Anatomy of the Human Body

Henry Gray

CONTENTS

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

I. Embryology

1 THE TERM **Embryology,** in its widest sense, is applied to the various changes which take place during the growth of an animal from the egg to the adult condition: it is, however, usually restricted to the phenomena which occur before birth. Embryology may be studied from two aspects: (1) that of **ontogeny,** which deals only with the development of the individual; and (2) that of **phylogeny,** which concerns itself with the evolutionary history of the animal kingdom.

2 In vertebrate animals the development of a new being can only take place when a female germ cell or **ovum** has been fertilized by a male germ cell or **spermatozoön.** The ovum is a nucleated cell, and all the complicated changes by which the various tissues and organs of the body are formed from it, after it has been fertilized, are the result of two general processes, viz., **segmentation** and **differentiation** of cells. Thus, the fertilized ovum undergoes repeated segmentation into a number of cells which at first closely resemble one another, but are, sooner or later, differentiated into two groups: (1) **somatic cells,** the function of which is to build up the various tissues of the body; and (2) **germinal cells,** which become imbedded in the sexual glands—the ovaries in the female and the testes in the male—and are destined for the perpetuation of the species.

3 Having regard to the main purpose of this work, it is impossible, in the space available in this section, to describe fully, or illustrate adequately, all the phenomena which occur in the different stages of the development of the human body. Only the principal facts are given, and the student is referred for further details to one or other of the text-books [1] on human embryology.

1. The Animal Cell

4 All the tissues and organs of the body originate from a microscopic structure (the **fertilized ovum**), which consists of a soft jelly-like material enclosed in a membrane and containing a vesicle or small spherical body inside which are one or more denser spots. This may be regarded as a complete cell. All the solid tissues consist largely of cells essentially similar to it in nature but differing in external form.

5 In the higher organisms a cell may be defined as "a nucleated mass of protoplasm of microscopic size." Its two essentials, therefore, are: a soft jelly-like material, similar to that found in the ovum, and usually styled **cytoplasm,** and a small spherical body imbedded in it, and termed a **nucleus.** Some of the unicellular protozoa contain no nuclei but granular particles which, like true nuclei, stain with basic dyes. The other constituents of the ovum, viz., its limiting membrane and the denser spot contained in the nucleus, called the **nucleolus,** are not essential to the type cell, and in fact many cells exist without them.

6 **Cytoplasm** (*protoplasm*) is a material probably of variable constitution during life, but yielding on its disintegration bodies chiefly of proteid nature. Lecithin and cholesterin are constantly found in it, as well as inorganic salts, chief among which are the phosphates and chlorides of potassium, sodium, and calcium. It is of a semifluid, viscid consistence, and probably colloidal in nature. The living cytoplasm appears to consist of a homogeneous and structureless ground-substance in which are embedded granules of various types. The **mitochondria** are the most constant type of granule and vary in form from granules to rods and threads. Their function is unknown. Some of the granules are proteid in nature and probably essential constituents; others are fat, glycogen, or pigment granules, and are regarded as adventitious material taken in from without, and hence are styled cell-inclusions or **paraplasm.** When, however, cells have been "fixed" by reagents a fibrillar or granular appearance can often be made out under a high power of the microscope. The fibrils are usually arranged in a network or reticulum, to which the term **spongioplasm** is applied, the clear substance in the meshes being termed **hyaloplasm.** The size and shape of the meshes of the spongioplasm vary in different cells and in different parts of the same cell. The relative amounts of spongioplasm and hyaloplasm also vary in different cells, the latter preponderating in the young cell and the former increasing at the expense of the hyaloplasm as the cell grows. Such appearances in fixed cells are no indication whatsoever of the existence of similar structures in the living, although there must have been something in the living cell to give rise to the fixed structures. The peripheral layer of a cell is in all cases modified, either by the formation of a definite **cell membrane** as in the ovum, or more frequently in the case of animal cells, by a transformation, probably chemical in nature, which is only recognizable by the fact that the surface of the cell behaves as a semipermeable membrane.

