeltiere, *die therapie des monats* (Boehringer), no. 13. Mannheim.

Magerstädt, K. 1950. Die Haut und die Dreigliederung. *Beiträge zu einer Erweiterung der Heilkunst nach geisteswissenschaftlichen Erkenntnissen,* vol. 3, no. 3/4: 87-90. Stuttgart.

———1956. Die Haut und ihre Dreigliederung. In Husemann, F. *Das Bild des Menschen als Grundlage der Heilkunst,* vol. 2, p. 661. Stuttgart.

McAnally, R. A. and Philipson, A. T. 1944. Digestion in the ruminant. *Biological Revue,* vol. 19: 41—54.

Meckel, J. F. 1811. System einer Darstellung der zwischen dem Embryonalzustand der höheren Tiere und dem permanenten der niederen stattfindenden Parallele. *Beiträge zur vergleichenden Anatomie,* vol. 2. Leipzig.

Milne, L. J. and M. 1968. *Die Sinneswelt der Tiere und des Menschen.* Hamburg and Berlin.

Mitscherlich, A. 1967. Trauer nach Terminkalender. *Die Zeit*, no. 47: 18.
Mohr, E. 1952. *Der Wisent.* Die Neue Brehm-Bücherei, no. 74. Leipzig.
———1957. *Sirenen oder Seekühe.* Die Neue Brehm-Bücherei, no. 197: Wittenberg Lutherstadt.
———1958. *Säugetiere. Sammlung naturkundlicher Tafeln,* ed. E. Cramer. Hamburg.
———1959. *Das Urwildpferd.* Die Neue Brehm-Bücherei, no. 249. Wittenberg Lutherstadt.
———1960. *Wilde Schweine.* Die Neue Brehm-Bücherei, no. 247. Wittenberg Lutherstadt.
Moore, R. S. and Moore, D. N. 1975. *Better late than early, a new approach to your child's education.* New York.
Müller, F. 1864. *Für Darwin.* Leipzig.
Müller, J. 1840. Über den glatten Hai des Aristoteles. *Abhandlungen der Berliner Akademie.* Berlin.
Müller-Using, D. and Haltenorth, T. 1954. Simpsons Neuordnung der *Mammalia* in ihre Bedeutung für die deutsche Säugetierkunde. *Säugetierkundliche Mitteilungen,* vol. 2: 102-9. Stuttgart.
Nitsche, H. 1891. Studien über das Elchwild. *Zoologischer Anzeiger,* vol. 14: 181-91. Leipzig.
———1898. Untersuchungen über mehrstangige Geweihe und die Morphologie der Huftierhörner im allgemeinen. *Studien über Hirsche, Part 1.* Leipzig.
Ognew, S. I. 1959. *Säugetiere und ihre Welt.* German trans. (First printed 1951, Moscow.) Berlin.
Oken, L. 1837. Vögel. In *Allgemeine Naturgeschichte für alle Stände.* Stuttgart.
———1838. Haartiere. In *Allgemeine Naturgeschichte für alle Stände.* Stuttgart.
Oloff, H.B. 1955. Rotwild. In *Jagd und Hege in aller Welt, Erinnerungswerk an die Internationale Ausstellung Jagd und Sportfischerei Düsseldorf 1954.* Düsseldorf.
Ortega y Gasset, J. 1957. Über die Jagd, *rowohlts deutsche enzyklopädie,* no. 42. Reinbek.
Paede, P. 1948. Eine dynamische Anatomie des Herzens. *Ärzterundbrief der Arbeitsgemeinschaft anthroposophischer Ärzte,* no. 9/10. Stuttgart.
Pantenburg, V. 1965. Moschusochsen werden gezähmt. *Der Kleine Tierfreund,* vol. 11: 13. Mainz.
Pedersen, A. 1958. *Der Moschusochs.* Die Neue Brehm-Bücherei, no. 215. Wittenberg Lutherstadt.
———1962. Verhalten und Lebensweise des nordischen Braunbären. *Kosmos,* vol. 58, no. 12: 505-10. Stuttgart.
Peiper, A. 1955. Der menschliche Säugling als Nesthocker und Nestflüchter. *Kinderärztliche Praxis,* vol. 23: 507—9. Leipzig.
Pflugfelder, O. 1962. *Lehrbuch der Entwicklungsgeschichte und Entwicklungsphysiologie der Tiere,* p. 278. Jena.
Pilleri, G. 1959—60. Beiträge zur vergleichenden Morphologie des Nagetiergehirnes. *Acta anatomica,* Supplements 38 and 40. Basel.
———1962a. Die zentralnervöse Rangordnung der *Cetacea (Mammalia). Acta anatomica,* Supplement 51: 241-58. Basel.
———1962 b. Biber sind findige Köpfe. *Das Tier,* vol. 2, no. 11: 12-15. Stuttgart and Bern.
Poppelbaum, H. 1949. Hörner und Geweihe. *Sternkalender 1950,* vol. 22: 59-65. Dornach.

———1954. *Tier-Wesenskunde.* 2nd. ed. First printed 1937. Dornach.
———1956. *Mensch und Tier, fünf Einblicke in ihren Wesensunterschied.* 6th ed. (Trans. 1931. *Man and animal. Their essential difference.* New York.) First printed 1928. Dornach.
Portmann, A. 1938-39. Die Ontogenese der Säugetiere als Evolutionsproblem I u. IL *Biomorphis,* vol. 1: 49-66 and 109-26. Basel and New York.
———1948. *Die Tiergestalt, Studien über die Bedeutung der tierischen Erscheinung.* (Trans. 1952. *Animal forms and patterns.* London.) Basel.
———1957. Die Erscheinung der lebendigen Gestalten im Lichtfelde. In *Wesen und Wirklichkeit des Menschen, Festschrift für Helmut Plessner,* ed. K. Ziegler. Göttingen.
———1958. *Meerestiere und ihre Geheimnisse,* p. 51-53. Basel.
———1959. Zoologie und das neue Bild des Menschen, biologische Fragmente zu einer Lehre vom Menschen, *rowohlts deutsche enzyklopädie.* 3rd ed. Reinbek.
———1960. *Neue Wege der Biologie*, p. 149. Munich.
———1962. Zerebralisation und Ontogenese. *Medizinische Grundlagenforschung,* vol. 4: 1-62. Stuttgart.
———1965. Erhaltung und Erscheinung als Aufgaben des Lebendigen. *Naturwissenschaften und Medizin,* vol. 2, no. 8: 3-17. Mannheim.
———1969. *Einführung in die vergleichende Morphologie der Wirbeltiere,* 2nd ed. First printed 1948. Basel.
Rau, A. 1931. *Das Rehgehörn*, pp. 219 and 226. Neudamm.
Rauber, A. and Kopsch, F. 1912. *Lehrbuch der Anatomie des Menschen,* vol. 5, p. 731. Leipzig.
Ray, J. 1963. *Synopsis methodica animalium quadrupedum et serpentini generis.* London.
Rensch, B. 1947. *Neuere Probleme der Abstammungslehre.* Stuttgart.
Rhumbler, L. 1911. Über die Abhängigkeit des Geweihwachstums der Hirsche, speziell des Edelhirsches vom Verlauf der Blutgefäße im Kolbengeweih. *Zeitschrift für Forst- und Jagdwesen,* p. 295-314. Berlin.
———1913. Fehlt den Cerviden das *Os cornu? Zoologischer Anzeiger*, vol. 42: 81-95. Leipzig.
Riemann, B. 1923. *Über die Hypothesen, welche der Geometrie zu Grunde liegen.* 3rd. ed. Berlin.
Ritter, G. 1935. Hörn und Geweih. *Sternkalender 1935136,* vol. 7: 53-57. Dornach.
Roger. 1886-87. Über die Hirsche. *Bericht des naturwissenschaftlichen Vereins,* p. 51-93. Regensburg.
Romer, A. S. 1971. *The vertebrate story.* Chicago.
Sanderson, I. T. 1956. *Knauers Tierbuch in Farben, Säugetiere.* Munich and Zürich.
Sarich, V. M. In *Nature,* vol. 245, no. 5422: 218-20.
Schad, W. 1965. Stauphänomene am menschlichen Knochenbau. *Elemente der Naturwissenschaft,* no. 3: 15-27. Dornach.
———1966. Biologisches Denken. *Elemente der Naturwissenschaft,* vol. 5: 10-19. Dornach.
———1969 a. Friedrich Siegmund Voigt und Albert Wigand. *Elemente der Naturwissenschaft,* vol. 10: 48-49. Dornach.
———1969 b. Die Ohr-Organisation. *Die Drei,* vol. 39, no. 5: 335-48. Stuttgart.
———1970. Zum Todesgeschehen in der Natur, eine Seite des Darwinismus. *Die Drei,* vol. 40, no. 2: 66-75. Stuttgart.

Schaub, S. 1953. Remarks on the distribution and Classification of the *Hystricomorpha. Verhandlungen der naturforschenden Gesellschaft Basel,* vol. 64: 389-400. Basel.

Scheffer, V. B. 1958. *Seals, sea lions and walruses. A revlew of the Pinnipedia.* London and Stanford.

Scheler, G. Graf von. 1892. Über die Ursachen abnormer Geweihentwicklung insbesondere der Bildung von mehr als zwei Geweihstangen. *Jahreshefte des Vereins für vaterländische Naturkunde in Württemberg,* p. 135-78, plates 3-6. Stuttgart.

Scheunert, A. 1932. Magen. In *Handwörterbuch der Naturwissenschaften,* 2nd ed. vol. 6, p. 622-38. Jena.

Schmidt, P. 1965. *Das Jahr des Rehes,* pp. 32 and 149. Basel.

Schmücker, K. 1932. Die manometrische Messung des Luftaustausches in der Kieferhöhle und ihre praktische Bedeutung. *Zeitschrift Hals-, Nasen- und Ohrenheilkunde,* vol. 30: 638-46. Berlin.

Schrammen, A. 1910—12. Die Kieselspongien der oberen Kreide von Nordwestdeutschland, Parts 1 and 2. *Palaeontographica,* Supplement vol. 10: 1-374. Stuttgart.

———1924. op. cit., Part 3. *Monographien zur Geologie und Palaeontologie,* ser. 1, no. 2: 1-154. Berlin.

———1927. Die Lösung des Ceratitenproblems. *Zeitschrift der deutschen geologischen Gesellschaft,* vol. 79: 26—42. Berlin.

———1930. *Die gesetzmäßigen Ursachen der Umbildung und des Verganges der Tierwelt und des Menschen.* Hildesheim and Leipzig.

Schreber, J. C. D. von. 1775. *Die Säugthiere in Abbildungen nach der Natur mit Beschreibungen. 7* vols. (Supplements 1-5 completed by J. A. Wagner, 1855. Leipzig) Erlangen.

Schubert, G. H. 1837. *Die Geschichte der Natur,* vol. 3. p. 447. Erlangen.

———1850. *Die Geschichte der Seele,* vol. 1, 4th ed. Stuttgart and Tübingen.

Schultz, A. H. 1956. Postembryonic age changes. *Primatologia, Handbuch der Primatenkunde,* vol. 1: 887-964. Basel and New York.

Schumann, H. 1957. Die Glöckchen bei Schwein, Schaf und Ziege. *Zeitschrift für Tierzüchtung und Züchtungsbiologie,* vol. 69: 24-29. Berlin.

Sheldon, W. H. 1942. *The varieties of temperaments.* New York and London.

Sheldon, W. H., Stephens, S.S., and Tucker, W.B. 1940. *The varieties of human physique.* New York.

Sigaud, C. 1914. *La Forme humaine.* Paris.

Simpson, G. G. 1945. The principles of Classification and a Classification of mammals. *Bulletin of the American Museum of Natural History,* vol. 85, p. I-XVI and 1-350. New York.

Slijper, E. J. 1936. Die Cetaceen, vergleichend anatomisch und systematisch. *Capita Zoologica,* vol. 7. The Hague.

———1960. Die Geburt der Säugetiere. In *Handbuch der Zoologie,* vol. 8, no. 25, part 9: 1-108. Berlin.

