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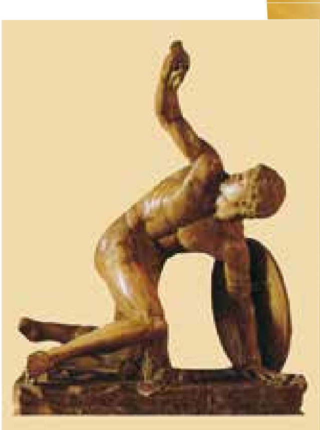
Anatomy

Morphological Anatomy from a Phenomenological Point of View



Guus van der Bie MD

BOLK'S COMPANIONS
FOR THE STUDY OF MEDICINE

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The Louis Bolk Institute has conducted scientific research to further the development of organic and sustainable agriculture, nutrition, and health care since 1976. Its basic tenet is that nature is the source of knowledge about life. The Institute plays a pioneering role in its field through national and international collaboration by using *experiential knowledge* and by considering data as part of a greater whole. Through its groundbreaking research, the Institute seeks to contribute to a healthy future for people, animals, and the environment. For the Companions, the Institute works together with the Kingfisher Foundation.

Publication number GVO 03
ISBN/EAN: 978-90-74021-30-1
Price € 10
Postage € 7,50

KvK 41197208
Triodos Bank 212185764
IBAN: NL77 TRIO 0212185764
BIC code/Swift code: TRIONL 2U
For credit card payment visit our website at
www.louisbolk.nl/companions

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Colofon:

Cover: www.fingerprint.nl
Coversculpture: Discobolus of Monnot, Capitol, Rome
Translation: Sandy Reijnhart

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About the Author

Guus van der Bie MD (1945) worked as a lecturer at the Department of Medical Anatomy and Embryology at Utrecht State University, Holland from1967 to1976. Next to his practice as a general practitioner since 1976, he continued to educate physicians and therapists, and medical students at Utrecht State University and the University of Witten/Herdecke, Germany. He is a member of the Medical Section of the School of Spiritual Science at the Goetheanum, Dornach, Switzerland.

About the Project

The project *Renewal of Medical Education* aims to produce Companions that demonstrate how the insights of current biomedical science can be broadened by using the Goethean phenomenological method. This method innovates current concepts and expands the understanding of biochemical, physiological, psychological, and morphological factors in living organisms and their development in time and space, and in health, illness, and therapy. The project is commissioned by the Kingfisher Foundation, which aspires the development, application, and publication of the Goethean phenomenological research method in the widest sense, to complement and innovate the accepted scientific view and research method.

BOLK'S COMPANIONS FOR THE STUDY OF MEDICINE complement current medical education, specifically disclosing human qualities in the fundamental biomedical sciences of today.

BOLK'S COMPANIONS FOR THE PRACTICE OF MEDICINE contribute to a scientific phenomenological basis for integrative medicine and integral psychiatry.

Preface

In his book *Lifelines* Steven Rose states: "The challenge to the opponents of biological determinism is that, while we may have been effective in our critique of its reductionist claims, we have failed to offer a coherent alternative framework within which to interpret living processes".

We have the same challenge with regard to morphology. It is imperative to offer a satisfactory alternative framework. In trying to remedy this problem we have striven for two goals: first, to indicate an 'alternative framework' in morphology, and second, to show that the alternative framework opens new possibilities for interpreting morphological facts.

We used a Goethean approach that allows us to position the detailed knowledge of Anatomy in the context of the whole of the organism. In this method, a careful description is followed by portraying the dynamic quality of the studied part, for instance the humerus. Comparison of different parts of the skeleton helps us to see patterns in what we have observed. We become aware of a blueprint that can eventually show us the role the humerus plays in the whole of the skeleton from a dynamic viewpoint.

We chose *the dynamic quality in morphology* for this purpose since it allows us to see coherence in the facts. *The dynamic quality in morphology* can be shown to refer to functional processes in biology.

This results in new concepts in morphology. These new concepts recapture an understanding of morphologic facts in living organisms. This gives us, for instance, a possibility of understanding the relation between consciousness and behavior to the shape of the body.

We hope that this framework will be helpful for medical students, who have to learn and remember many anatomical details.

Experience has taught us that an overview of the whole makes remembering the details easier. We present this module in an effort to aid medical students and others to take in the wonderful world of anatomical morphology and remember it better in later study and work. We want to emphasize that this module does not replace the textbook on anatomy. The information in the module is compact and presupposes the knowledge contained in regular textbooks.

1. Introduction

The module *Morphological Anatomy* in the series '**BOLK**'S COMPANIONS FOR THE STUDY OF MEDICINE is intended for medical students, physicians, paramedics, nurses and others employed in health care. The special character of this series lies in its phenomenological approach to the human organism. This phenomenological approach offers the possibility to develop a vision of the human organism that complements the usual analytic approach. The particular phenomenological method we have chosen, as introduced by Goethe, offers the possibility for a dynamic view of the human organism. By arranging and interpreting the facts in a new way, a different view on the human organism originates which provides novel insights into the significant connections between various morphological details.

The essence of Goethe's method is, fundamentally, based on the participatory attitude of the researcher. Because of this fundamental attitude, the observation is transformed into *empathetic observation* such that the observed object is dynamically perceived. This *dynamic aspect* leads to the introduction of a new, dynamic framework in morphology that can be linked also to dynamic aspects of consciousness. This way of working does not only concern physical phenomena, but also offers leads for investigating the relation between organism and consciousness.

Morphology and psychology can be studied in their relationship to each other based on the phenomenological insights that have been gained. Using a morphological approach, the form, the function and the effect of anatomical structures can be described based on the relation they have to each other.

2. General Aspects concerning the Module Morphological Anatomy

2.1. The Anatomical Approach

The *anatomical approach* of the organism illuminates a tremendous amount of detailed information. The skeleton, the muscles, the senses, the nerves, and the internal organs are laid open and made available for study.

Knowledge of details does not, however, provide us with *insight* into the *form of the organism in its totality* and the topographical relationship and morphological specificity of the various details.*

If, after an anatomical dissection, we want to reassemble the parts we have found into a whole organism, that would only be possible if we have the original form in mind. Knowledge of the details, as such, does not provide any insight into the external form or the *blueprint* of the organism. Someone who has never observed a human organism *in toto* will not be able to come up with a meaningful combination of the separate parts. It appears, therefore, that the blueprint - or the 'Gestalt'- of the organism has, by rights, its own identity and that the details can be seen as additions to that identity.

Knowledge of the whole is the basis for all morphological insights. With the aid of Goethe's methodology one is able to create a cognitive process in which typical morphological characteristics provide an overall insight into the morphology of the whole organism.

* Neither does modern genetics provide us here with an answer to the question of the true nature of morphological structures. The protein chemistry of genetics has no explanation for the macroscopic form of the various parts of the organism or of the organism as a whole.

2.2. The Existence of a Blueprint

Comparative anatomy shows, in a way that is immediately visible, that organisms develop according to a specific blueprint. Thus, the organisms of higher mammals always have a distinguishable head, a torso and limbs. This structure can be found as far back as the fossils, and the **tri**lobites even owe their name to this *trichotomy*.

In the head, we find the nervous system concentrated in the form of brains, the limbs are moved by the muscles and the torso contains the internal organs. The *head, torso, and limbs* - the macroscopic form of the mammalian organism - can always be distinguished.

This is not exclusive to mammals. Birds, amphibians, reptiles, and many insects display the same blueprint in their organisms.

2.3. The Reality of the Blueprint

In order to be able to recognize the blueprint of an organism, a comparative, descriptive research method is necessary. That research may include a wide range of organisms in order to be able to recognize the similarities and differences in their morphology.

A second possibility is to study the morphological characteristics of the various systems within one organism in order to discover how the blueprint manifests itself within diverse tissue types and organ systems.

In this module, we will, in particular, adhere to the latter method. Our objective is to be able to recognize and describe *generally active morphological dynamics*. Once the general morphological characteristics have been found, the variations in the details of the various systems can be described.

The reality of a blueprint can be derived from macromorphology, the morphology of organs and organisms as a whole. The problem that arises here is that each individual organism is a variation of the blueprint. Therefore, it goes without saying that the blueprint could be rejected in favor of the existence of the individually developing organisms. However, the possibility of a division in, for example, species and families, already demonstrates that morphology has always recognized the existence of general principles of shape and form. For example, the division of the animal kingdom into mollusks, coelenterates, invertebrates,

vertebrates, etc. is an example of the recognition of *species specificity based on morphological characteristics*. The fact that, alongside of the clearly typically formed organisms, there are also morphological 'borderline cases' does not rule out the existence of blueprints.