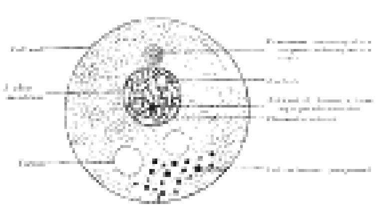

FIG. 1– Diagram of a cell. (Modified from Wilson.) (See enlarged image)

Nucleus.—The nucleus is a minute body, imbedded in the protoplasm, and usually of a spherical or oval form, its size having little relation to that of the cell. It is surrounded by a well-defined wall, the **nuclear membrane;** this encloses the **nuclear substance** (*nuclear matrix*), which is composed of a homogeneous material in which is usually embedded one or two nucleoli. In fixed cells the nucleus seems to consist of a clear substance or **karyoplasm** and a network or **karyomitome.** The former is probably of the same nature as the hyaloplasm of the cell, but the latter, which forms also the wall of the nucleus, differs from the spongioplasm of the cell substance. It consists of fibers or filaments arranged in a reticular manner. These filaments are composed of a homogeneous material known as **linin,** which stains with acid dyes and contains embedded in its substance particles which have a strong affinity for basic dyes. These basophil granules have been named **chromatin** or **basichromatin** and owe their staining properties to the presence of nucleic acid. Within the nuclear matrix are one or more highly refracting bodies, termed **nucleoli,** connected with the nuclear membrane by the nuclear filaments. They are regarded as being of two kinds. Some are mere local condensations ("net-knots") of the chromatin; these are irregular in shape and are termed **pseudo-nucleoli;** others are distinct bodies differing from the pseudo-nucleoli both in nature and chemical composition; they may be termed **true nucleoli,** and are usually found in resting cells. The true nucleoli are oxyphil, *i.e.,* they stain with acid dyes. 7

Most living cells contain, in addition to their protoplasm and nucleus, a small particle which usually lies near the nucleus and is termed the **centrosome.** In the middle of the centrosome is a minute body called the **centriole,** and surrounding this is a clear spherical mass known as the **centrosphere.** The protoplasm surrounding the centrosphere is frequently arranged in radiating fibrillar rows of granules, forming what is termed the **attraction sphere.** 8

Reproduction of Cells.—Reproduction of cells is effected either by **direct** or by **indirect division.** In reproduction by **direct division** the nucleus becomes constricted in its center, assuming an hour-glass shape, and then divides into two. This is followed by a cleavage or division of the whole protoplasmic mass of the cell; and thus two daughter cells are formed, each containing a nucleus. These daughter cells are at first smaller than the original mother cell; but they grow, and the process may be repeated in them, so that multiplication may take place rapidly. **Indirect division** or **karyokinesis** (*karyomitosis*) has been observed in all the tissues—generative cells, epithelial tissue, connective tissue, muscular tissue, and nerve tissue. It is possible that cell division may always take place by the indirect method. 9

The process of indirect cell division is characterized by a series of complex changes in the nucleus, leading to its subdivision; this is followed by cleavage of the cell protoplasm. Starting with the nucleus in the quiescent or **resting stage,** these changes may be briefly grouped under the four following phases (Fig. 2). 10

1. **Prophase.**—The nuclear network of chromatin filaments assumes the form of a twisted *skein* or *spirem,* while the nuclear membrane and nucleolus disappear. The convoluted skein of chromatin divides into a definite number of V-shaped segments or **chromosomes.** The number of chromosomes varies in different animals, but is constant for all the cells in an animal of any given species; in man the number is given by Flemming and Duesberg as twenty-four. 2 Coincidently with or preceding these changes the centriole, which usually lies by the side of the nucleus, undergoes subdivision, and the two resulting centrioles, each surrounded by a centrosphere, are seen to be connected by a spindle of delicate achromatic fibers the **achromatic spindle.** The centrioles move away from each other—one toward either extremity of the nucleus—and the fibrils of the achromatic spindle are correspondingly lengthened. A line encircling the spindle midway between its extremities or **poles** is named the **equator,** and around this the V-shaped chromosomes arrange themselves in the form of a star, thus constituting the **mother star** or **monaster.** 11

2. **Metaphase.**—Each V-shaped chromosome now undergoes longitudinal cleavage into two equal parts or **daughter chromosomes,** the cleavage commencing at the apex of the V and extending along its divergent limbs. 12

3. **Anaphase.**—The daughter chromosomes, thus separated, travel in opposite directions along the fibrils of the achromatic spindle toward the centrioles, around which they group themselves, and thus two star-like figures are formed, one at either pole of the achromatic spindle. This constitutes the **diaster.** The daughter chromosomes now arrange themselves into a *skein* or *spirem,* and eventually form the network of chromatin which is characteristic of the resting nucleus. 13

4. **Telophase.**—The cell protoplasm begins to appear constricted around the equator of the achromatic spindle, where double rows of granules are also sometimes seen. The constriction deepens and the original cell gradually becomes divided into two new cells, each with its own nucleus and centrosome, which assume the ordinary positions occupied by such structures in the resting stage. The nuclear membrane and nucleolus are also differentiated during this phase. 14