———1962. *Riesen des Meeres.* Verständliche Wissenschaft, vol. 80. Berlin, Heidelberg, and Göttingen.

———1967. *Riesen und Zwerge im Tierreich,* p. 132. Hamburg and Berlin.

Sokolov, I. I. 1953. Versuch einer natürlichen Klassifikation der Hohlhörner *(Bovidae). Abhandlungen des Zoologischen Instituts der Akademie der Wissenschaften der USSR,* vol. 14: 1-295 [in Russian]. Moscow and Leningrad.

Sokolowsky, A. 1918. Zur Biologie des Riesenhirsches. *Biologisches Zentralblatt,* vol. 38, no. 3: 101-10. Leipzig.

Spinage, C. A. 1962. Aus dem Leben des Spitzmaulnashorns. *Kosmos,* vol. 58, no. 2: 77-79. Stuttgart.

Stanek, V. J. 1962. *Das Große Bilderlexikon der Tiere.* Hamburg.

———Introducing the cat family. Spring Books, London.

Starck, D. 1955. *Embryologie, ein Lehrbuch auf allgemein biologischer Grundlage.* Stuttgart.

———1956a. Über den Reifegrad neugeborener Ursiden im Vergleich mit anderen Carnivoren. *Säugetierkundliche Mitteilungen,* vol. 4. Stuttgart.

———1956b. Primitiventwicklung und Plazentation der Primaten. *Primatologia, Handbuch der Primatenkunde:* 723-886. Basel and New York.

———1959. Ontogenie und Entwicklungsphysiologie der Säugetiere. *Handbuch der Zoologie,* vol. 8, no. 22: 1-276. Berlin.

Steinbacher, G. 1941. Geburt und Kindheit eines Schimpansen. *Zeitschrift für Tierpsychologie,* vol. 4: 188-203. Hamburg and Berlin.

Steiner, R. 1883—97. Einleitungen zu Goethes naturwissenschaftlichen Schriften. In *Deutsche Nationalliteratur,* vol. 114-17. (Trans. 1950. *Goethe the scientist.* New York.) Stuttgart.

———1897. *Goethes Weltanschauung.* (Trans. 1928. *Goethe''s conception of the world.* New York.) Weimar.

———1904. *Theosophie, Einführung in übersinnliche Welterkenntnis und Menschenbestimmung.* (Trans. 1971. *Theosophy.* New York.) Berlin.

———1903-8. *Reinkarnation und Karma.* (Trans. 1960. *Reincarnation and karma. Their significance in modern culture.* London.)

———1907 a. *Die Theosophie des Rosenkreuzes.* (Trans. 1966. *Theosophy of the Rosicrucians.* London.)

———1907 b. *Weihnacht, eine Betrachtung aus der Lebensweisheit (Vitaesophia).* (Reprinted 1948. Stuttgart.)

———1912. *Menschengeschichte im Lichte der Geistesforschung,* lecture 13. (Reprinted 1962. Dornach.)

———1916. *Kosmische und menschliche Geschichte,* lecture 6. (Reprinted 1964. Dornach.)

———1917a. *Geist und Stoff, Leben und Tod,* lecture 6. (Reprinted 1961. Dornach.)

———1917 b. *Von Seelenrätseln.* (Trans., abr., 1970. *The case for anthroposophy.* London.) Berlin.

———1918 a. *Das Ewige in der Menschenseele, Unsterblichkeit und Freiheit,* lecture 8. (Reprinted 1962. Dornach.)

———1918 b. *Erdensterben und Weltenleben,* lecture 12. (Trans, abr., 1927. *Erarthly death and cosmic life.* London and New York.)

———1919 a. *Allgemeine Menschenkunde.* (Trans. 1960. *Study of man.* London.)

———1919 b. *Erziehungskunst, Methodisch-Didaktisches.* (Trans. 1976. *Practical advice to teachers.* London.)

———1919 c. *Die Kernpunkte der Sozialen Frage.* (Trans. 1953. *The inner aspect of the social question.* New York.)

———1920. *Geisteswissenschaft und Medizin,* lecture 4. (Trans. 1948. *Spiritual science and mediane.* London.)

———1924. *Geisteswissenschaftliche Grundlagen zum Gedeihen der Landwirtschaft,* lecture 4. (Trans. 1958. *Agriculture.* London.)

———1925. *Mein Lebensgang.* (Trans. 1951. *The course of my life.* New York.) Dornach.

———1961. *Das literarische und künstlerische Werk, eine bibliographische Übersicht.* Dornach.

———1970. *Die Bedeutung des Zahnwechsels in der Entwicklung des Kindes.* compiled by H. Matthiolius. Mimeographed. Stuttgart: Vereinigung der Waldorfkindergärten.
———1973. *Books by Rudolf Steiner in English translation. An annotated bibliography.* ed. J. W. Haslett. Chicago.
Stoneham. H. 1955. Meat-eating duikers. *Journal of the East African Uganda Natur-al History Society,* vol. 22: 205 ff. Nairobi.
Strahl, H. 1902 and 1906. Die Embryonalhüllen der Säuger und die Plazenta. In *Handbuch der vergleichenden und experimentellen Entwicklungslehre der Wirbeltiere.* 2 vols. ed. O. Hertwig. Jena.
Suchantke, A. 1964. Was spricht sich in den Prachtkleidern der Vögel aus? *Die Drei,* vol. 34, no. 4: 278-98. Stuttgart.
———1966. Das Urtümliche des Menschen gegenüber dem Tiere. Versuch, einige Ergebnisse der Verhaltensforschung für die Menschenerkenntnis fruchtbar zu machen. *Die Drei,* vol. 36, no. 2 and 3. Stuttgart.
———1968a. Konvergente Evolution des Skeletts in verschiedenen Tiergruppen. *Elemente der Naturwissenschaft,* no. 8: 8—26. Dornach.
———1968 b. Evolution und Typus. *Elemente der Naturwissenschaft,* no. 9: 56-61. Dornach.
———1972. *Sonnensavannen und Nebelwälder—Pflanzen, Tiere und Menschen in Ostafrika.* Stuttgart.
Teilhard de Chardin, P. 1967. *Auswahl aus dem Werk.* Fischer-Bücherei no. 793. Frankfort and Hamburg.
Thenius, E. 1969. Stammesgeschichte der Menschenartigen. In Grzimek's *Tierleben,* vol. 11, p. 53 and 459-60. Munich.
———1972. *Grundzüge der Verbreitungsgeschichte der Säugetiere, eine historische Tiergeographie.* Jena.
Thenius, E. and Hofer, H. 1960. *Stammesgeschichte der Säugetiere.* Heidelberg.
Thompson, d'A. W. 1959. *On growth and form.* 2nd ed. Cambridge.
Tittmann, W. 1961. Das Wachstumsauge der Pflanze als Bild der stammesgeschichtlichen Stellung des Menschen. *Erziehungskunst,* vol. 15, no. 9: 279-85. Stuttgart.
Treichler, R. 1962. *Vom Wesen der Epilepsie.* Stuttgart.
———1967. *Der schizophrene Prozess.* Stuttgart.
Tullberg, T. 1899. *Über das System der Nagetiere, eine phylogenetische Studie.* Uppsala.
Vaerst, G. 1886. *Über das Vorkommen der Herzknochen bei Wiederkäuern.* Dissertation. Erlangen.
Verheyen, R. 1954. *Monographie ethologique de l'Hippopotame (Hippopotamus amphibius Linne).* Institut des parcs nationaux du Congo Beige. Bruxelles.
Vogel, L. 1967. *Der dreigliedrige Mensch.* Dornach.
Wäscha-Kwonnesin (Grey Owl). 1936. *Tales from an empty cabin.* London.
———1971a. *Pilgrims of the wild.* New York.
——— 1971b. *Sajo and the beaver people.* New York.
Weber, M. 1927-28. *Die Säugetiere.* 2 vols. 2nd ed. Jena.
Werr, J. 1929. Das Tier in der Landwirtschaft. *Gäa Sophia-Jahrbuch,* vol. 4: 242-48. Stuttgart, The Hague and London.
———1930. Die Stirnbeinaufsätze der Wiederkäuer. *Gäa Sophia-Jahrbuch,* vol. 5: 226-34. Stuttgart, The Hague and London.
———1933. Tierzucht und Tiermedizin im Rahmen biologisch-dynamischer Landwirtschaft. *Lebendige Erde.* Stuttgart.

Westenhöfer, M. 1929. Die hintere FuBwurzel von Mensch und Gorilla. *Zeitschrift für Säugetierkunde,* vol. 4: 186-92. Hamburg and Berlin.

Westphal, W. H. 1953. *Physik, ein Lehrbuch.* Berlin, Göttingen and Heidelberg.

Weyl, H. 1949. *Philosophy of mathematics and natural science.* Princeton.

———1952. *Symmetry.* Princeton.

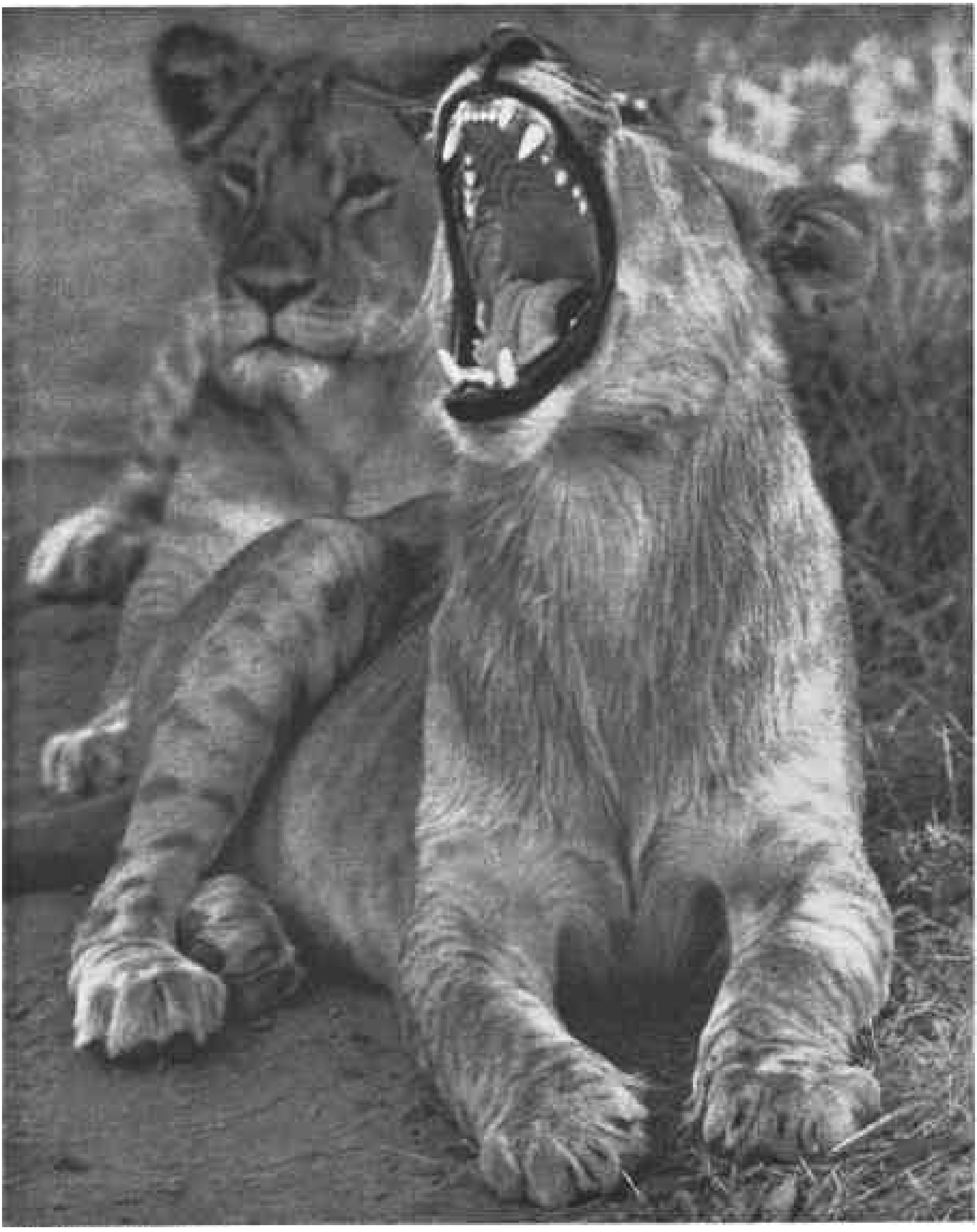
Wirz, K. 1950. Zur quantitativen Bestimmung der Rangordnung bei Säugetieren. *Acta Anatomica,* vol. 9, fasc. 1/2. Basel.