➔ *In this module Morphological Anatomy, we use capita selecta to search for and demonstrate the underlying blueprint of the human organism. A descriptive, phenomenological method is used for this.*

2.4. About the Module

In this module, anatomical/morphological aspects of the human organism are described. It is not our goal here to be as thorough as would be expected of an anatomy textbook. There are a great number of anatomy textbooks and many are of excellent quality.
The anatomy subjects discussed here have been selected because of their value in learning about the blueprint that pervades the entire organism and because they lend themselves to a phenomenological approach. This does not imply that other anatomical details or systems would not be suitable for such an approach. A conscious decision has been made for a selection because this is about *teaching the reader to develop his or her phenomenological skills.* We have not limited ourselves to the discussion of only one area of anatomy - for example, the skeleton - because a comparison of the blueprint across various systems provides us with a better idea of what precisely is repeated and what precisely has metamorphosized among these systems. The reader could, of course, do a phenomenological study himself of those anatomical systems that we have not discussed.

3. Morphological Characteristics based on the Skeleton

3.1. Introduction

In many natural history museums, one finds displays of skeletons of existing and extinct animals. For both the educated and the uneducated visitor, the *form of the entire organism* becomes clear from simply looking at the skeleton. This expressiveness and the relationship to the true form is so powerful that even paleontology sees the skeleton as *representative of the form of the entire organism.* In paleontology, reconstructions of organisms are made using skeletons - and parts of skeletons - that have been found. These reconstructions are considered to be extremely reliable because the parts of the skeleton have a relationship to the macroscopic form of the entire organism.
Therefore, the skeleton occupies a unique position among all the organ systems:

the skeleton is the most characteristic expression of the specific ***form*** *of the entire organism.*

The skeleton forms an extremely reliable basis for a scientific study of the morphology of the human organism. This is why this module begins with a study of the human skeleton.

3.1.1. The Shape of the Skull

Morphologically, the most characteristic portion of the human skull is the spherical, domed crown of the skull. From the eyebrows to the foramen magnum, the neurocranium has, within a certain variation, a nearly perfectly spherical form. The base of the skull and a portion of the maxilla and mandible effortlessly fill in the missing segment of the sphere so that the head *as a whole* (the bones of the neurocranium and the bones of the base of the skull and the face) give the impression of being spherical.
When we study the growth of the skull of a small child up through adulthood (fig. 3.1.), keeping the spherical form in mind, it is striking that the characteristic, spherical form remains intact during the development of the skull. The growth of the skull displays, therefore, a specific growth dynamic: on the inside of the skull, bone disappears while, on

the outside, apposition of bone tissue occurs. This applies, in particular, to the neurocranium. During their development and growth, the cranial bones maintain an equal distance from an imaginary midpoint of a sphere.

The flat bones of the skull, that develop through membranous ossification, provide the growth of the skull as a whole with a dynamic of all-round growth. As appears from figure 3.1., the development of the face also adjusts itself to this dynamic and, therefore, places itself within the morphological dynamic of this spherical development. The human head maintains the characteristic spherical shape from early development until the end of life.

It is striking that only the head - within the blueprint of the body - develops and maintains the spherical form at the macroscopic level during further growth (fig. 3.2.). This aspect becomes particularly clear for the dynamic, comparative view when the development of the skull is compared to that of the extremities (Chapter 3.2.).

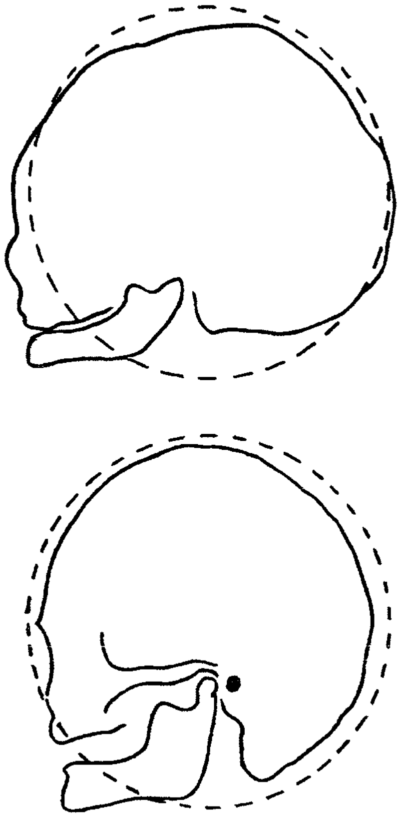


Fig. 3.1. Spherical form of the head during lifetime

3.1.2. The Desmoid and Endochondral Ossification Centers of the Skull

The bones of the *neurocranium* originate primarily through *membranous (desmoid) ossification* or through a combination of desmoid and endochondral ossification, as is the case with the sphenoid bone, the temporal bone and the occipital bone. Of these bones, the parts that belong to the base of the skull tend to be endochondral and those that are a part of the neurocranium tend to be desmoid. The connective tissue around the primitive

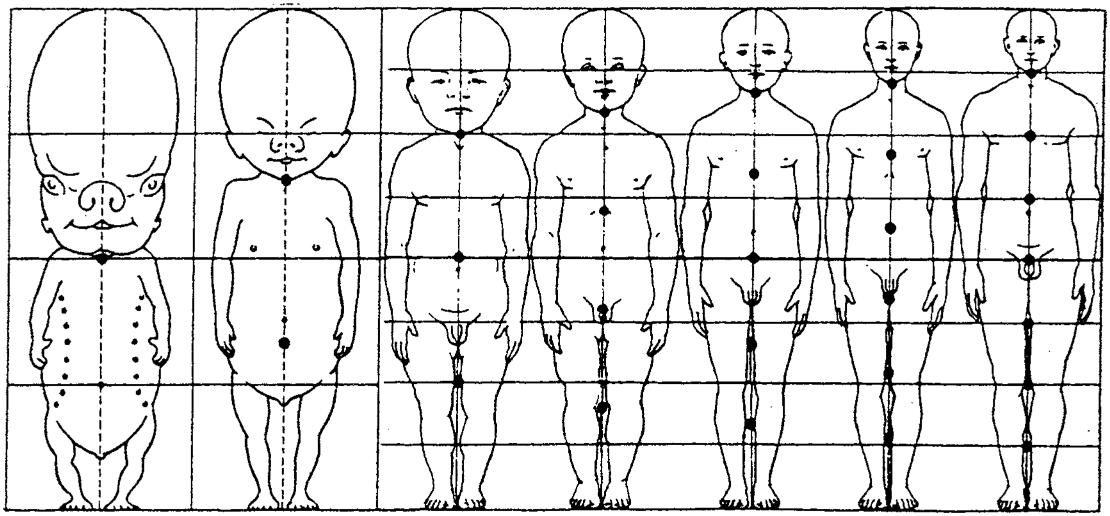


Fig. 3.2. Development of the shape of the body and the head during lifetime (Husemann 1982)

brain functions as the preliminary stage for the desmoid bone that grows in the form of rounded, flat plates of interstitial tissue (fig. 3.4.). The cells for these interstitial plates develop from the *ectoderm (neural crest)* and *not*, as is the case in the remaining bone tissue, from the mesoderm. In membranous ossification, the osteoblasts develop directly from mesenchymal cells. They occupy a special position in the skeletal development process, which originates through endochondral ossification nearly everywhere else.

The occipital bone and the elements that will form the base of the skull and the jaw develop from mesodermal tissue. For the base of the skull, that is mesoderm from the paraxial somites and the pharyngeal arches (fig. 3.3.). The osteogenesis of these parts of the skull shows a relationship to the osteogenesis that occurs in the extremities (Chapter 3.2.3.).

3.1.3. Ossification Process of the Neurocranium

The way in which ossification takes place in the bones of the neurocranium is unique in the organism. In every cranial bone, there is a centrally located ossification center. From these ossification centers, primitive bone trabeculae develop centrifugally toward the periphery. The ossification takes place via *radial and centrifugal* growth (fig. 3.4.) in the flat area of the bone primordium. In this form of ossification, we recognize the circle with a midpoint and the accompanying rays as the archetype.