FIG. 2– Diagram showing the changes which occur in the centrosomes and nucleus of a cell in the process of mitotic division. (Schäfer.) *I* to *III,* prophase; *IV,* metaphase; *V* and *VI,* anaphase; *VII* and *VIII,* telophase.
(See enlarged image)

Note 1. Manual of Human Embryology, Keibel and Mall; Handbuch der vergleichenden und experimentellen Entwickelungslehre der Wirbeltiere, Oskar Hertwig; Lehrbuch der Entwickelungsgeschichte, Bonnet; The Physiology of Reproduction, Marshall. [back]

Note 2. Dr. J. Duesberg, Anat. Anz., Band xxviii, S. 475. [back]

2. The Ovum

The ova are developed from the primitive germ cells which are imbedded in the substance of the ovaries. Each primitive germ cell gives rise, by repeated divisions, to a number of smaller cells termed **oögonia,** from which the **ova** or **primary oöcytes** are developed. 1

Human ova are extremely minute, measuring about 0.2 mm. in diameter, and are enclosed within the egg follicles of the ovaries; as a rule each follicle contains a single ovum, but sometimes two or more are present. 3 By the enlargement and subsequent rupture of a follicle at the surface of the ovary, an ovum is liberated and conveyed by the uterine tube to the cavity of the uterus. Unless it be fertilized it undergoes no further development and is discharged from the uterus, but if fertilization take place it is retained within the uterus and is developed into a new being. 2

In appearance and structure the ovum (Fig. 3) differs little from an ordinary cell, but distinctive names have been applied to its several parts; thus, the cell substance is known as the **yolk** or **oöplasm,** the nucleus as the **germinal vesicle,** and the nucleolus as the **germinal spot.** The ovum is enclosed within a thick, transparent envelope, the **zona striata** or **zona pellucida,** adhering to the outer surface of which are several layers of cells, derived from those of the follicle and collectively constituting the **corona radiata.** 3

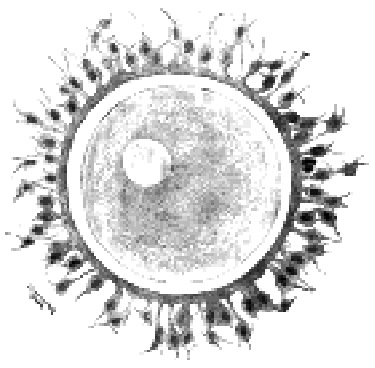

FIG. 3– Human ovum examined fresh in the liquor folliculi. (Waldeyer.) The zona pellucida is seen as a thick clear girdle surrounded by the cells of the corona radiata. The egg itself shows a central granular deutoplasmic area and a peripheral clear layer, and encloses the germinal vesicle, in which is seen the germinal spot. (See enlarged image)

Yolk.—The yolk comprises (1) the **cytoplasm** of the ordinary animal cell with its spongioplasm and hyaloplasm; this is frequently termed the **formative yolk;** (2) the **nutritive yolk** or **deutoplasm,** which consists of numerous rounded granules of fatty and albuminoid substances imbedded in the cytoplasm. In the mammalian ovum the nutritive yolk is extremely small in amount, and is of service in nourishing the embryo in the early stages of its development only, whereas in the egg of the bird there is sufficient to supply the chick with nutriment throughout the whole period of incubation. The nutritive yolk not only varies in amount, but in its mode of distribution within the egg; thus, in some animals it is almost uniformly distributed throughout the cytoplasm; in some it is centrally placed and is surrounded by the cytoplasm; in others it is accumulated at the lower pole of the ovum, while the cytoplasm occupies the upper pole. A **centrosome** and **centriole** are present and lie in the immediate neighborhood of the nucleus. 4

Germinal Vesicle.—The germinal vesicle or nucleus is a large spherical body which at first occupies a nearly central position, but becomes eccentric as the growth of the ovum proceeds. Its structure is that of an ordinary cell-nucleus, viz., it consists of a reticulum or karyomitome, the meshes of which are filled with karyoplasm, while connected with, or imbedded in, the reticulum are a number of chromatin masses or chromosomes, which may present the appearance of a skein or may assume the form of rods or loops. The nucleus is enclosed by a delicate nuclear membrane, and contains in its interior a well-defined nucleolus or germinal spot. 5