Wood, A. E. 1955. A revised classification of the rodents. *Journal of Mammology,* vol. 36, no. 2: 165-87. Baltimore.

Wrangel, H. von. 1939. Beiträge zur Biologie der Rötelmaus. *Zeitschrift für Säugetierkunde,* vol. 14: 52 ff. Hamburg and Berlin.

Ziswiler, V. 1965. *Bedrohte und ausgerottete Tiere, eine Biologie des Aussterbens und Überlebens.* Verständliche Wissenschaft, vol. 86. Berlin, Heidelberg and New York.

Register



105. Young lions are spotted. In all carnivores the canines are dominant.

106. Two Malayan tree shrews. Their tails (not visible in this picture) are long and bushy (head and body 20 cm., or about 8 in.).

107. The ermine in its white winter coat. It hesitates only a moment to investigate its surroundings before hiding (head and body 22-29 cm., or 8V2-HV2 in.).

108. The polecat's face shows the mask pattern (about natural size).

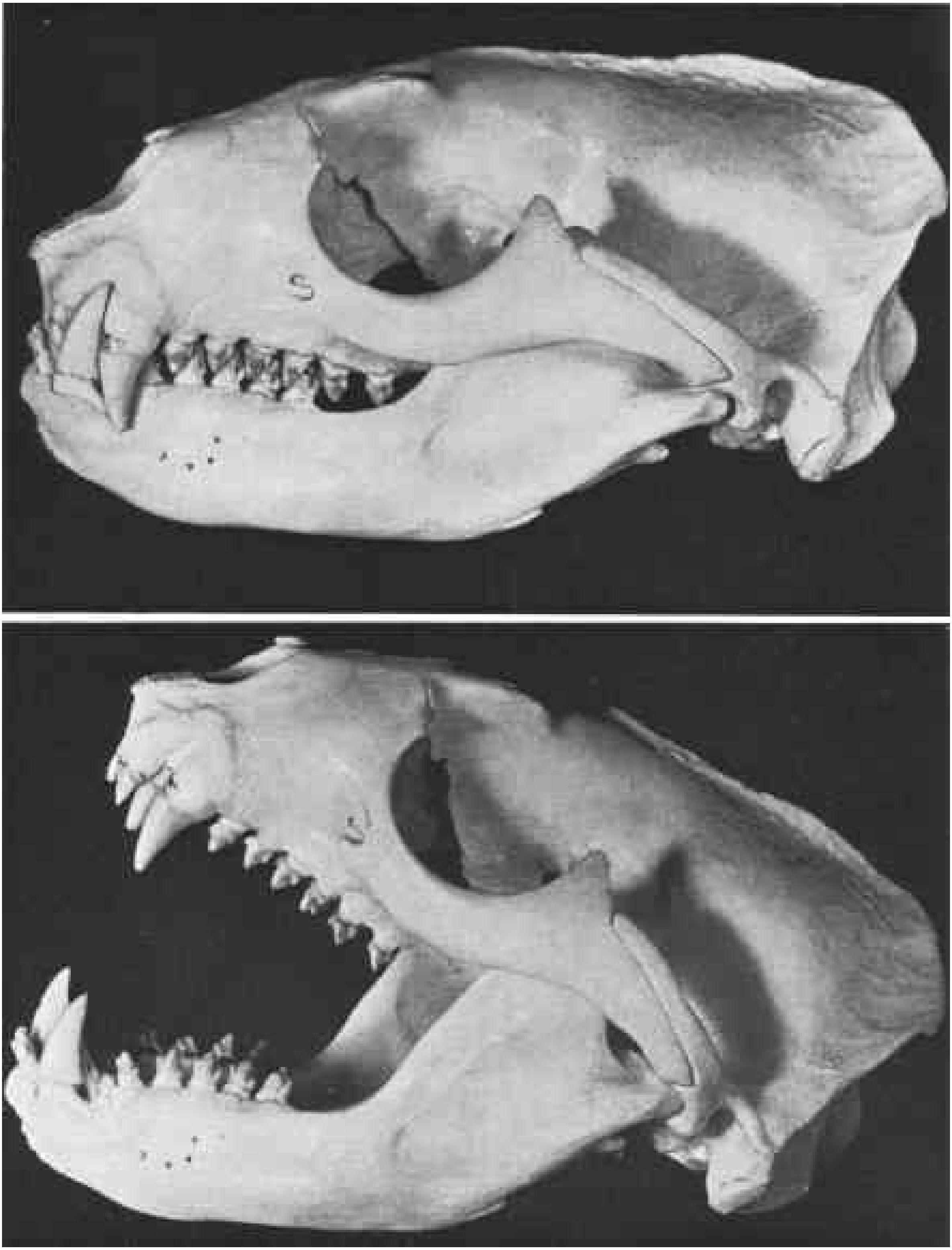
109. The otter, whose ancestors, like those of all its close relatives, were certainly land animals, seeks the water as a habitat (total length 1.20 m., or about 4 ft.).

110. The ringed seal is the smallest of the seals (1.20-1.85 m., or 4-6 ft.). It lives near the Arctic Ocean and in the northern parts of the Baltic Sea.

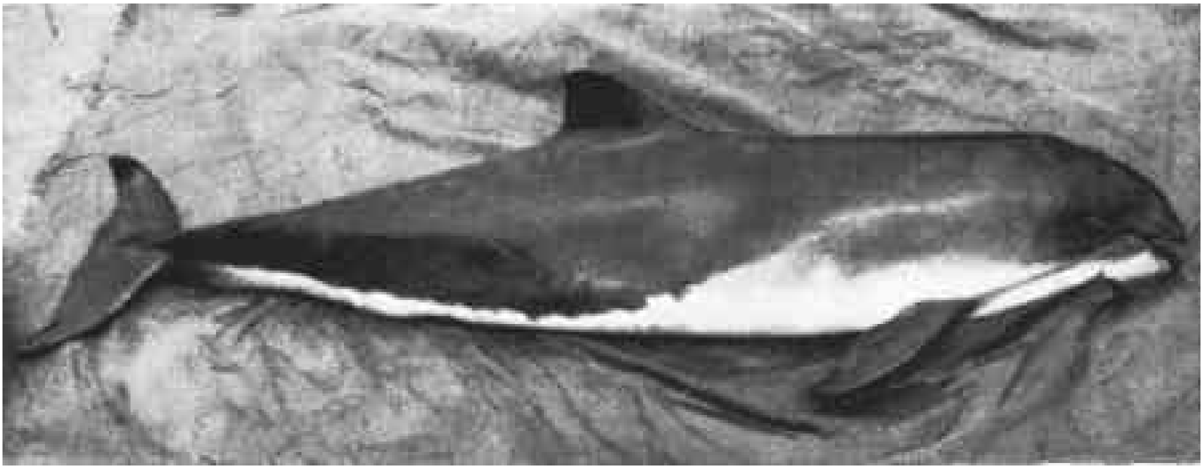
111. Two rival grey seal bulls (on the shore of Shillay Isle, in the Hebrides), each measuring 3 meters (or about 10 feet) in length.

112. Two South American fur seals sunning themselves (about 2 m., or 6V2 ft. long). Note the presence of external ears, as well as vestigial claws high up on the flippers.

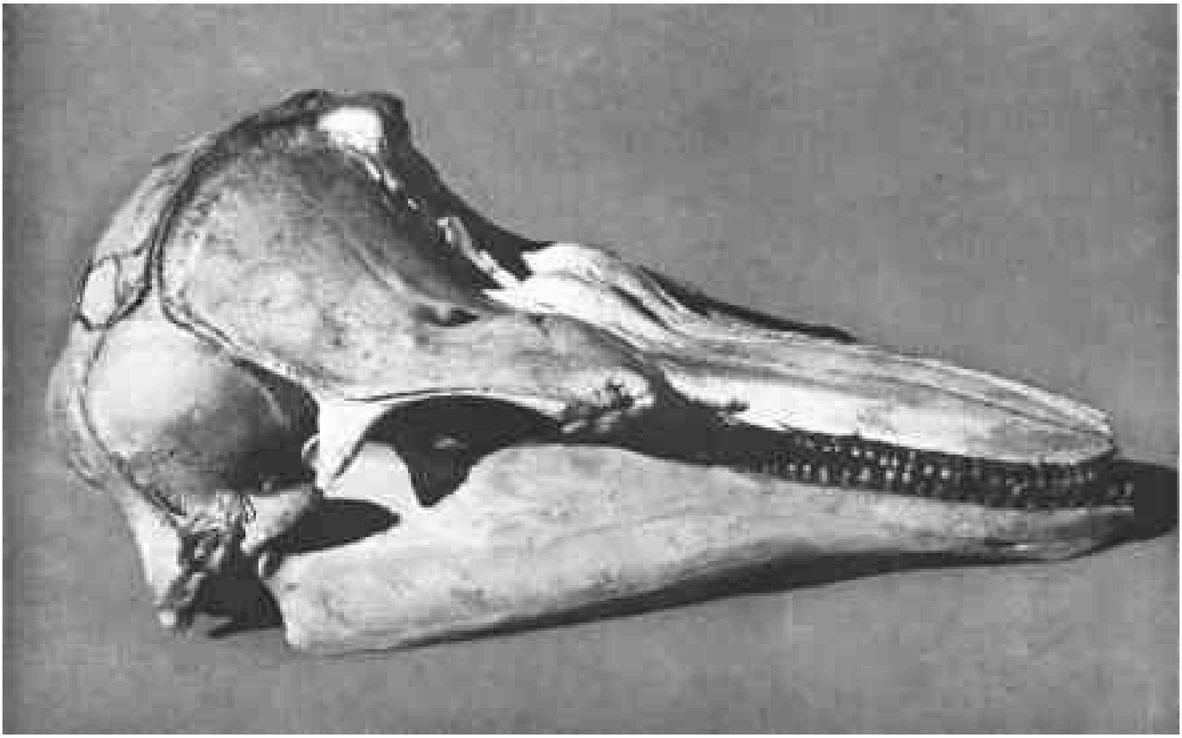
113. California sea lion mother (1.80 m., or about 6 ft.) playing in the water with her young.



114 a, b. Skull of a South African fur seal found near Capetown (length *27 cm.*, or about lO'Ain.). Even the molars are pointed, and thus resemble canines.



115/116. This porpoise was caught accidentally by North Sea fishermen (1.60 m., over 5 ft., long). In its open mouth the numerous spatula-like teeth are clearly visible.



117. Common porpoise.
The skull of the specimen shown in 115/116, after preparation (26 cm., or about 10 in.).

118. Two enormous sperm whales on the pier at Rotterdam; they were found stranded on the coast of Holland in 1937. The animal in the foreground measured 59 feet (or about 18 meters) and weighed about 52 tons.

119. Brown bear mother (2.50 m., or about 8 ft.) with young, which have the white neck band characteristic of young bears.