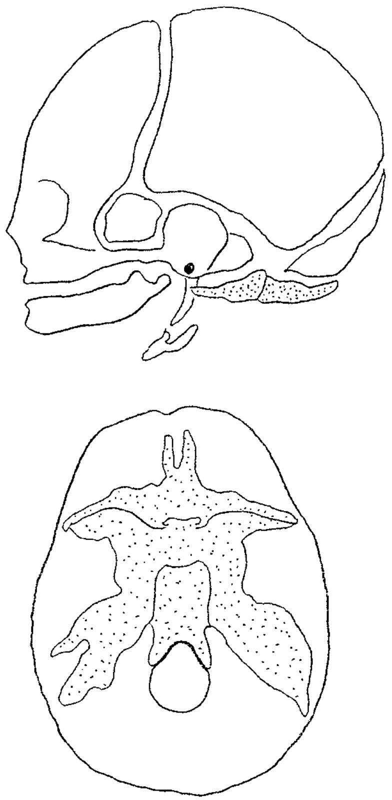


Fig. 3.3. Membranous (white) and endochondral ossification (dotted area) of the skull

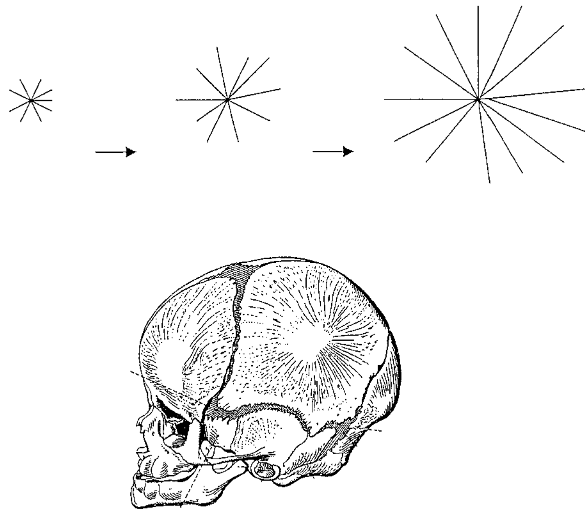


Fig. 3.4. Diagram of radial form of ossification of the cranial bones (Benninghof and Goerttler 1964)

3.1.4. Joining of Cranial Bones: Synostoses and Sutures

The joining of various parts of the skeleton to each other varies greatly according to their topography within the body. The most intensive connection of the skeletal parts can be found in the skull, in particular in the neurocranium. In the adult, the frontal bone is made up of one piece, where there were originally two frontal bones. The original suture between the frontal bones (fig. 3.5.) disappears completely. This osteoid connection is, therefore, called a *synostosis*. The connection with the parietal bones is the coronal *suture*. The anatomical construction of the sutures leads to a near immobilization of the bones of the skull with respect to each other. The morphological association that is expressed here can be characterized as a tendency towards *convergence and immobility.*

Joints that allow any free movement between the bones of the skull are not present in the neurocranium. The joints and articulating sections of bone that do occur in the head, such as the temporomandibular joint and the joints of the auricular bones, are derived from the branchial arches and are, in the restricted sense, not seen as part of the development of the cranium.

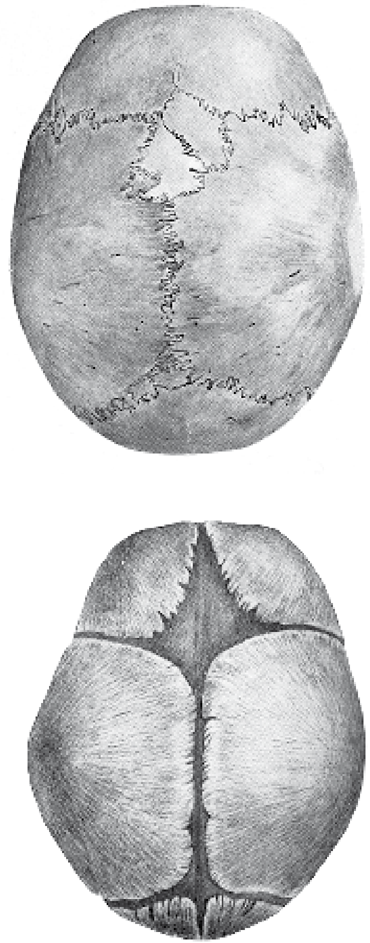


Fig. 3.5. Skull of newborn infant and adult (Woerdeman 1954)

3.1.5. The Exoskeleton

In the head, the brain, the large blood vessels, and the points of origin of the cranial nerves, lie within the neurocranium. The bone lies directly underneath the skin and is immediately observable. The head - in particular, the neurocranium - is, therefore, essentially an *exoskeleton*.
The eye appears to be the exception to this general rule because it is outside the skull but, nonetheless, inside the orbit.
The eyes are, however, not immobile sense organs as are the auditory organ, the organ of balance, and the olfactory organ. Due to the presence of the eye muscles, the eyes have an added element of movement which is comparable to that of the limbs: the eyes can move in the same manner as the arms and legs. In this sense, the eyes are also strongly related to the limbs which follow different morphological laws, since they have endoskeletons. The orbits display characteristics of both cranial and limb systems. The orbit partially encloses the eyes and surround them with bone, as is characteristic of the neurocranium. At the same time, they are not part of the cranial cavity. The orbits also form the points of attachment of the eye muscles as the pelvis does for the muscles of the leg, thereby fulfilling the function of an endoskeleton.

At the base of the skull, we find two structures that function as endoskeleton: the styloid process and the pterygoid process.
Both of these are, however, typically structures that have arisen from the base of the skull, the portion of the skull that originally displayed such a close relationship to the extremities see the desmoid and enchondral ossification (Chapter 3.1.2.). The styloid process and the pterygoid process function as points of attachment for the chewing and swallowing muscles and the muscles of the nasal pharynx. Thus it becomes clear that, within one part of the body - in this case, the head - a polarizing principle can be retraced consistently and in great detail (Chapter 9.).

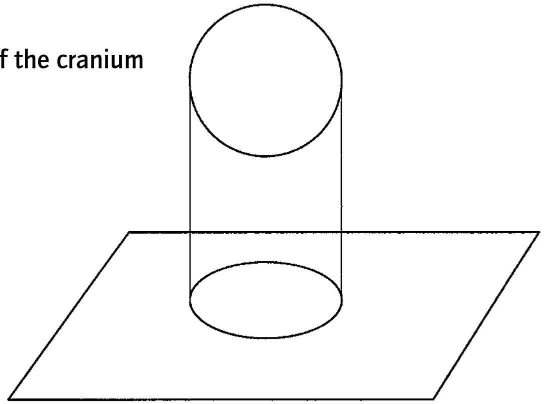


Fig. 3.6. Spheres and planes in the morphology of the cranium

3.1.6. Morphological Characteristics of the Head

The human head has the characteristic *spherical form* that is primarily constructed from the *planes* of the neurocranial bones. This morphological tendency is displayed in many ways. In the macroscopic appearance of the human head, this tendency is immediately observable and finds its maximal expression in the formation of the neurocranium. Microscopically the form of the ossification centers (Chapter 3.1.3.) can be placed within the geometry of planes and spheres, since the circle with its midpoint and corresponding rays can be seen as the projection of the sphere onto a flat surface (fig. 3.6.). The *plane* (mathematically, a sphere with an infinitely long radius) and the *sphere* are the forms that are the foundation of the form and the development of the cranium in the human being.

➔ *The plane and the sphere are characteristic for the morphology of the head and the cranium.*

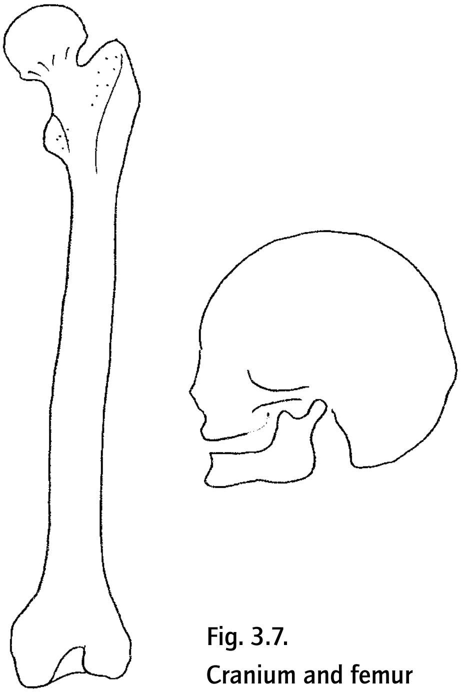
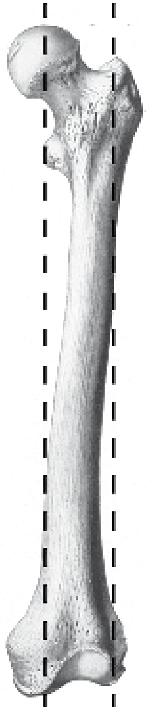


Fig. 3.7.
Cranium and femur

Fig. 3.8. Radial aspect and parallelism as characteristic of the extremities



3.2. The Limbs

3.2.1. The Form of the Limbs

The skeleton of the limbs is primarily formed by the long (cylindrical) bones. The term 'long bone' was perfectly chosen by ancient anatomists. An upper arm or an upper leg is, however, hardly tubular in the true meaning of the word. It is clear that the ancient anatomists chose their nomenclature based on a natural feeling for the morphological dynamic. Long bones have a *radial and parallel structure*, are hollow and have, when cross-sectioned, a nearly circular shaft.
When compared with the cranium, the differences in morphological characteristics between the cranium and the long bones are immediately apparent (fig. 3.7.).