Coverings of the Ovum.—The **zona striata** or **zona pellucida** (Fig. 3) is a thick membrane, which, under the higher powers of the microscope, is seen to be radially striated. It persists for some time after fertilization has occurred, and may serve for protection during the earlier stages of segmentation. It is not yet determined whether the zona striata is a product of the cytoplasm of the ovum or of the cells of the corona radiata, or both. 6

The **corona radiata** (Fig. 3) consists or two or three strata of cells; they are derived from the cells of the follicle, and adhere to the outer surface of the zona striata when the ovum is set free from the follicle; the cells are radially arranged around the zona, those of the innermost layer being columnar in shape. The cells of the corona radiata soon disappear; in some animals they secrete, or are replaced by, a layer of adhesive protein, which may assist in protecting and nourishing the ovum. 7

The phenomena attending the discharge of the ova from the follicles belong more to the ordinary functions of the ovary than to the general subject of embryology, and are therefore described with the anatomy of the ovaries. 4 8

9 **Maturation of the Ovum.**—Before an ovum can be fertilized it must undergo a process of **maturation** or **ripening.** This takes place previous to or immediately after its escape from the follicle, and consists essentially of an unequal subdivision of the ovum (Fig. 4) first into two and then into four cells. Three of the four cells are small, incapable of further development, and are termed **polar bodies** or **polocytes,** while the fourth is large, and constitutes the **mature ovum.** The process of maturation has not been observed in the human ovum, but has been carefully studied in the ova of some of the lower animals, to which the following description applies.

10 It was pointed out on page 37 that the number of chromosomes found in the nucleus is constant for all the cells in an animal of any given species, and that in man the number is probably twenty-four. This applies not only to the somatic cells but to the primitive ova and their descendants. For the purpose of illustrating the process of maturation a species may be taken in which the number of nuclear chromosomes is four (Fig. 5). If an ovum from such be observed at the beginning of the maturation process it will be seen that the number of its chromosomes is apparently reduced to two. In reality, however, the number is doubled, since each chromosome consists of four granules grouped to form a **tetrad.** During the metaphase (see page 37) each tetrad divides into two **dyads,** which are equally distributed between the nuclei of the two cells formed by the first division of the ovum. One of the cells is almost as large as the original ovum, and is named the **secondary oöcyte;** the other is small, and is termed the **first polar body.** The secondary oöcyte now undergoes subdivision, during which each dyad divides and contributes a single chromosome to the nucleus of each of the two resulting cells.

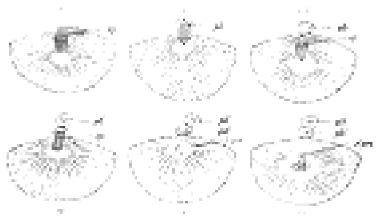

FIG. 4– Formation of polar bodies in Asterias glacialis. (Slightly modified from Hertwig.) In *I* the polar spindle (*sp*) has advanced to the surface of the egg. In *II* a small elevation (pb^1) is formed which receives half of the spindle. In *III* the elevation is constricted off, forming the first polar body (pb^1), and a second spindle is formed. In *IV* is seen a second elevation which in *V* has been constricted off as the second polar body (pb^2). Out of the remainder of the spindle (*f.pn* in *VI*) the female pronucleus is developed. (See enlarged image)

FIG. 5– Diagram showing the reduction in number of the chromosomes in the process of maturation of the ovum. (See enlarged image)

11 This second division is also unequal, producing a large cell which constitutes the **mature ovum,** and a small cell, the **second polar body.** The first polar body frequently divides while the second is being formed, and as a final result four cells are produced, viz., the mature ovum and three polar bodies, each of which contains two chromosomes, *i.e.,* one-half the number present in the nuclei of the somatic cells of members of the same species. The nucleus of the mature ovum is termed the **female pronucleus.**

Note 3. See description of the ovary on a future page. [back]

Note 4. See description of the ovary on a future page. [back]

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3. The Spermatozoön

The **spermatozoa** or **male germ cells** are developed in the testes and are present in enormous numbers in the seminal fluid. Each consists of a small but greatly modified cell. The human spermatozoön possesses a **head,** a **neck,** a **connecting piece** or **body,** and a **tail** (Fig. 6). 1

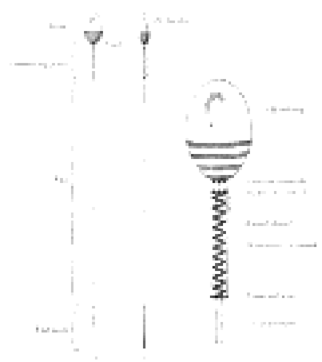

FIG. 6– Human spermatozoön. Diagrammatic. *A.* Surface view. *B.* Profile view. In *C* the head, neck, and connecting piece are more highly magnified. (See enlarged image)