120. Aardwolf with two cubs (height of the adult 50 cm., or about 20 in.).

121. Wood mouse with her winter supply of acorns (2 X).

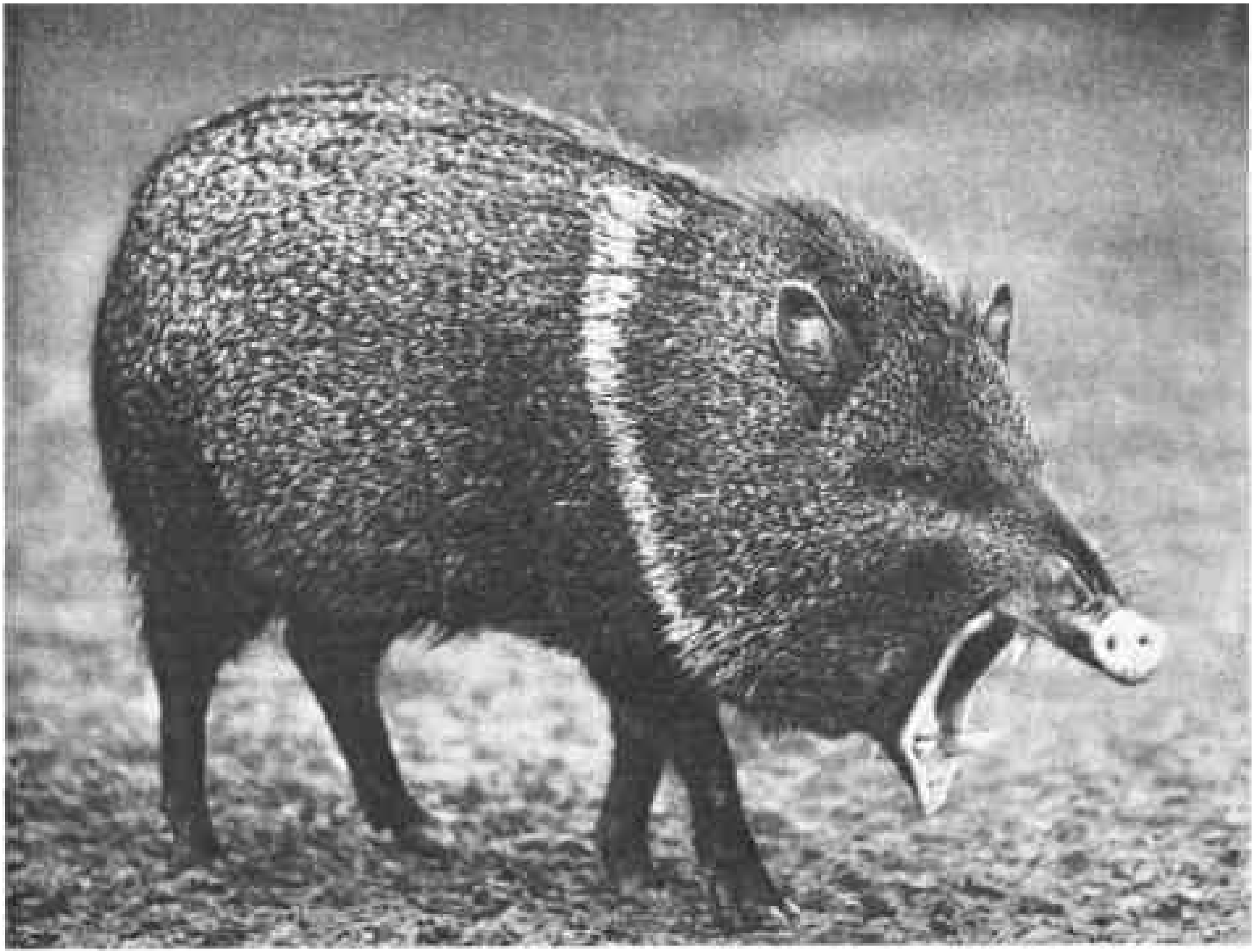
122. European house mouse (natural size).

123. Head of a bank vole (3 X).

124. Young stallions fighting. Note the presence of upper incisors.

125. The wild boar has greatly elongated canines (height 90 cm., or 3 ft.).

126. Unlike adults of their species, young wild boars have a rhythmically alternating pattern of stripes.



127. The peccary has dangerous canines with razor sharp edges (shoulder height 50-60 cm., or 20-24 in.).

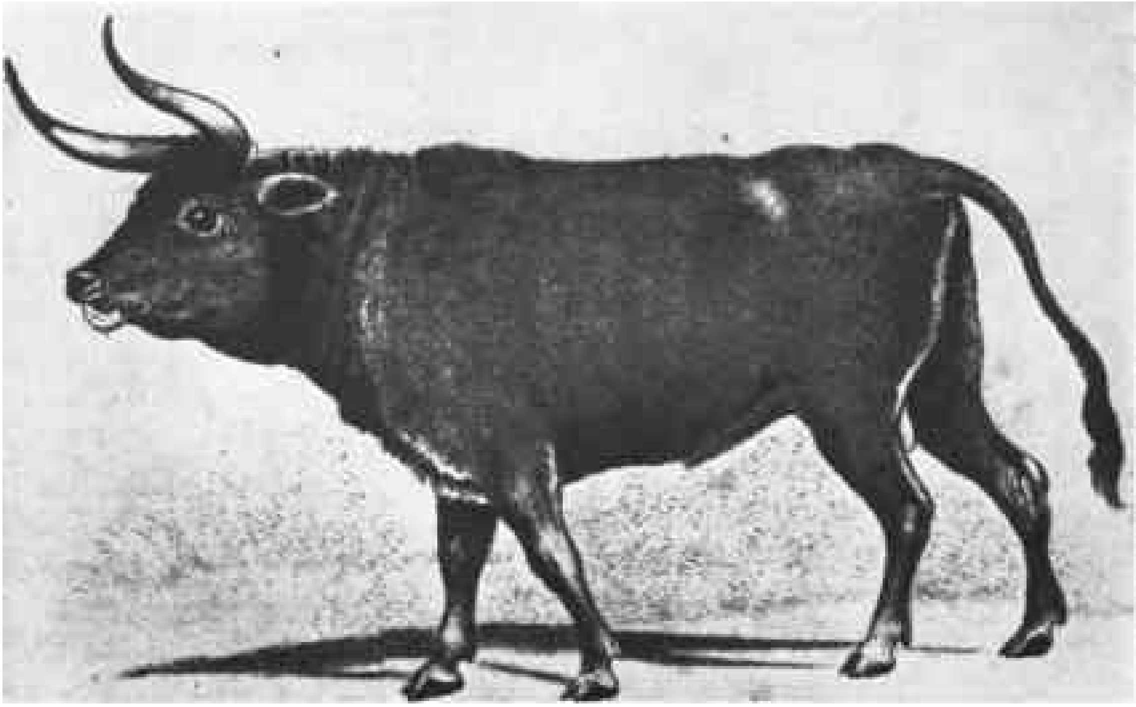
128. Lowland tapir of Brazil, yawning (in zoo).

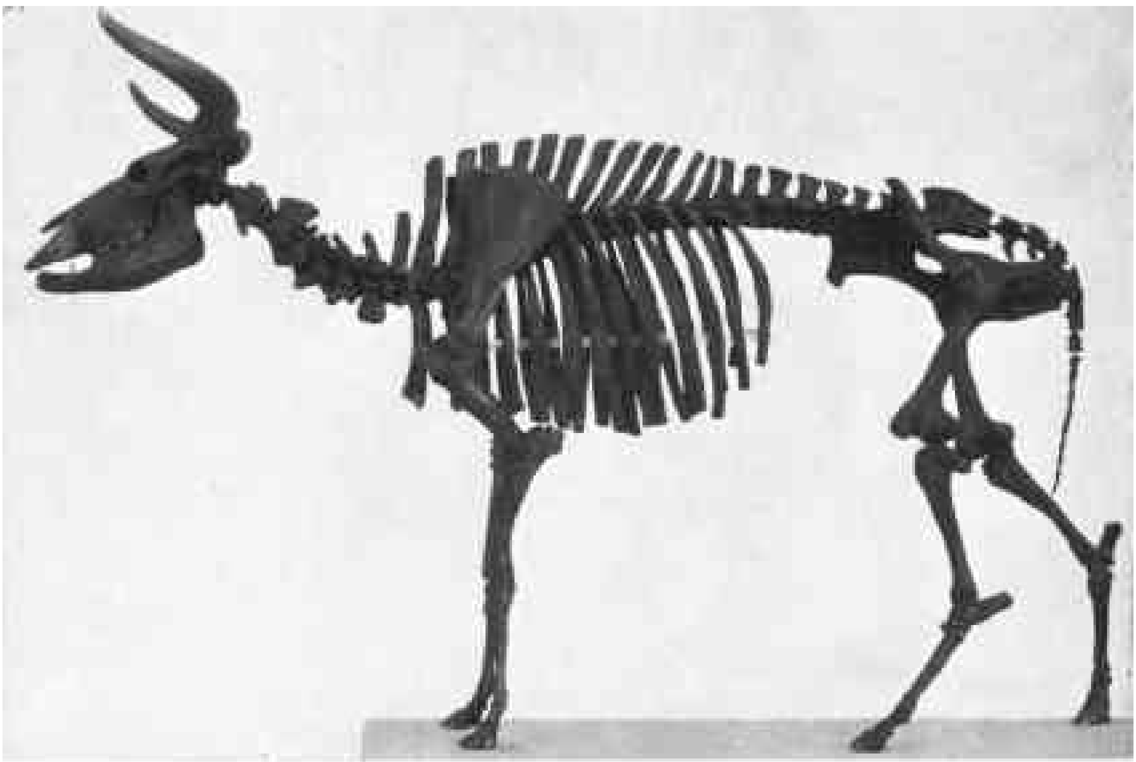
129. The Sumatran rhinoceros is covered with hair, especially when young. Note the two small horns. (Copenhagen Zoo, 1960; length 2 m., or about 6V2 ft.).

130. The Indian rhinoceros has only one horn. This calf was the first to be born in captivity (Bale Zoo, 1956; shoulder height of the adult 1.70 m., or **5Vs** ft.).

131. African black rhino with young, in the Amboscli Game Reserve in Kenya. The cow's larger horn is about 4 feet (1.27 meters) long.

132. Late Ice Age cave painting of a woolly rhinoceros, with a massive fatty hump on its back (Rouffignac/Dordogne in France, Magdalene).





133. The last picture drawn from nature of an aurochs (Poland, 1525).
134. Aurochs skeleton recovered from a moor in Saxony (Natural History Museum of Braunschweig). The sheaths covering the horns were, of course, longer than the bony core that remains (head and body 3 m., or about 10 ft.).

135. Semi-domesticated cattle of Portugal. The male is deep black, while the females are reddish in color.

136. European lowland bison, a 3 year old male in the Pforzheim Nature Preserve (head and body 2.70 m., or 9 ft.).

137. The domesticated dwarf goats of Morocco climb trees to eat the foliage.

138. Attentive mouflon ram, with its powerful curved horns (shoulder height 65-75 cm., or 26-30 in.).

139. Stag following its does.

140. The red deer (with a shoulder height of 0.90-1.50 m., 3-5 ft.) is much larger than the roe deer (0.65-0.75 m., 26-30 in.). A rare photograph taken in the wild.

141. Sleeping red deer. In this picture (taken at midsummer) the velvet still covers the antlers.

142. The mice and squirrels of the forest often gnaw on antlers that the deer have shed.

143. Startled herd of roe deer, in October. Soon the buck will shed its antlers. Note the accentuation of the body's posterior pole.