3.2.2. The Dynamic Morphology of the Extremities

The shape of the long bones displays a completely different dynamic than the shape of the cranium. The form of the cranium has the characteristic of a sphere, the long bones have a *radial and parallel* structure. Just as the cranium is not a perfect sphere, neither are the long bones perfectly radial. One must, therefore, use the term *morphological characteristic*. In those places where several bones in the arm or leg are positioned next to each other, there is a clear parallel aspect: the bones of the lower leg, the forearm, the metacarpal bones and metatarsal bones, the fingers, and the toes run practically *parallel* to each other (fig. 3.8.).

➔ *The characteristic of the long bones is that they are radial in form and run parallel to each other*

3.2.3. Enchondral Ossification

The long bones are created by the ossification of *cartilaginous skeleton,* which functions as the precursor of the definitive skeleton. It is of *mesodermal* origin and the ossification occurs by the replacement of cartilage by bone. In enchondral ossification, the mesoderm first develops into cartilage and then into bone (in the neurocranium, mesenchyme from the neural crest is converted directly into bone).

3.2.4. The Ossification of the Long Bones

The ossification of the long bones occurs from two ossification centers: the epiphyseal ossification centers in the proximal and distal parts of the bone and the ossification from the periost of the diaphysis. Between the epiphysal centers and the diaphysis are ring-shaped discs of cartilage (the epiphyseal plates) that continue to produce cartilage for a long period of time.

The bone spicules that originate from enchondral ossification are *parallel* and are situated lengthwise in the direction of the bone. The bone increases in thickness because it is built up peripherally and is dissolved in the center of the shaft such that the bone marrow cavity is created. This type of skeletal forming has a direct connection with the impact of gravity on the organism. The morphology and the degree of calcification of the long bones are, to a great degree, determined by the effect of gravity. Research on the structure of the bone spicules in relation to the effect of gravity is unequivocal in this. Bone spicules are formed in accordance with the lines of gravity that are operative in the skeleton (fig. 3.9.). In a weightless situation, the skeleton of the torso and the extremities is particularly threatened by decalcification because of the effect of insufficient gravity.

Enchondral ossification of the skeletal bones in the head also occurs in that portion of the cranium that develops from the branchial arches and the paraxial sclerotomes (fig. 3.3.). The architecture of the bone spicules in this portion of the skeleton displays the same characteristics as the architecture of the extremities (fig. 3.10.).

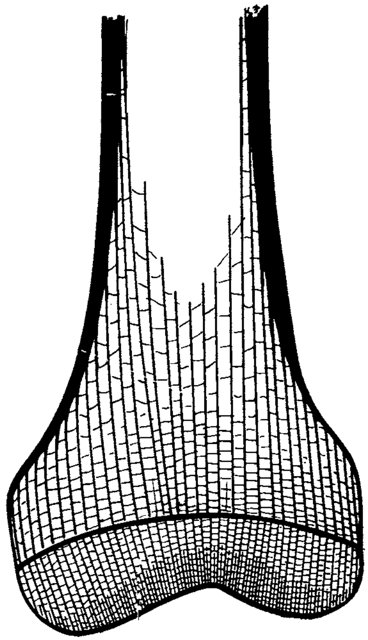


Fig. 3.9. Bone spicules in the skeleton of the extremities (Kiss 1964)

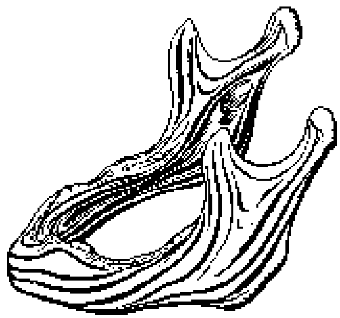


Fig. 3.10. Bone spicules in the skeleton of the developing branchial arch (Benninghof 1964)

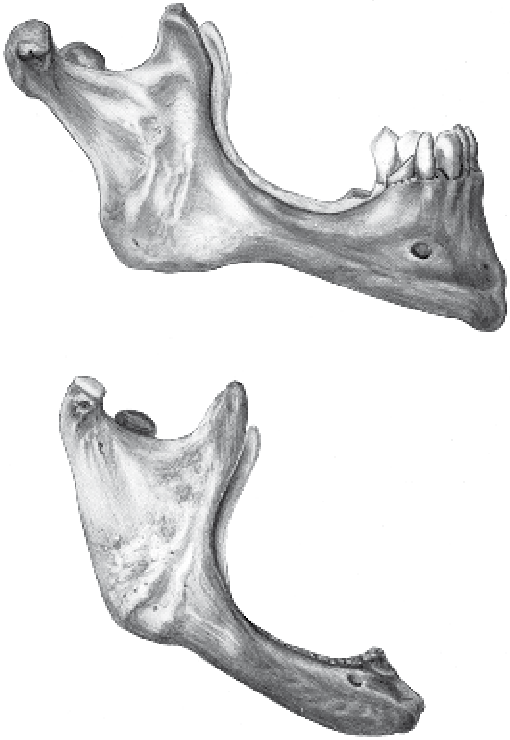


Fig. 3.11. Skeletal decline through loss of teeth (Woerdeman 1954)

In this area, we also find the forces that are exerted on the skeleton by the chewing musculature. Most of the bone tissue disappears from those areas where these forces can no longer influence the skeleton. This is particularly the case after the loss of teeth, which normally transfer these mechanical forces onto the skeleton. (fig. 3.11.).

3.2.5.The Connection between the Skeletal Parts of the Long Bones: the Joints

One outstanding example of a connection between the skeletal parts of the extremities is the *synovial joint.* This type of joint is characterized by a total discontinuance of skeletal continuity. In a synovial joint, the continuity is provided by tendons and ligaments and not by bone or cartilage. This type of joint, creates a maximum possibility for movement of the skeletal parts in the extremities with respect to each other and, therefore, of the body as a whole.

Thus, the greatest possible polarity is obtained with respect to what is found in the neurocranium where synostoses and sutures are formed (3.1.4.).

A synovial joint consists of a ball and a socket surrounded by ligaments. Both the ball and the socket are covered by a layer of *cartilage*. Nowhere the cartilaginous sections are connected to each other. This is one of the reasons why it is possible for a synovial joint to have optimum freedom of movement. Cartilage is not found anywhere in the skeleton of the neurocranium.

3.2.6. The Divergent Configuration of the Long Bones

One striking phenomenon in the morphology of the extremities is the principle of *divergence*. If we trace the parts of the skeleton of the limbs from proximal to distal, we find an increasing number of bones.

Upper arm/upper leg 1
Forearm/lower leg 2
Carpal bones: proximal 3
Tarsal bones: proximal 3
Carpal bones: distal 4
Tarsal bones: distal 4
Metacarpal bones/metatarsal bones 5
Finger/toe bones: per hand/foot14

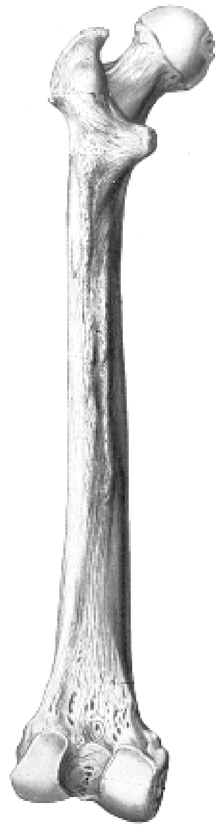


Fig. 3.12. Divergence in the structure of the upper leg (Benninghof 1964)

One can find this tendency towards *divergence* not only in the number of skeletal parts but also in the morphology of the skeletal parts themselves. It can be seen, for example, on the dorsal side of the femur and the humerus: on the femur, we find the divergence of the linea aspera (fig. 3.12.) and on the humerus, we find the broadening and division of the medial and lateral margins that surround the olecranon fossa. The two condyles of the femur and the humerus develop out of these diverging lines.
This tendency towards divergence then continues in the shape of the lower leg and forearm which both consist of two bones: the tibia and the fibula, and the ulna and the radius. These skeletal parts also display a divergence in their form as a duo which, in the lower leg, leads to the formation of both malleoli and, in the forearm, to the styloid processes.