The **head** is oval or elliptical, but flattened, so that when viewed in profile it is pear-shaped. Its anterior two-thirds are covered by a layer of modified protoplasm, which is named the **head-cap.** This, in some animals, *e. g.,* the salamander, is prolonged into a barbed spear-like process or **perforator,** which probably facilitates the entrance of the spermatozoön into the ovum. The posterior part of the head exhibits an affinity for certain reagents, and presents a transversely striated appearance, being crossed by three or four dark bands. In some animals a central rodlike filament extends forward for about two-thirds of the length of the head, while in others a rounded body is seen near its center. The head contains a mass of chromatin, and is generally regarded as the nucleus of the cell surrounded by a thin envelope. 2

The **neck** is less constricted in the human spermatozoön than in those of some of the lower animals. The **anterior centriole,** represented by two or three rounded particles, is situated at the junction of the head and neck, and behind it is a band of homogeneous substance. 3

The **connecting piece** or **body** is rod-like, and is limited behind by a *terminal disk.* The **posterior centriole** is placed at the junction of the body and neck and, like the anterior, consists of two or three rounded particles. From this centriole an **axial filament,** surrounded by a sheath, runs backward through the body and tail. In the body the sheath of the axial filament is encircled by a **spiral thread,** around which is an envelope containing mitochondria granules, and termed the **mitochondria sheath.** 4

The **tail** is of great length, and consists of the axial thread or filament, surrounded by its sheath, which may contain a spiral thread or may present a striated appearance. The terminal portion or **end-piece** of the tail consists of the axial filament only. 5

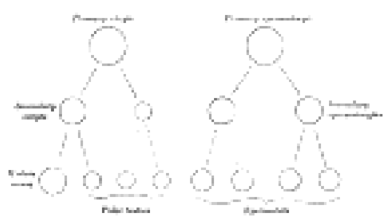

FIG. 7– Scheme showing analogies in the process of maturation of the ovum and the development of the spermatids (young spermatozoa). (See enlarged image)

Krause gives the length of the human spermatozoön as between 52 and 62, the head measuring 4 to 5, the connecting piece 6, and the tail from 41 to 52. 6

By virtue of their tails, which act as propellers, the spermatozoa are capable of free movement, and if placed in favorable surroundings, *e. g.,* in the female passages, will retain their vitality and power of fertilizing for several days. In certain animals, *e. g.,* bats, it has been proved that spermatozoa retained in the female passages for several months are capable of fertilizing. 7

The spermatozoa are developed from the primitive germ cells which have become imbedded in the testes, and the stages of their development are very similar to those of the maturation of the ovum. The primary germ cells undergo division and produce a number of cells termed **spermatogonia,** and from these the **primary spermatocytes** are derived. Each primary spermatocyte divides into two **secondary spermatocytes,** and each secondary spermatocyte into two **spermatids** or young spermatozoa; from this it will be seen that a primary spermatocyte gives rise to *four* spermatozoa. On comparing this process with that of the maturation of the ovum (Fig. 7) it will be observed that the primary spermatocyte gives rise to two cells, the secondary spermatocytes, and the primary oöcyte to two cells, the secondary oöcyte and the first polar body. Again, the two secondary spermatocytes by their subdivision give origin to four spermatozoa, and the secondary oöcyte and first polar body to four cells, the mature ovum and three polar bodies. In the development of the spermatozoa, as in the maturation of the ovum, there is a reduction of the nuclear chromosomes to one-half of those present in the primary spermatocyte. But here the similarity ends, for it must be noted that the four spermatozoa are of equal size, and each is capable of fertilizing a mature ovum, whereas the three polar bodies are not only very much smaller than the mature ovum but are incapable of further development, and may be regarded as abortive ova. 8

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4. Fertilization of the Ovum

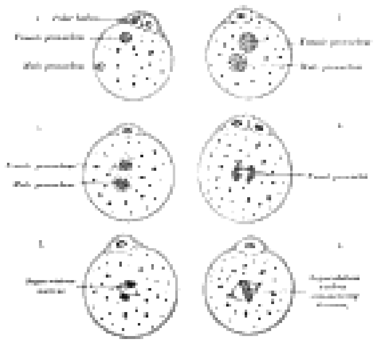

FIG. 8– The process of fertilization in the ovum of a mouse. (After Sobotta.) (See enlarged image)