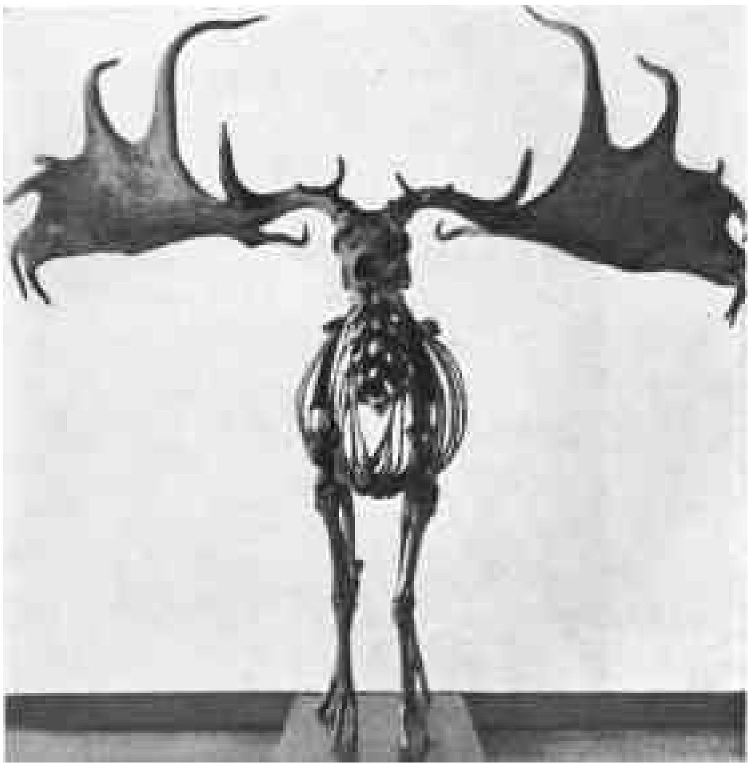
144. The roe often gives birth to two fawns. Like the young of most deer, these are spotted. Along the back bone, the spots are arranged in longitudinal rows.

145. In contrast with the red deer the roebuck grows his antlers in the dead of winter.

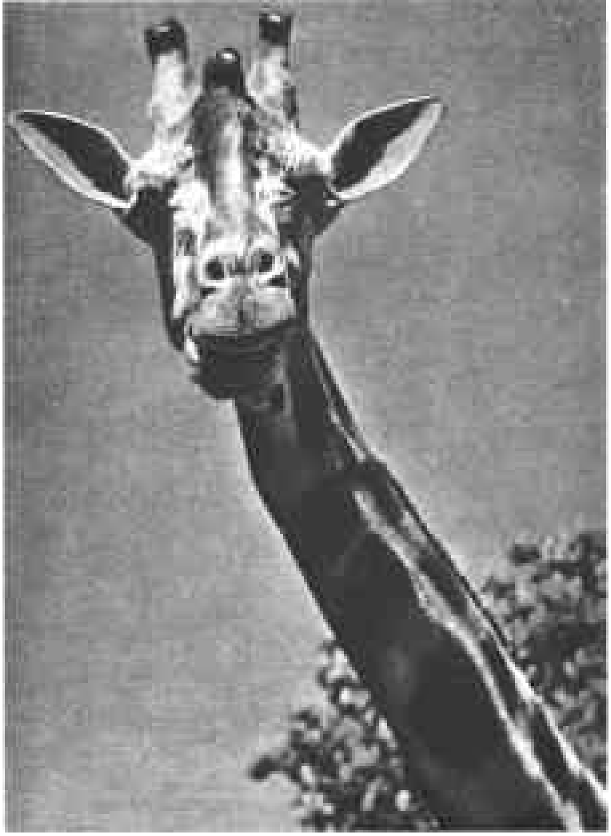
146. A wild moose bathing in the Baltic Sea.

147. Canadian moose, shot by a hunter. The largest living member of the deer family, the moose is an enormous animal, over 7 feet (2.50 meters) high at the shoulder.

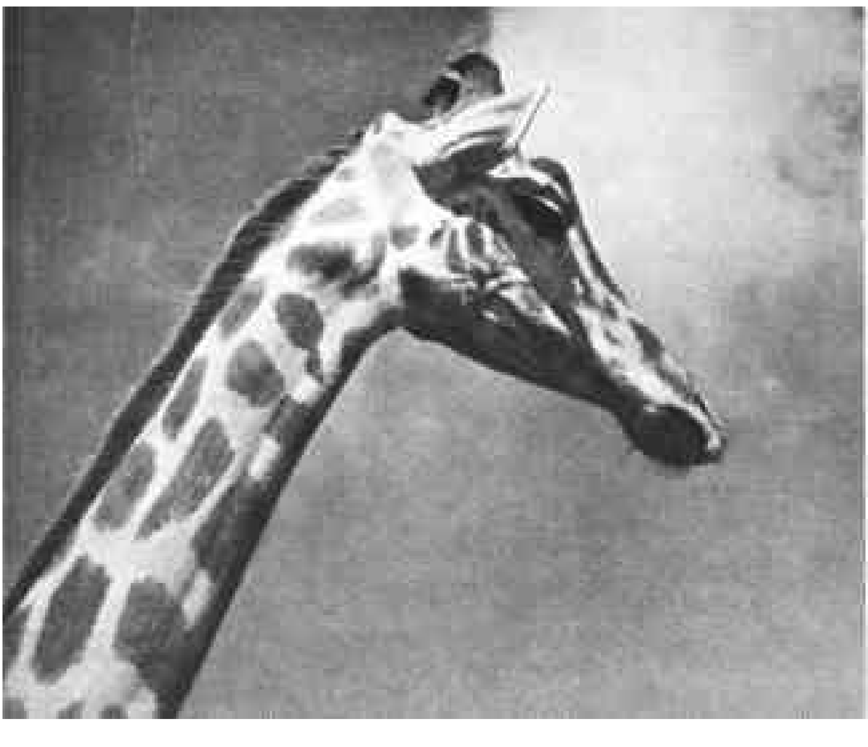
148. European red deer with crowned antlers.

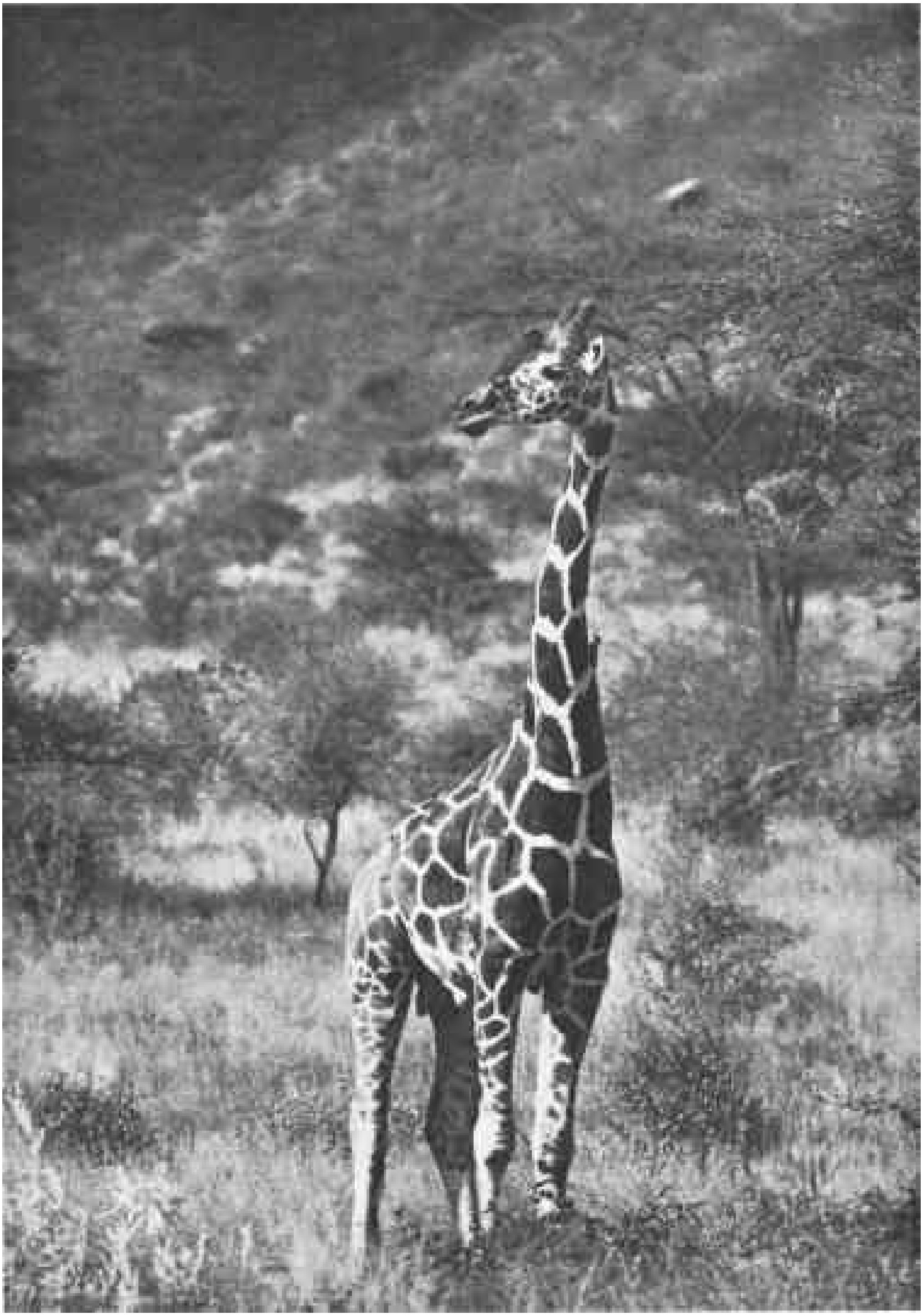


149. Skeleton of the extinct Irish elk (Natural History Museum of Magdeburg).



150/151.
Two giraffes. Note the peculiar features of their heads.