3.2.7. The Endoskeleton

The bones of the extremities are generally completely surrounded by muscles, tendons and ligaments in contrast to the neurocranial bones. The large blood vessels and the nerves are also part of the surrounding structures of the skeleton (3.1.4.). In the neurocranium, the bones are on the outside and are clearly visible. Because of their structure, the bones of the extremities are, for the most part, hidden from view.

Therefore, the form of the extremities has, topographically, an architecture that is diametrically opposed to that of the cranium and, in particular, to that of the neurocranium.

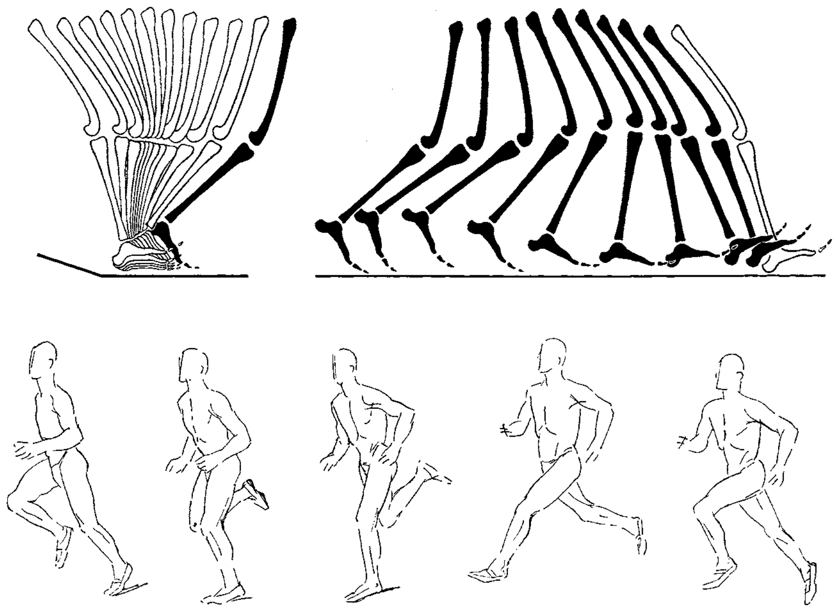


Fig. 3.13. Form change through movement (Benninghof and Goerttler 1964)

3.2.8. Form and Movement

When watching a human or an animal in motion, we experience a continuous *process of metamorphosis*. When the limbs move (change in posture and facial expression) the body configuration dissolves, only to settle down again when we stand still. During movement, the various forms flow smoothly into each other. The number of forms adapted by the human or animal during movement is infinitely large, because of the fluid character of these movements.

This applies both to the individual extremities and to the body as a whole (fig. 3.13.). The only exception to this is the neurocranium, which does not change in form. Here, the polarity between head and limbs once again becomes visible.

3.2.9. Morphological Characteristics of the Extremities

The configuration of the extremities displays a completely opposite dynamic, in comparison to the cranium. The morphological characteristic of the extremities displays a *radial and parallel configuration*. The number of bones in limb sections increases progressively towards the periphery which creates a clearly *divergent architecture* of the bones. The ossification process leads to an inner bone structure in which the *spicules* run primarily *parallel* to each other.

There is no question of solid connections among the bone sections themselves, the *synovial joints* rather allow a maximum amount of *freedom of movement*.

In the extremities, the skeleton becomes an *endoskeleton*, with muscles, tendons, blood vessels, lymphatic vessels, and nerves arranged around it.

When the organism as a whole moves, it is *in constant change*: one position flows into another and there is no longer any question of a fixed form.

3.3. The Thorax

3.3.1. The Form of the Torso

One large and characteristic portion of the torso is formed by the thorax. The shape of the thorax can be seen as a combination of the skull shape on the one hand, and the shape of the long bones, on the other. On the cranial side, the first pairs of ribs display a close connection to the shape of the neurocranium. The upper ribs are relatively flat and broad in comparison to the lower ribs which, in shape, are more closely related to the long bones. The upper ribs are nearly horizontal in position.
The clavicle, which is among the determinates of the external human form, has both types of ossification. Distally, there is desmoid ossification that is reminiscent of the neurocranium; proximally, there is enchondral ossification that is a preview of the situation in the extremities.

The form of the top of the thorax is continued in the parietal pleura. The portion of the parietal pleura that protrudes over the first rib is called the *pleural cupula.* The tendency towards the formation of spherical surfaces is clearly expressed in this term and accentuates the morphological tendency that is characteristic for the skull shape.
The vertebrae and the sternum contribute to the development of the form of the thorax. It is striking that, in the cranial portion of the thorax, the joints only allow limited movement. Both the costovertebral joints and the sternocostal joints are stiff in nature. The components of the joints, that consist of connective tissue and cartilage are partially responsible - due to their form - for the limited movement. Here we see another relationship to the dynamic of the cranial bones with respect to the *restricted and limited movement*.

The lower thorax and the lower ribs display an opposing dynamic. From cranial to caudal, mobility becomes increasingly greater, with an increasing range of movement in relationship to the sternum. The floating ribs hang free from the spine and no longer have a cartilaginous connection with each other or with the sternum. The possibilities for movement are relatively large and here the costovertebral joint allows the necessary movement.

The nearly vertical position in space and the radial or nearby tubular form of the lower ribs complete their similarity to the long bones.

➔ *Cranially, the thorax closes itself in a rounded arch, caudally it 'opens up' in a more radial gesture.*

3.3.2. The Rhythmic Structure of the Thorax: Repetition and Metamorphosis

If we survey all twelve ribs in their relation to each other, it then appears that there is a true series of metamorphoses. This means that, in the configuration of the ribs, in their position in space, and in their possibilities for movement from cranial to caudal, metamorphosis is clearly manifested (fig. 3.14.).

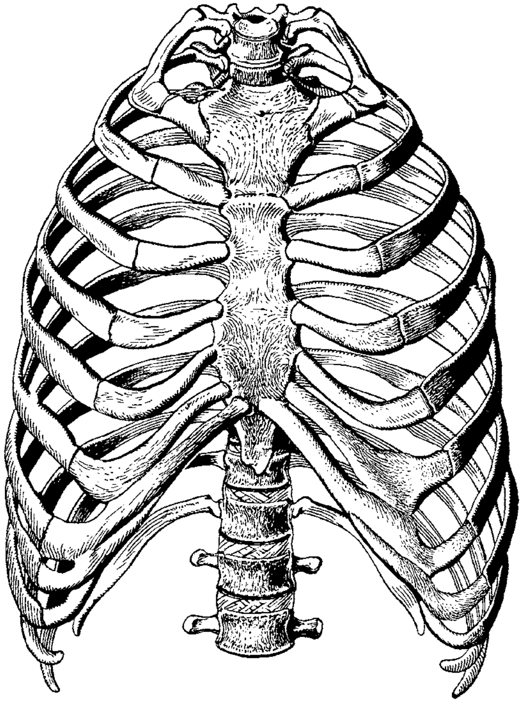


Fig. 3.14. Overview of metamorphosis of the ribs (Vogel 1979)

3.3.3. The Bony Connections of the Thorax and the Spinal Column

The connections between the bones of the thorax and the spinal column are, to a large degree, determined by the presence of cartilage. That is, of course, also true of the extremities, but the role of cartilage is in each situation entirely different. At the front of the thorax, cartilage forms the fixed connection between the ribs and the sternum. At the spinal column, we find cartilage on the costal capitulae, where the ribs articulate with the vertebrae, and on the intervertebral discs, which allow articulation between vertebrae. Therefore, at the front, the bony connection is more closely related to the morphology of the cranium where immoveable connections are characteristic. At the spinal column, however, there are synovial joints such as are characteristic for the extremities. In all cases, there is some mobility in both front and back albeit it to a limited degree.