Fertilization consists in the union of the spermatozoön with the mature ovum (Fig. 8). Nothing is known regarding the fertilization of the human ovum, but the various stages of the process have been studied in other mammals, and from the knowledge so obtained it is believed that fertilization of the human ovum takes place in the lateral or ampullary part of the uterine tube, and the ovum is then conveyed along the tube to the cavity of the uterus—a journey probably occupying seven or eight days and during which the ovum loses its corona radiata and zona striata and undergoes segmentation. Sometimes the fertilized ovum is arrested in the uterine tube, and there undergoes development, giving rise to a *tubal pregnancy;* or it may fall into the abdominal cavity and produce an *abdominal pregnancy.* Occasionally the ovum is not expelled from the follicle when the latter ruptures, but is fertilized within the follicle and produces what is known as an *ovarian pregnancy.* Under normal conditions only one spermatozoön enters the yolk and takes part in the process of fertilization. At the point where the spermatozoön is about to pierce, the yolk is drawn out into a conical elevation, termed the **cone of attraction.** As soon as the spermatozoön has entered the yolk, the peripheral portion of the latter is transformed into a membrane, the **vitelline membrane** which prevents the passage of additional spermatozoa. Occasionally a second spermatozoön may enter the yolk, thus giving rise to a condition of *polyspermy:* when this occurs the ovum usually develops in an abnormal manner and gives rise to a monstrosity. Having pierced the yolk, the spermatozoön loses its tail, while its head and connecting piece assume the form of a nucleus containing a cluster of chromosomes. This constitutes the **male pronucleus,** and associated with it there are a centriole and centrosome. The male pronucleus passes more deeply into the yolk, and coincidently with this the granules of the cytoplasm surrounding it become radially arranged. The male and female pronuclei migrate toward each other, and, meeting near the center of the yolk, fuse to form a new nucleus, the **segmentation nucleus,** which therefore contains both male and female nuclear substance; the former transmits the individualities of the male ancestors, the latter those of the female ancestors, to the future embryo. By the union of the male and female pronuclei the number of chromosomes is restored to that which is present in the nuclei of the somatic cells. 1

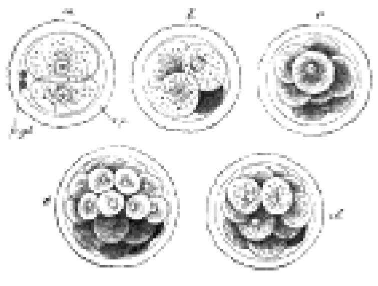

FIG. 9– First stages of segmentation of a mammalian ovum. Semidiagrammatic. (From a drawing by Allen Thomson.) *z.p.* Zona striata. *p.gl.* Polar bodies. *a.* Two-cell stage. *b.* Four-cell stage. *c.* Eight-cell stage. *d, e.* Morula stage. (See enlarged image)

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5. Segmentation of the Fertilized Ovum

The early segmentation of the human ovum has not yet been observed, but judging from what is known to occur in other mammals it may be regarded as certain that the process starts immediately after the ovum has been fertilized, *i. e.,* while the ovum is in the uterine tube. The segmentation nucleus exhibits the usual mitotic changes, and these are succeeded by a division of the ovum into two cells of nearly equal size. 5 The process is repeated again and again, so that the two cells are succeeded by four, eight, sixteen, thirty-two, and so on, with the result that a mass of cells is found within the zona striata, and to this mass the term **morula** is applied (Fig. 9). The segmentation of the mammalian ovum may not take place in the regular sequence of two, four, eight, etc., since one of the two first formed cells may subdivide more rapidly than the other, giving rise to a three-or a five-cell stage. The cells of the morula are at first closely aggregated, but soon they become arranged into an outer or peripheral layer, the **trophoblast,** which does not contribute to the formation of the embryo proper, and an **inner cell-mass,** from which the embryo is developed. Fluid collects between the trophoblast and the greater part of the inner cell-mass, and thus the morula is converted into a vesicle, the **blastodermic vesicle** (Fig. 10). The inner cell-mass remains in contact, however, with the trophoblast at one pole of the ovum; this is named the **embryonic pole,** since it indicates the situation where the future embryo will be developed. The cells of the trophoblast become differentiated into two strata: an outer, termed the **syncytium** or **syncytiotrophoblast,** so named because it consists of a layer of protoplasm studded with nuclei, but showing no evidence of subdivision into cells; and an inner layer, the **cytotrophoblast** or **layer of Langhans,** in which the cell outlines are defined. As already stated, the cells of the trophoblast do not contribute to the formation of the embryo proper; they form the ectoderm of the chorion and play an important part in the development of the placenta. On the deep surface of the inner cell-mass a layer of flattened cells, the **entoderm,** is differentiated and quickly assumes the form of a small sac, the **yolk-sac.** Spaces appear between the remaining cells of the mass (Fig. 11), and by the enlargement and coalescence of these spaces a cavity, termed the **amniotic cavity** (Fig. 12), is gradually developed. The floor of this cavity is formed by the **embryonic disk** composed of a layer of prismatic cells, the **embryonic ectoderm,** derived from the inner cell-mass and lying in apposition with the entoderm. 1