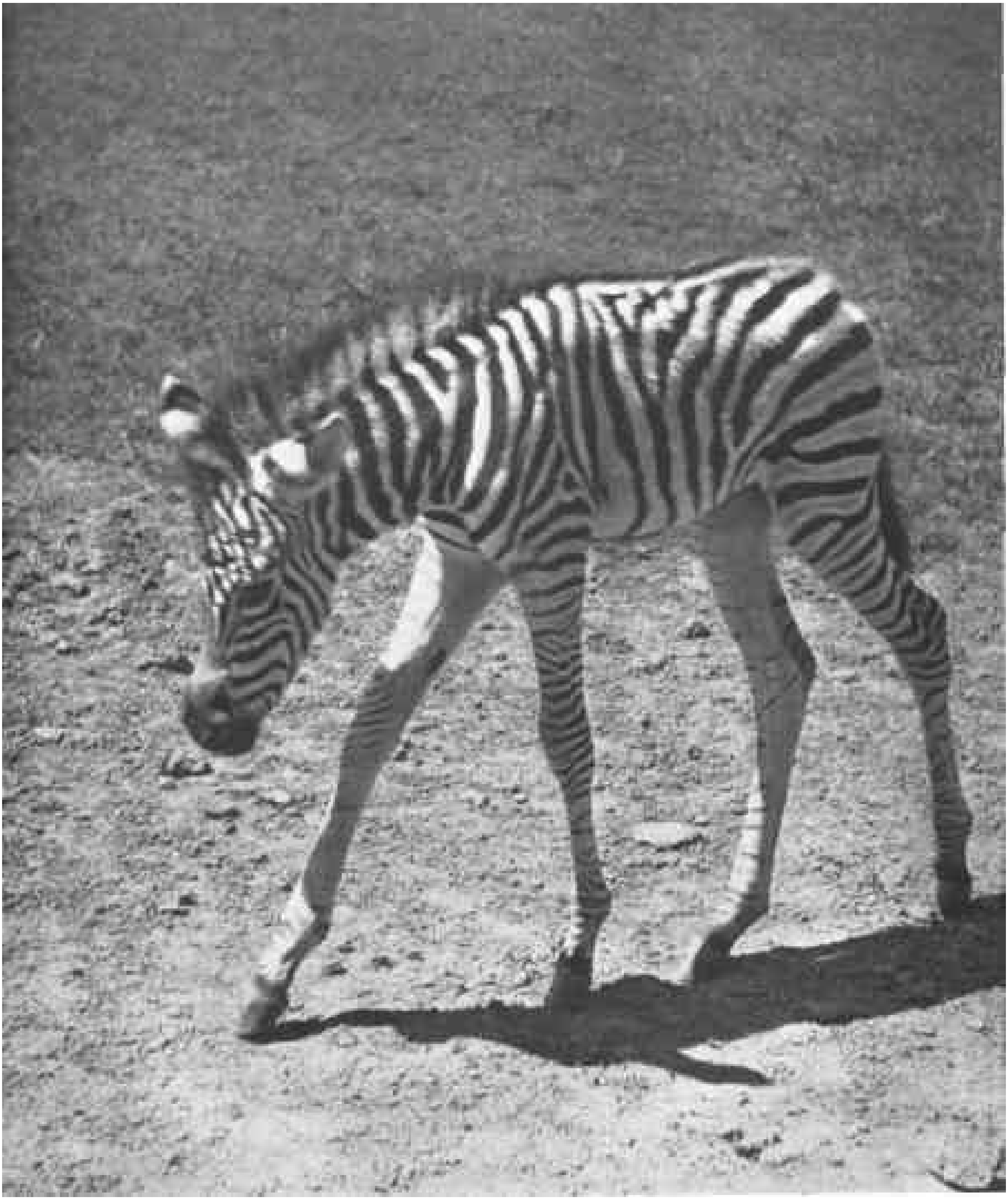




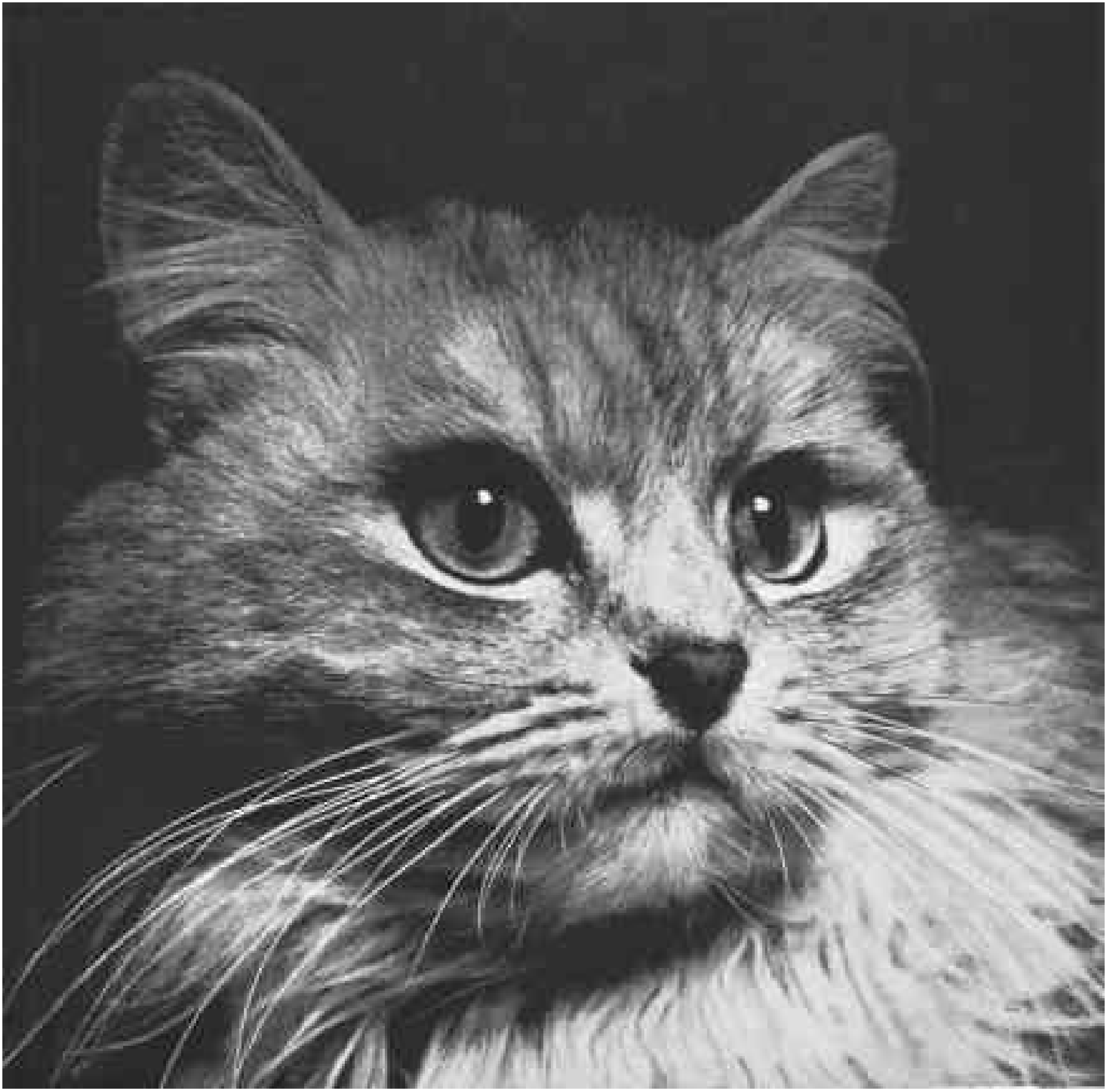
152. Three-horned male giraffe, in Kenya (height 5.40 m., or 17V2ft.). Insectivorous birds search in its coat for food.

153. Okapi, the wild giraffe of the Congo, with offspring. The females are hornless (Bale Zoo, 1960; shoulder height of the adult 1.60 m., over 5 ft.).

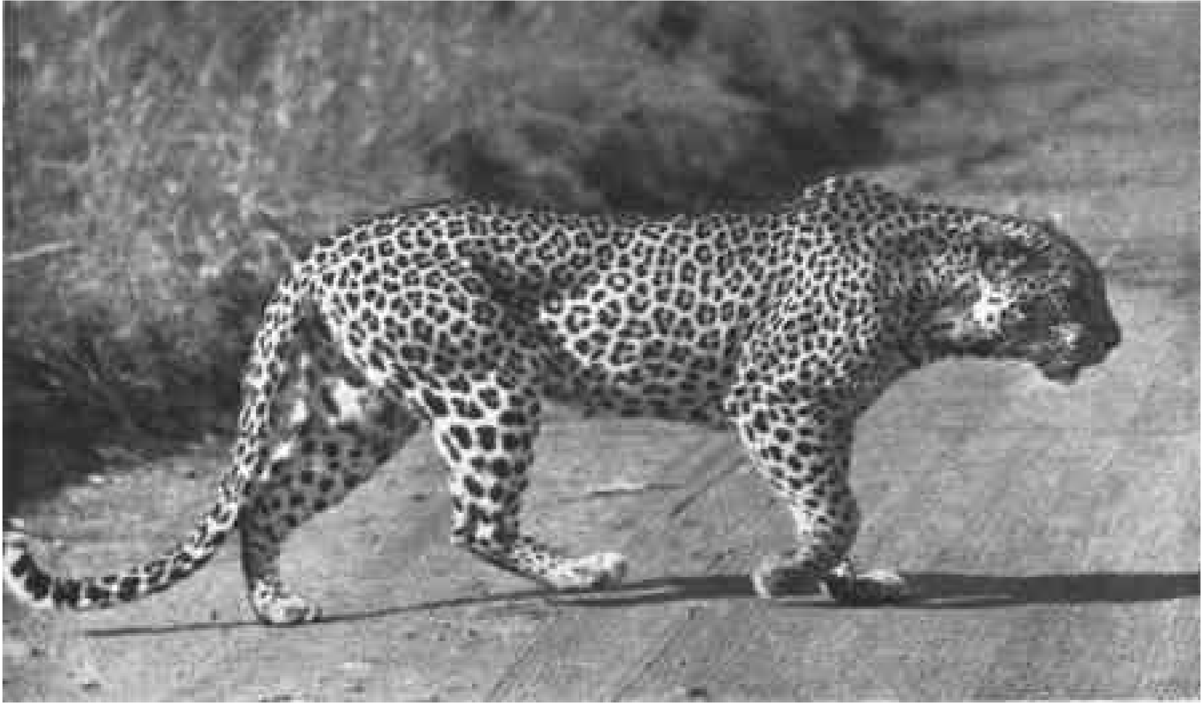
154. The Norwegian fjord horse still shows the leg stripes of the extinct tarpan (shoulder height 1.40 m., or 472 ft.).



155. This Chapman's zebra foal is only a few days old. Its legs seem almost too long for its body.



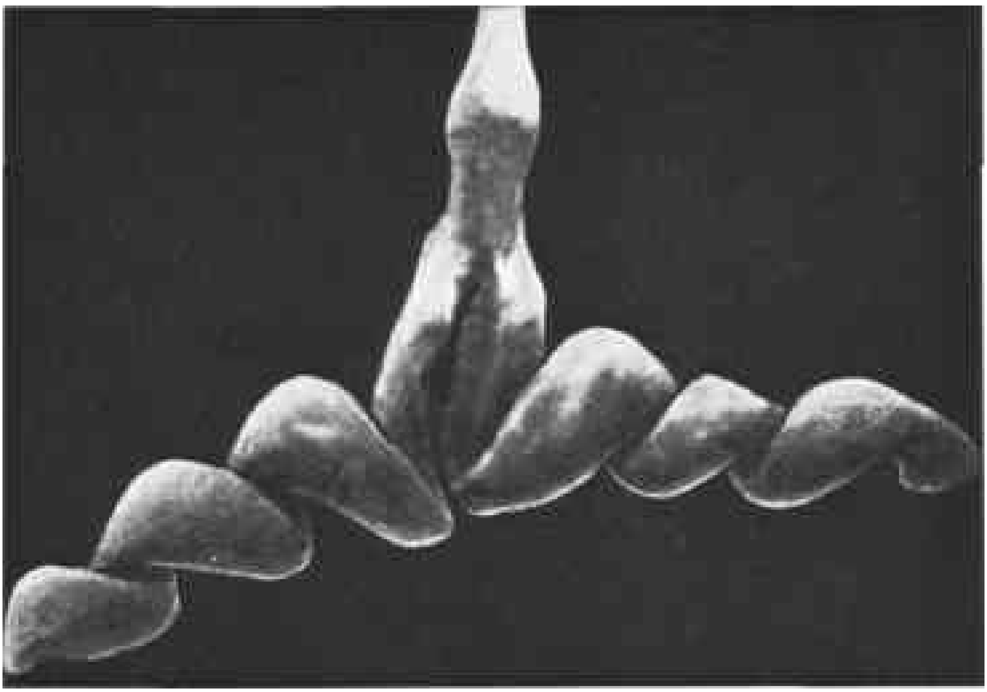
156. Head of an angora cat, whose active emotional life is revealed in the alert expression of its eyes. During the day its pupils contract to narrow, vertical slits.



157. An adult leopard steals soundlessly across the road in the Kriiger National Park, in South Africa (head and body 1.30 m., over 4 ft.).