➔ *In the skeleton, we find, in the direction from cranial to caudal, a metamorphosis in the structure and function of cartilage at the places where the bones are connected to each other.*

1. *In the cranium: no cartilage between the bone sections of the neurocranium, so that an immoveable bone connection is created. The cartilage that is present in the cranium is related to the development of the branchial arches (maxillary joint, nasal cavity and surroundings, ears).*
2. *In the thorax and the spinal column: cartilage is part of a fixed bone connection with limited movement.*
3. *In the extremities: a layer of cartilage covers the bones in the synovial joints with a high degree of free movement in all directions.*

3.3.4. From Exoskeleton to Endoskeleton

Topographically, the sternum, the clavicle and the *upper* ribs occupy the position of an exoskeleton, as we know from the neurocranium. The sternum lies directly under the skin and, together with the ribs, surrounds the organs situated in the thorax. The intercostal muscles are attached to the cranial and caudal sides of the ribs and leave the ventral and dorsal sides free.

The *lower* ribs surround the vital organs of the thorax cavity, and here the intercostal musculature, blood vessels, and nerves surround more and more the ribs. Once again, it is striking that the *upper* ribs have more the character of an exoskeleton and the *lower* ribs more the character of an endoskeleton. The ribs occupy a middle position between exoskeleton and endoskeleton.

Topographically, the spinal column occupies the typical position of an endoskeleton. In the cervical, thoracic, and lumbar regions, the spinal column is surrounded by powerful muscles such as the short and long muscles that are connected dorsally and ventrally to it. The characteristic morphological 'mid-position' of the thorax between the dynamic of the cranium and that of the extremities is also expressed here.

3.3.5. Morphological Characteristics of the Thorax

Characteristic for the morphology of the thorax is the *rhythmic configuration* and the *metamorphosis* of the form of the ribs and vertebrae (Chapter 4). Metamorphosis is a phenomenon in which, in the one hand, there is repetition of a morphological item, such as a rib or a vertebra but, at the same time, a change becomes visible within that repetition.
The change in the repetition can be further clarified morphologically. In a cranial direction, it tends to the characteristic form of the cranium (3.1.6.) and, in a caudal direction, of the extremities.
The rhythmical aspect does not only affect the ribs and the vertebrae, but also the organs in the thorax. The trachea, the sympathetic trunk, the intercostal musculature, the intercostal arteries and nerves, the dermatomes and the segmented structure of the spinal column, all display the same principles of rhythm and metamorphosis: *repetition and change.*
The thoracic organs that are not rhythmically structured, such as the heart, lungs, and diaphragm, display the rhythmical element at the *functional* level: systole and diastole for the heart, inhaling and exhaling for the lungs and contraction and relaxation for the diaphragm.

➔ *The thorax is the center for rhythmic phenomena: in space through its morphology and in time through its functionality.*
In the thorax, the morphological tendencies of the cranium and the extremities reach a synthesis that results in a morphological space that is free from one-sidedness. The tendency towards the specific forms on the cranial and caudal sides of the organism create, in mutual harmony, a morphological center in which the human being can 'breathe freely.'

3.4. Summary and Conclusions

The morphology of the skeleton displays two dynamic, polar processes represented by the form of the cranium and of the long bones. Spherical surfaces dominate in the cranium, while the radial formations dominate in the extremities.
The rhythmical structure of the thorax occupies a position that is midway between the skull and the extremities, in which change and repetition permeate each other. In the metamorphosis resulting from this, the polar dynamic of the cranium and the long bones is still recognizable in rudimentary form as morphological processes; these processes permeate each other but do not lead to a one-sided morphological dynamic.

All rays of a sphere intersect each other at the center point. As far as the human skull is concerned, the center lies behind the base of the nose, intracranially between the two temporal bones.

As for the parallel rays of the extremities, their point of intersection lies at an infinitely distant peripheral point.

The thorax displays a series of metamorphoses in which both poles permeate each other.

In relation to movement a polarity is created between the immobile spherical cranium and the mobile extremity bones. In the thorax, we find an accentuation of immobility on the cranial end and an accentuation of free mobility on the caudal end, and rhythm of movement is characteristic in this part.

3.5. Goethean Aspects

3.5.1. Form and Dynamic

A living organism possesses its own *form.* This form is, for each organism, subject to the blueprint and possibilities offered to that species. Just how one form (or species) can develop from another form (or species) is the primary question of every theory of evolution. The singular form of an organism is created in the course of its development. When studying this development, it becomes evident that organisms and organs evolve out of moving streams of fluid, through the migration of cell groups, and through the changes in form of the cells involved. At the cellular level, it is evident that every form change in a cell is preceded by movement, either in the cell plasma, or in the cell organelles and cell compartments at the sub-cellular and molecular biological level. These observations justify the formulation of a basic law in morphology:

Form arises from movement

For a phenomenological viewpoint, one can differentiate between characterizing the *form* and characterizing the *dynamic*. The dynamic can be derived by characterizing the *movements* that have led to the development of the form. A specific dynamic will lead to a specific form, as was described in the previous chapter.
The phenomenological characterization of the morphology of the skeleton, therefore, makes a conscious distinction between form and dynamic. The relationship that dynamic and form have to each other can then be more clearly expressed.

3.5.2. Centripetal Dynamic and the Spherical Form

The sphere and the circle are, dynamically seen, determined by the *orientation to a center*. This orientation can, from a dynamic perspective, be experienced as a centripetal tendency. Centripetally active forces come to rest in the center. The result of this process is that there is a lasting cohesion among the various points. Morphogenetically this leads to the existence of immobile continuity of form. The head, specifically the neurocranium of the human, is the prime example of a settling process coming to rest, leading to an *immobile, fixed form.* The cranial bones have become, to a large extent, an immovable object. The forming of synostoses and sutures between the cranial bones is proof of this.
Functionally, the centripetal tendency can be experienced in our own process of perception

and reflection.

The world can be experienced through the senses to become part of one's *conscious perception* and, through this, the world becomes the content of inner *cognitive processes*.

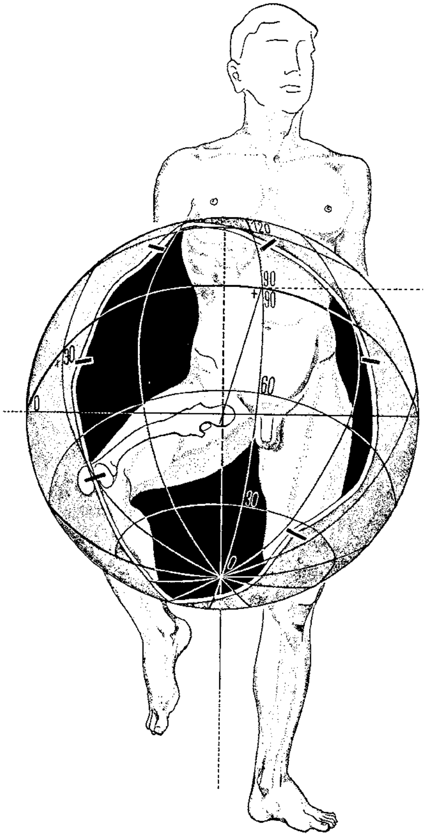


Fig. 3.15. Range of movement of the femur as a spherical segment (Benninghof and Goettler 1964)

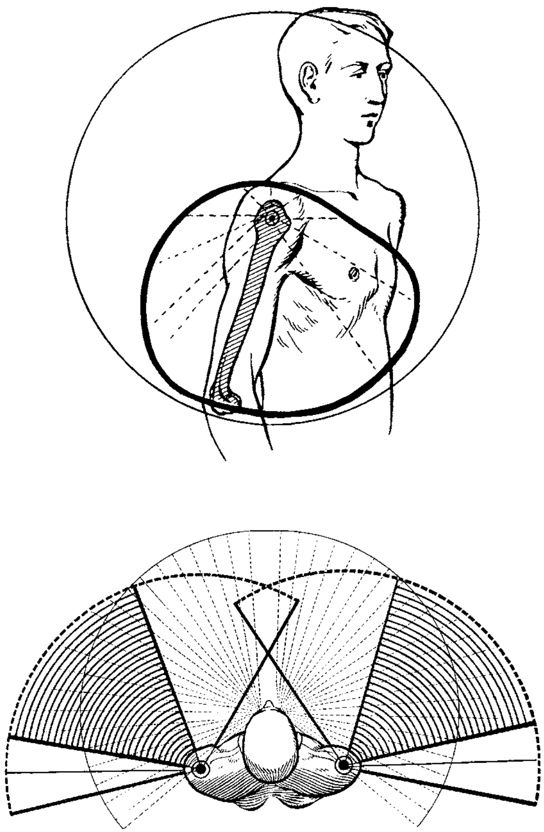


Fig. 3.16. Range of movement of the humerus as a spherical segment (Benninghof and Goerttler 1964)

3.5.3. Centrifugal Dynamic and the Radial Form

The limbs have a radial form and, in contrast to the skull, *have their point of orientation in the periphery*. The limbs are not aligned towards one point, but to a multitude of points in the periphery. Just as the form of the cranium is aligned towards a center, the form of the extremities is aligned towards a nearly infinite number of points in the periphery. Those peripheral points could, in theory, be thought of as (part of) a sphere. It is possible to show the range of movement of an extremity as part of a spherical segment.