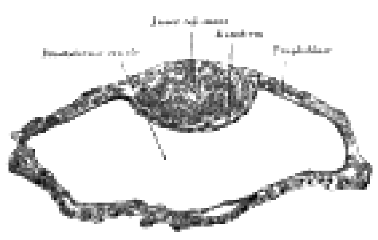

FIG. 10– Blastodermic vesicle of Vespertilio murinus. (After van Beneden.) (See enlarged image)

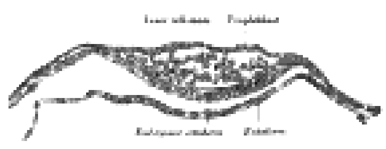

FIG. 11– Section through embryonic disk of Vespertilio murinus. (After van Beneden.) (See enlarged image)

FIG. 12– Section through embryonic area of Vespertilio murinus to show the formation of the amniotic cavity. (After van Beneden.) (See enlarged image)

The Primitive Streak; Formation of the Mesoderm.—The embryonic disk becomes oval and then pear-shaped, the wider end being directed forward. Near the narrow, posterior end an opaque streak, the **primitive streak** (Figs. 13 and 14), makes its appearance and extends along the middle of the disk for about one-half of its length; at the anterior end of the streak there is a knob-like thickening termed **Hensen's knot.** A shallow groove, the **primitive groove,** appears on the surface of the streak, and the anterior end of this groove communicates by means of an aperture, the **blastophore,** with the yolk-sac. The primitive streak is produced by a thickening of the axial part of the ectoderm, the cells of which multiply, grow downward, and blend with those of the subjacent entoderm (Fig. 15). From the sides of the primitive streak a third layer of cells, the **mesoderm,** extends lateralward between the ectoderm and entoderm; the caudal end of the primitive streak forms the cloacal membrane. 2

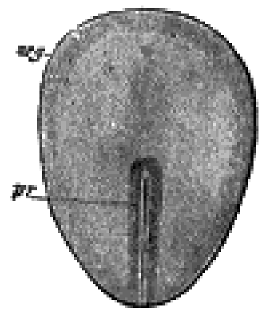

FIG. 13– Surface view of embryo of a rabbit. (After Kölliker.) *arg.* Embryonic disk. *pr.* Primitive streak. (See enlarged image)

The extension of the mesoderm takes place throughout the whole of the embryonic and extra-embryonic areas of the ovum, except in certain regions. One of these is seen immediately in front of the neural tube. Here the mesoderm extends forward in the form of two crescentic masses, which meet in the middle line so as to enclose behind them an area which is devoid of mesoderm. Over this area the ectoderm and entoderm come into direct contact with each other and constitute a thin membrane, the **buccopharyngeal membrane,** which forms a septum between the primitive mouth and pharynx. In front of the buccopharyngeal area, where the lateral crescents of mesoderm fuse in the middle line, the pericardium is afterward developed, and this region is therefore designated the **pericardial area.** A second region where the mesoderm is absent, at least for a time, is that immediately in front of the pericardial area. This is termed the **proamniotic area,** and is the region where the **proamnion** is developed; in man, however, a proamnion is apparently never formed. A third region is at the hind end of the embryo where the ectoderm and entoderm come into apposition and form the **cloacal membrane.** 3

The blastoderm now consists of three layers, named from without inward: ectoderm, mesoderm, and entoderm; each has distinctive characteristics and gives rise to certain tissues of the body. [6] 4

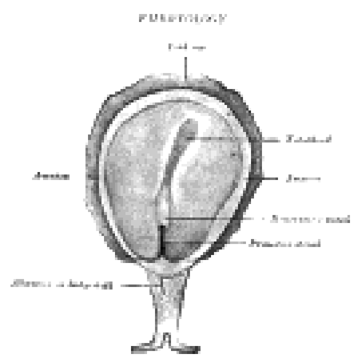

FIG. 14– Surface view of embryo of Hylobates concolor. (After Selenka.) The amnion has been opened to expose the embryonic disk. (See enlarged image)