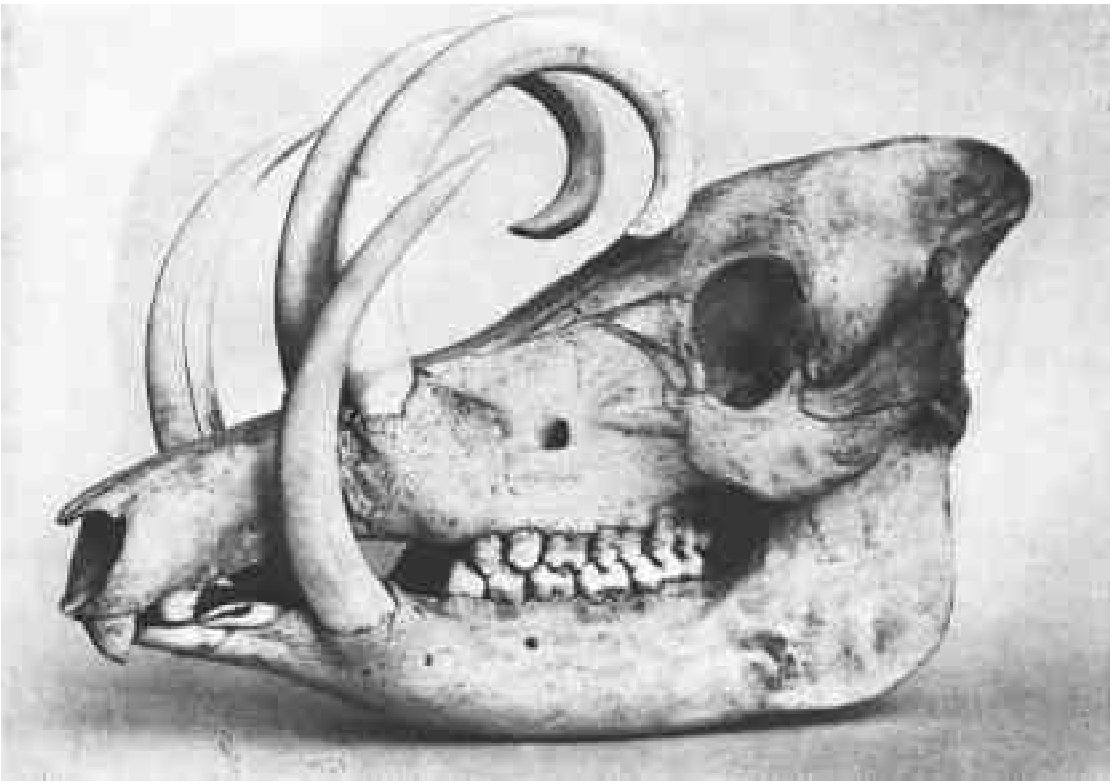
158. The American ocelot is brightly spotted (head and body 70-90 cm., or 28-36 in.).

159. The attenuated lateral hooves of the ungulates have the potentiality of becoming main hooves, as this anomalous roe deer hoof shows *(Deutsche Jagerzeitung* no. 9, Melsungen, 1962).



160. This sheep's hoof came from a merino ram that lived during the last century. The animal was elevated by straps so that its feet could not touch the ground and its hooves were prevented from wearing down naturally. Like the horns, the hooves grow in a spiral formation, thus demonstrating their formative tendency (from Duerst).

161. Babirusa boar, of Celebes and surrounding islands (head and body 1 m., or about 3 ft.).



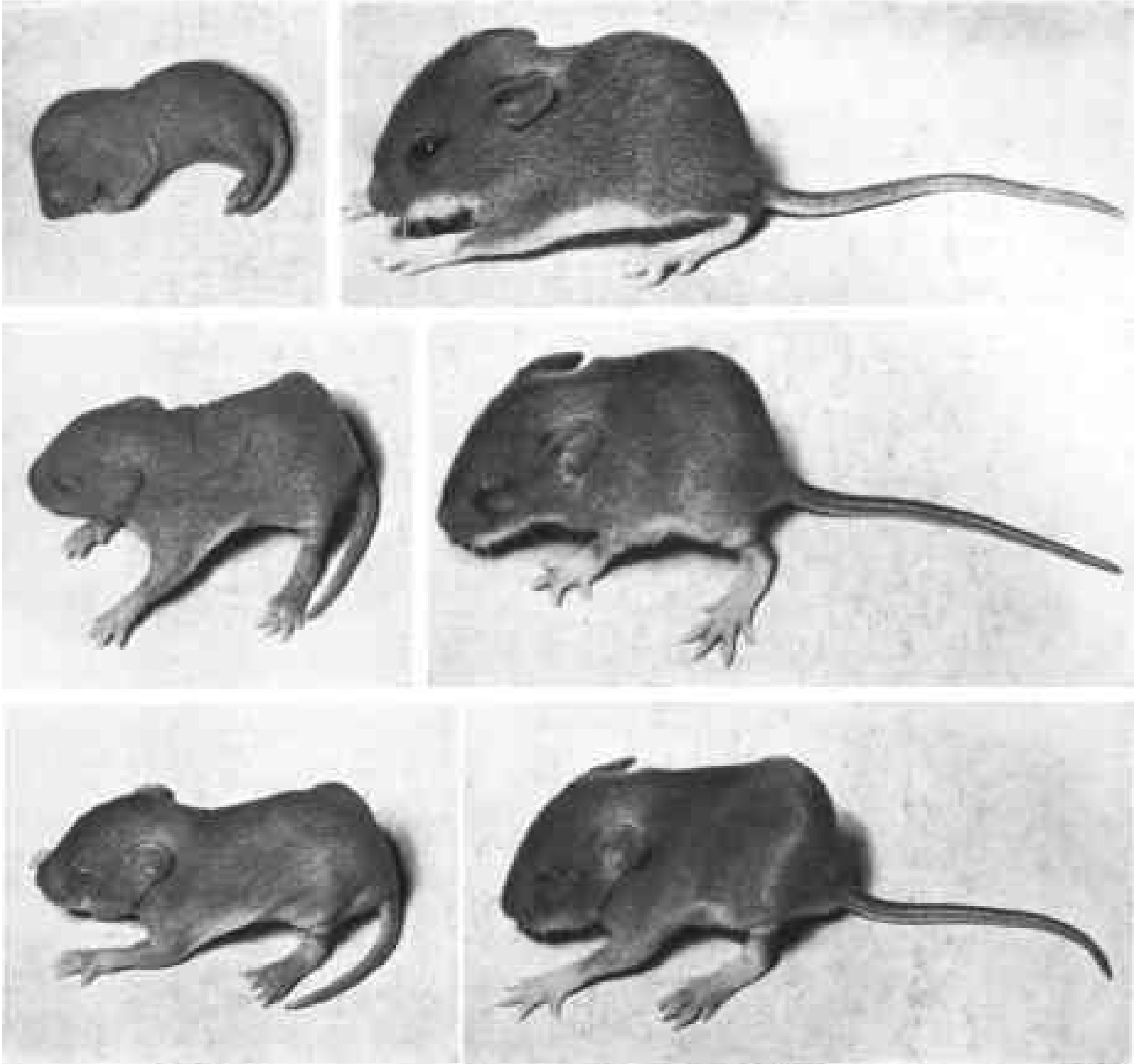
162. Skull of a babirusa. In the male all four canines grow upward (length of the skull 30 cm., or about 12 in.).

163. The Bates' pygmy antelope, of Cameroon (30 cm., or about 12 in. high at the shoulder), is only slightly taller than the royal antelope, of Liberia, the smallest ungulate in the world.

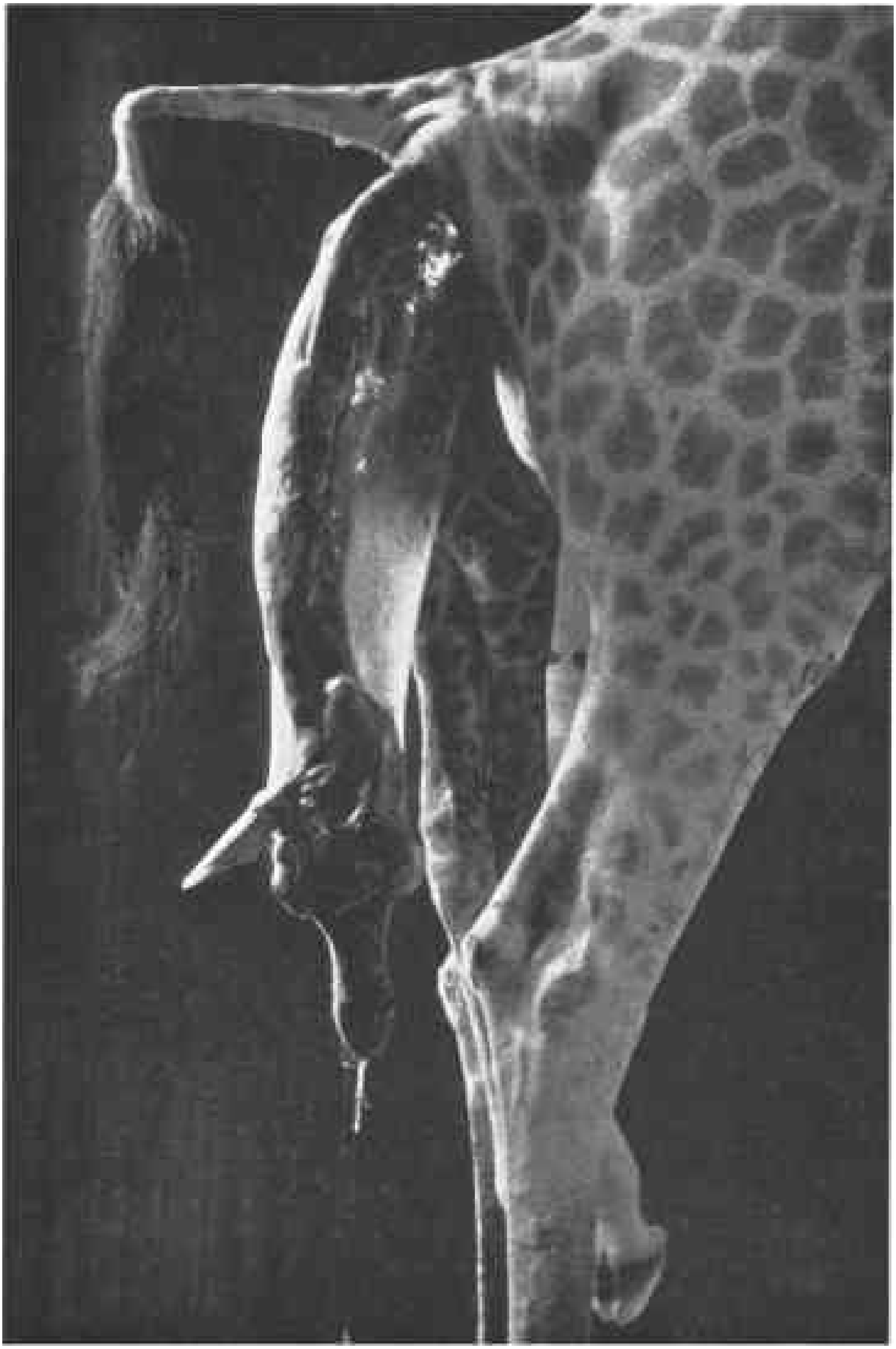
164. Closely related to the pygmy antelope of Liberia is Guenther's dik-dik of Kenya (shoulder height 35 cm., or 14 in.). Despite its sensitivity, this animal shows something of the dreaminess typical of all ruminants.

165. A Kirk's dik-dik fawn. Compare this tiny antelope with the largest frog *(Rana goliath)* in the world. Both animals are found in Angola.