The structure of the extremities does not only display an increase in the number of bones towards the periphery, there is also an increase in free mobility. The orientation of movement is *directed towards the periphery*. The range of movement can then be expressed in the number of degrees of a segment of the sphere within which that particular bone can move (fig. 3.15. and 3.16.).

Functionally, the limbs have the ability to change the surrounding world. Ultimately, all of our actions are based on motor activity. The entire cultural legacy originates from human actions. The spoken or written word is certainly no exception to this.

3.5.4. Rhythmical Dynamic and Rhythmical Form

The entire human thorax displays a *rhythmical form* that is particularly clear in the structure of the spinal column and the ribs.
The thorax form is, within certain boundaries, both fixed and changeable. The immobile and fixed is more characteristic of the vertebrae, which are dynamically comparable to the cranium, while the changeable is more typical of the ribs, which display a relationship to the extremities. The rhythmical center contains the centripetal and centrifugal in a state of equilibrium.

Rhythm as the merging of the centrifugal and the centripetal dynamic can be seen as an enhanced combination of both. Another consideration is, however, that the rhythmical center can be seen as something separate that already contains the centripetal and centrifugal within itself (see also: 4.3.2.). In that case, the opposing poles originate from the center in the course of development. In chapter 9, which deals with polarization and the role of the center in polarization, this will be further explained using developmental phenomena from comparative anatomy.

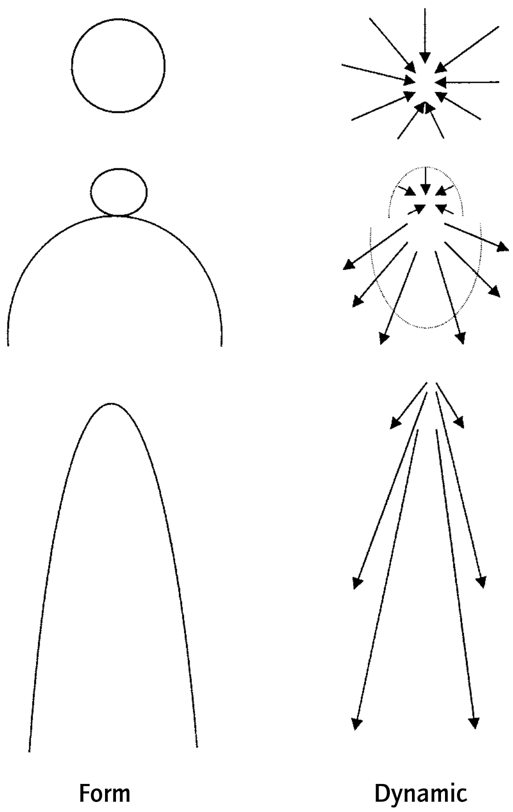


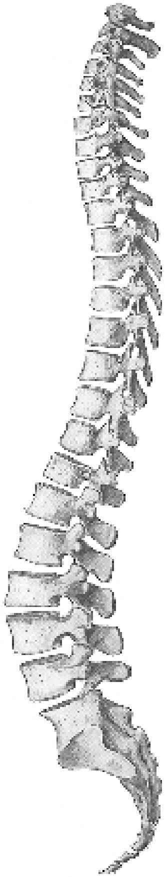
Fig. 3.17. Dynamic outline

3.6. Once Again, the Blueprint

We may characterize the dynamic outline of an organism from its blueprint. There are, essentially, three dynamic processes: the pursuit of spherical form through a centripetal dynamic, the pursuit of radial form through a centrifugal radial dynamic and a harmonizing, rhythmical dynamic which contains both of these dynamics as a potential.

The dynamic outline of the blueprint that can be seen as basic to the skeleton as a whole repeats itself, upon closer examination, in different parts of the skeleton as well as in organs and organ systems. This will be discussed in the following chapters.

4. The Morphology of the Spinal Column



4.1. Introduction

The ability to form a calcified internal skeleton is a developmental characteristic of the higher animal organism. The spinal column - and with it, the vertebrae - occupy a pivotal place in morphological classification of animals. Higher forms of animal life (the chordates) are subdivided into vertebrates and invertebrates. The first group possesses a spinal column in the organism itself, the second group does not. That difference is determining for the ranking of their position on the evolutionary ladder.
The internal support system of many of the lower vertebrates consists of cartilage rather than bone.

4.2. Metamorphosis in the Spinal Column

4.2.1. The Blueprint of the Vertebrae in Relation to the Ribs

We can differentiate among the various parts of the vertebra (fig. 4.1.): the vertebral body, the vertebral arch, and the transverse and spinous processes. The most typical vertebral structure can be found at the level of the 6th thoracic vertebra.

The thoracic vertebrae have a close relationship to the ribs. Together they form a functional unit (fig. 4.2.). Upon further consideration this relationship also exists in vertebrae which are not attached to any ribs, such as the cervical, lumbar and sacral vertebrae. It appears that these vertebrae have *rudimentary ribs* in their blueprint. That is how the transverse foramen develops in cervical vertebrae and the accessory process (processus costarius) on lumbar vertebrae (fig. 4.3.).

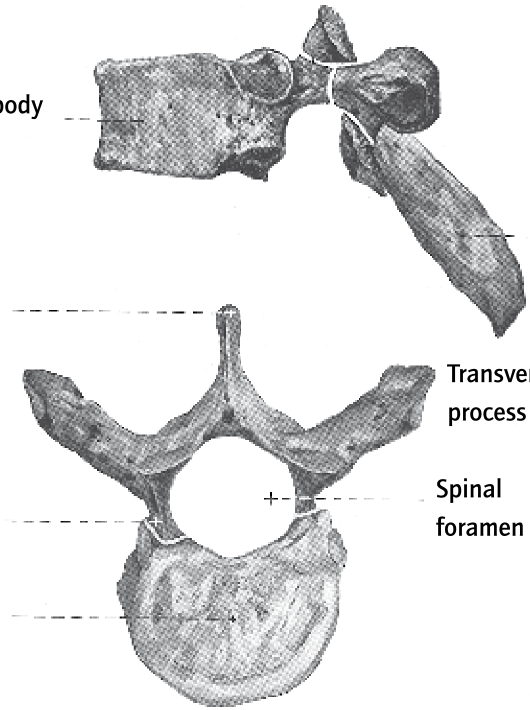


Fig. 4.1. A typical vertebra (Woerdeman 1954)

It is important to consider the fact that the variation in external form of the vertebrae including the ribs is determined by a metamorphosis of different parts. In the cervical, lumbar, and sacral regions, the ribs 'disappear' as a separate part of the skeleton but they add, rudimentarily, to the form of the cervical and lumbar vertebrae and the sacral bone. This implies that the metamorphosis of the vertebrae must be considered in the light of their relationship to the ribs.

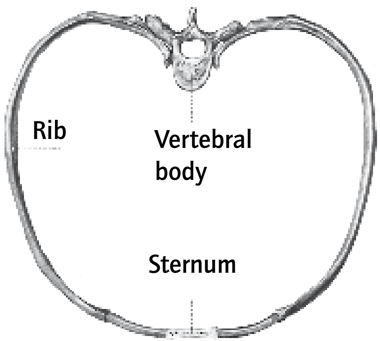


Fig. 4.2. Rib and vertebra (Woerdeman 1954)

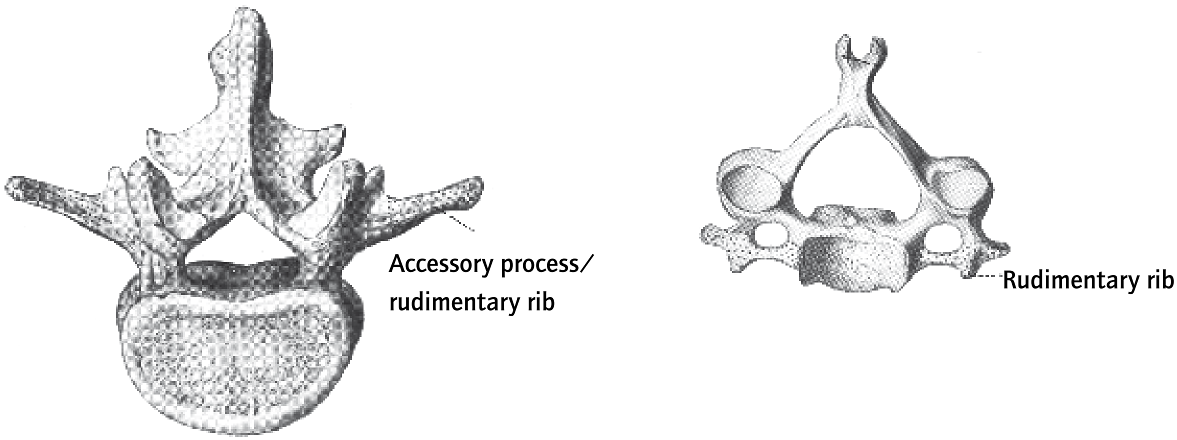


Fig. 4.3. Cervical vertebra and lumbar vertebra (Benninghof and Goerttler 1964)

4.2.2. Cervical Region

We may gain an understanding of the metamorphosis of the vertebrae by comparing the atlas vertebra, the fifth lumbar vertebra, and the sixth thoracic vertebra to each other (fig. 4.4.).

The *first cervical vertebra (atlas)* consists, for the most part, of a vertebral arch enclosing a relatively large lumen, which holds the central nervous system (the spinal cord).
The body of the atlantic vertebra hardly exists at all. The vertebral body is present in early development, but ultimately fuses with the vertebral body of C2, which results in the odontoid process. Of the spinous process, only the posterior tubercle remains.
The atlas, therefore, represents the ultimate reduction of the archetypal vertebra to a *vertebral arch*.
Three phenomena are of great significance when we look at the cervical vertebrae:

- the large, rounded space that is enclosed by the posterior arches of C1 and the other cervical vertebrae which provides space for the central nervous system
- their nearly horizontal position within the space

- the principle of forming planes dominates in their morphology.

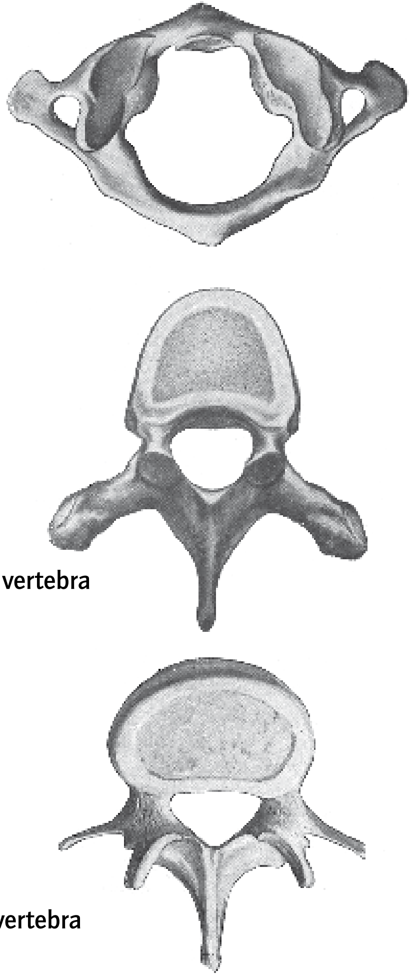
It is not difficult to trace these characteristics back to the morphology of the skull. The conclusion appears justified that the cervical vertebrae are morphologically related to the morphological dynamic of the skull, if we realize that the spherical form of the skull, when projected onto a flat surface, is converted into a circular form (fig. 3.6.).

4.2.3. Lumbar and Sacral Region

The lumbar vertebrae display a completely different morphology than the thoracic and, particularly, the cervical vertebrae. The heavy vertebral body is nearly round and, because of its height, gives the impression of being cylindrical. There is clearly a cortical layer of bone and a spongy section of bone marrow, as can also be found in the long bones. There is no longer a transverse process; in its place we find the accessory process (processus costarius), a rudimentary equivalent of the ribs (Chapter 4.1.1.).

The vertebral arch surrounds a limited area in which there is no more central nervous system, but the roots of the spinal nerves: the cauda equina. The spinous process is short and robust.

The sacrum is a portion of the skeleton that



Atlas

Thoracic vertebra

Lumbar vertebra

Fig. 4.4. Atlas, Th6 and L5 (Kiss 1964)

is composed of five vertebral elements. Because of the fusion of these elements, a quickly narrowing sacral canal develops a clearly *hollow vertical structure*.

4.2.4. Thoracic Region

The thoracic vertebrae come closest to a general blueprint of the vertebra: all parts are well developed and the vertebral body and vertebral arch are in balance. The spinous processes follow the dynamic of the ribs, in their position in space: the uppermost spinous processes are nearly *horizontal* but caudally they tend to become increasingly *vertical*. Cranially, the spinous processes are not robust but they become increasingly heavy in the lumbar direction. The vertebral body is heart-shaped.

4.3. Goethean Aspects

4.3.1. Morphological Characteristics of the Spinal Column

In the spinal column, two morphological forces appear to permeate each other and keep each other in balance: the morphological tendency of the head and the morphological tendency of the extremities. In the cervical spinal column, the former dominates and in the lumbar region, the latter. The thoracic region incorporates both tendencies harmoniously.

The morphological tendency of the skull had been characterized as a process generating an exoskeleton that surrounds the central nervous system by means of flat skeletal parts. The morphological tendencies of the long bones had been characterized as generating an endoskeleton that functions in the human movement system. The spinal column incorporates, as a true rhythmic center structure, both tendencies.

4.3.2. Morphological Characteristics of the Ribs

As was discussed above (Chapter 3.3.5.), the *metamorphosis of the ribs occurs parallel to the metamorphosis of the vertebrae*. It is clear from this that the development and structure of the spinal column must be seen as related to that of the ribs. The polar dynamic of head and limbs is, once again, visible here.

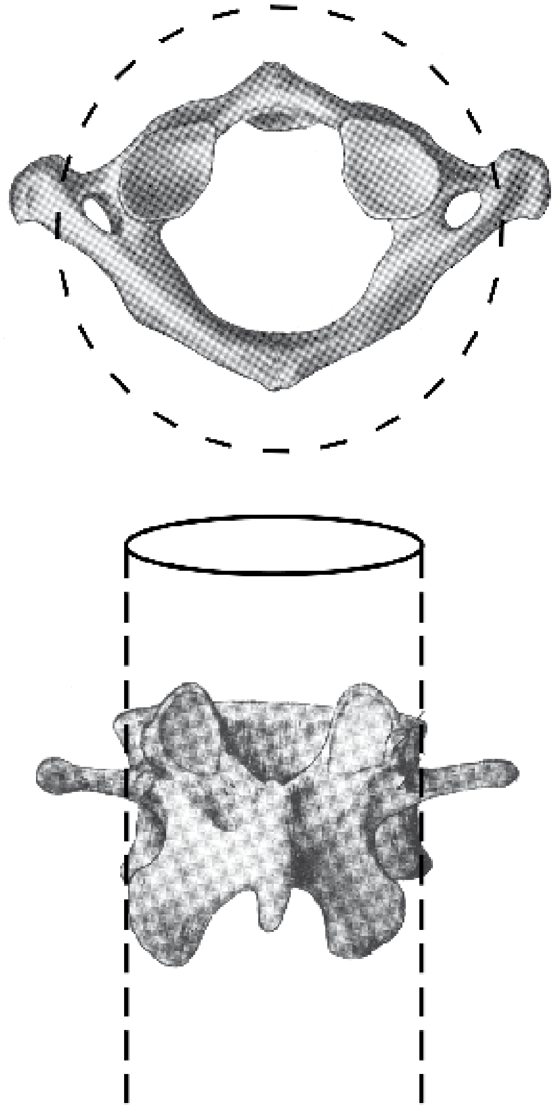


Fig. 4.5. Atlas as a circle and L5 as a cylinder

Anatomy

Morphological Anatomy from a Phenomenological Point of View

the natural source of knowledge

Can we give a scientific basis to our feeling that the human being has unique human features? Are the human mind and the human body 'nothing but' another variation of animal life? Can we find answers for these questions that satisfy both our head and our heart?

How these questions are answered depends on the scientific method we use. In this publication two methods are used: the current scientific method to learn about anatomical facts and the phenomenological method to understand the meaning of these facts.

Human morphology can then be understood as an expression of the unique and characteristic qualities of the human being. This results in new possibilities for understanding the relation between consciousness, psychology, behavior, and morphological aspects of the body.