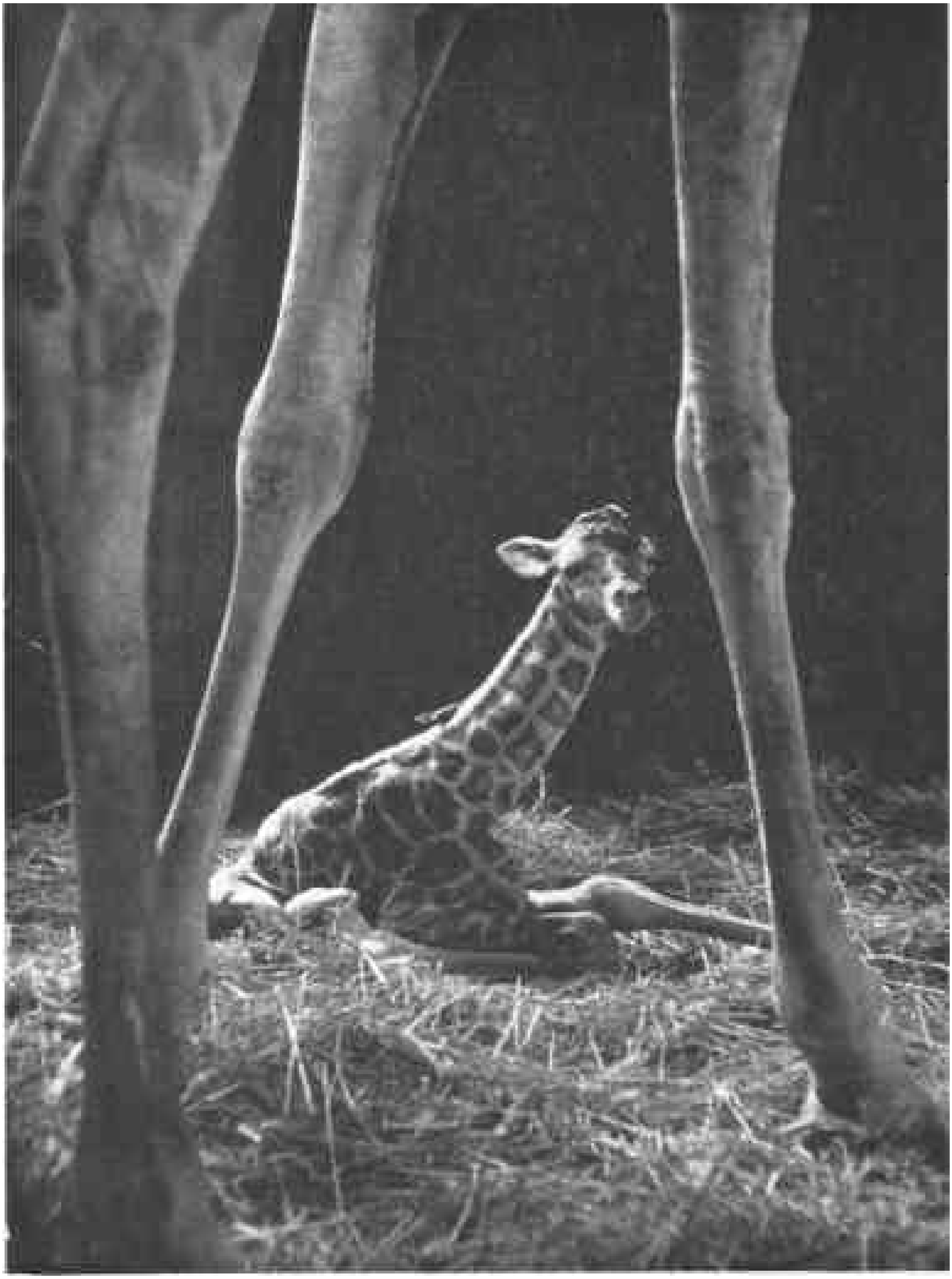
166/167. Yellow-necked field mouse in nest with her young. *Above,* the young are one day old. *Below,* after six days the first hair begins to grow along the back (head and body of the adult 8.8-13 cm., or 3Vs-5 in.).



168. The development of a yellow-necked field mouse from its almost embryonic state at birth, until it has become a young mouse with open eyes. *Left, from the top down,* 1, 5, and 7 days old. *Right, from the bottom up,* 10, 12, and 15 days old. The newborn is only 3 cm. long, without its tail (relative sizes are correct).



169. At birth the giraffe falls from a height of 6V2 feet (2 m.). It is still partly enclosed within the amniotic sac.



170. A few minutes after birth the giraffe raises its head, opens its eyes, and tries to lift its ears. Soon it stands up, and is almost as tall as a man (Tokyo Zoo).

171. Wild tiger killing a nilgai antelope calf.

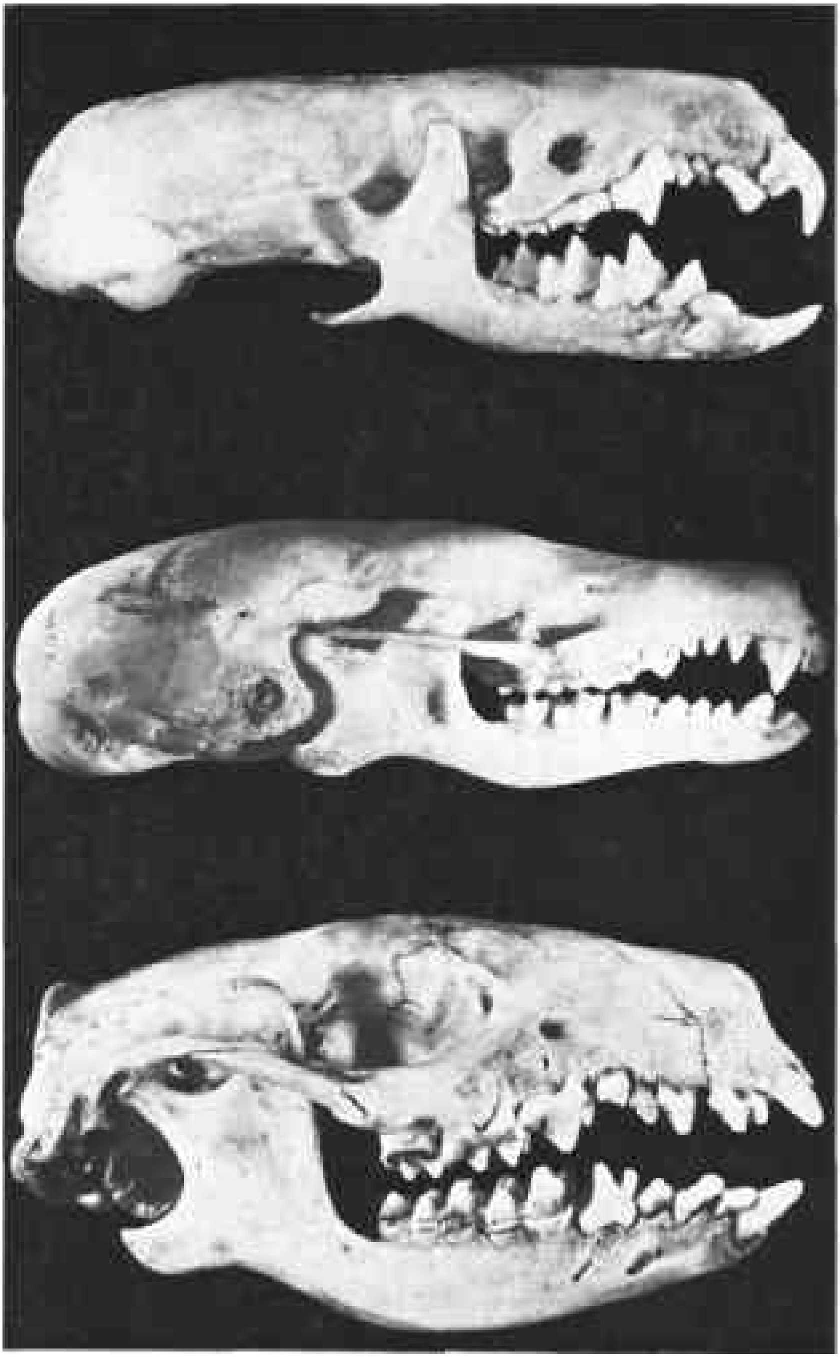
172. In contrast to the tiger, the lions hunt and eat in groups.

173. House cat hunting; here her prey is a black rat that has invaded the granary.

174. House mouse in the entrance of its burrow; it enjoys the feeling of being surrounded on all sides.

175. Portrait of a white-toothed shrew. Its open mouth is fringed with long whiskers (4 X).

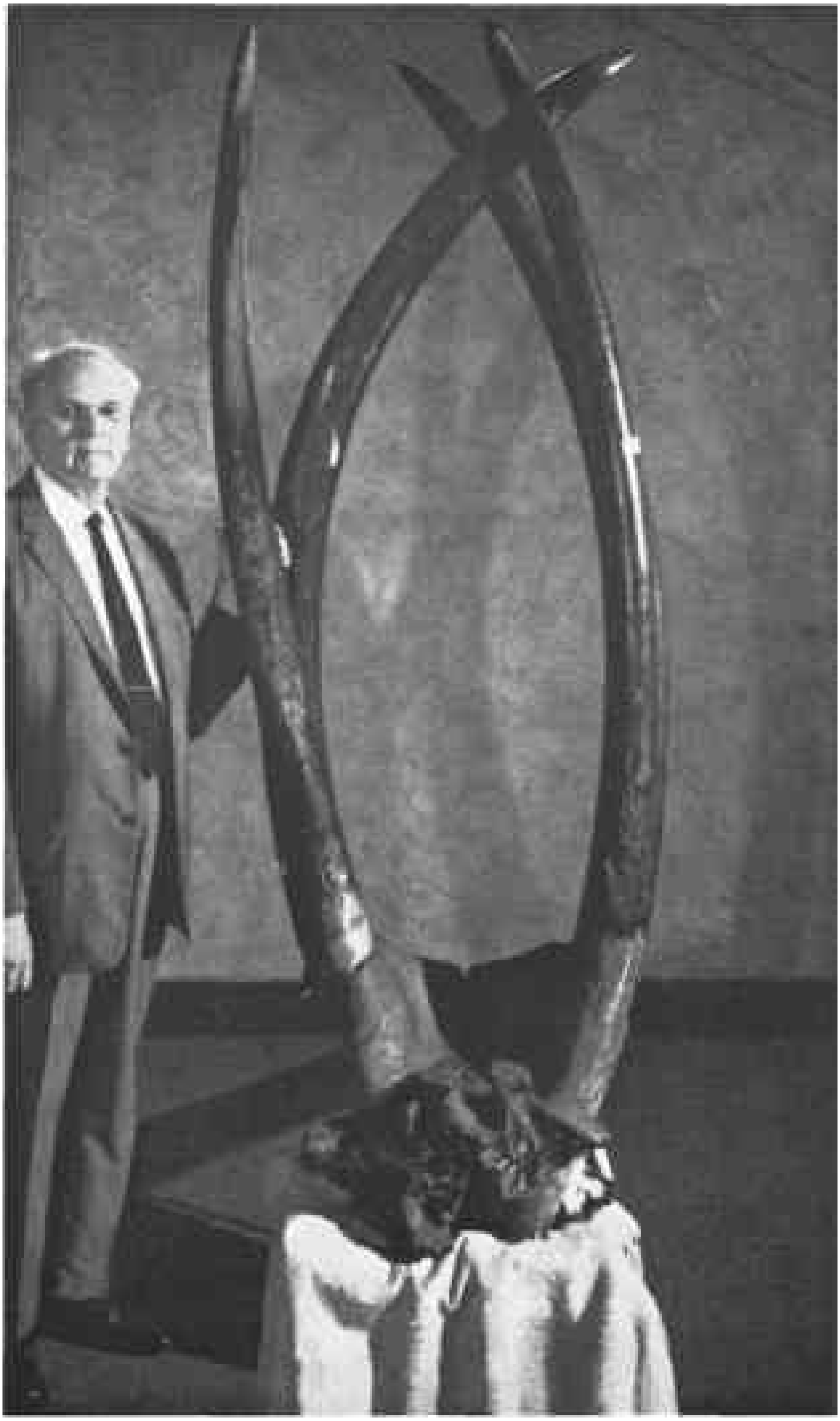
176. Shrew leading her young; each has its teeth clenched tightly in the fur of the one in front of it.



177. The dental structure of the three European insectivores (skulls enlarged to the same length). In the common shrew's skull (actual length 2 cm.) the incisors are dominant; in the mole (3.5 cm.) the canines are; and in the hedgehog (5.5 cm.) the molars dominate. All three kinds of teeth are always represented in members of this group.

178. Adult baboon, a male mandrill, with elongated canines.

179. The young baboon has in its set of milk teeth canines comparable to those of man.



180. Upper jaw of an African elephant with four tusks—it is rare that *two* pairs of incisors should become elongated (Armand Denis, *On Safari*, London, 1963).

181. African bull elephants at Lake Manyara Park in Tanzania (up to 4 m., or 13*/2 ft., tall).

182/183. Two bovine embryos surrounded by the fetal membranes. *Above,* 34 days old (1.5 X natural size). The innermost membrane is the amnion, followed by the brightly shining allantois, which in turn is surrounded by the chorion. *Below,* about 50 days old (actual size). The growing fetus has developed its fundamental organs and floats weightlessly in the amniotic fluid. The chorion (partly cut open) has begun to show signs of the developing placenta: On the chorion itself cotyledons are visible, as are the corresponding caruncles on the mucous membrane of the uterus (see p. 208).