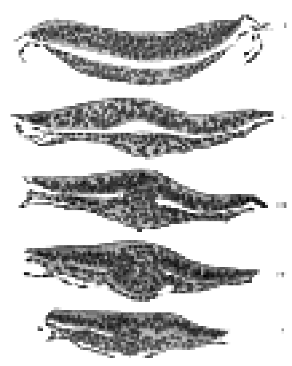

FIG. 15– Series of transverse sections through the embryonic disk of Tarsius. (After Hubrecht.) Section *I* passes through the disk, in front of Hensen's knot and shows only the ectoderm and entoderm. Sections *II, III,* and *IV* pass through Hensen's knot, which is seen in *V* tapering away into the primitive streak. In *III, IV,* and *V* the mesoderm is seen springing from the keel-like thickening of the ectoderm, which in *III* and *IV* is observed to be continuous into the entoderm. (See enlarged image)

Ectoderm.—The ectoderm consists of columnar cells, which are, however, somewhat flattened or cubical toward the margin of the embryonic disk. It forms the whole of the nervous system, the epidermis of the skin, the lining cells of the sebaceous, sudoriferous, and mammary glands, the hairs and nails, the epithelium of the nose and adjacent air sinuses, and that of the cheeks and roof of the mouth. From it also are derived the enamel of the teeth, and the anterior lobe of the hypophysis cerebri, the epithelium of the cornea, conjunctiva, and lacrimal glands, and the neuro-epithelium of the sense organs. 5

Entoderm.—The entoderm consists at first of flattened cells, which subsequently become columnar. It forms the epithelial lining of the whole of the digestive tube excepting part of the mouth and pharynx and the terminal part of the rectum (which are lined by involutions of the ectoderm), the lining cells of all the glands which open into the digestive tube, including those of the liver and pancreas, the epithelium of the auditory tube and tympanic cavity, of the trachea, bronchi, and air cells of the lungs, of the urinary bladder and part of the urethra, and that which lines the follicles of the thyroid gland and thymus. 6

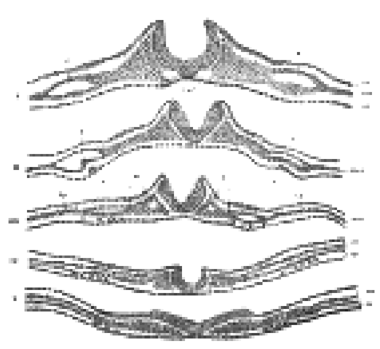

FIG. 16– A series of transverse sections through an embryo of the dog. (After Bonnet.) Section *I* is the most anterior. In *V* the neural plate is spread out nearly flat. The series shows the uprising of the neural folds to form the neural canal. *a.* Aortæ. *c.* Intermediate cell mass. *ect.* Ectoderm. *ent.* Entoderm. *h, h.* Rudiments of endothelial heart tubes. In *III, IV,* and *V* the scattered cells represented between the entoderm and splanchnic layer of mesoderm are the vasoformative cells which give origin in front, according to Bonnet, to the heart tubes, *h; l.p.* Lateral plate still undivided in *I, II,* and *III;* in *IV* and *V* split into somatic (*sm*) and splanchnic (*sp*) layers of mesoderm. *mes.* Mesoderm. *p.* Pericardium. *so.* Primitive segment. (See enlarged image)

Mesoderm.—The mesoderm consists of loosely arranged branched cells surrounded by a considerable amount of intercellular fluid. From it the remaining tissues of the body are developed. The endothelial lining of the heart and blood-vessels and the blood corpuscles are, however, regarded by some as being of entodermal origin. 7

As the mesoderm develops between the ectoderm and entoderm it is separated into lateral halves by the neural tube and notochord, presently to be described. A longitudinal groove appears on the dorsal surface of either half and divides it into a medial column, the **paraxial mesoderm,** lying on the side of the neural tube, and a lateral portion, the **lateral mesoderm.** The mesoderm in the floor of the groove connects the paraxial with the lateral mesoderm and is known as the **intermediate cell-mass;** in it the genito-urinary organs are developed. The lateral mesoderm splits into two layers, an outer or **somatic,** which becomes applied to the inner surface of the ectoderm, and with it forms the **somatopleure;** and an inner or **splanchnic,** which adheres to the entoderm, and with it forms the **splanchnopleure** (Fig. 16). The space between the two layers of the lateral mesoderm is termed the **celom.** 8

Note 5. In the mammalian ova the nutritive yolk or deutoplasm is small in amount and uniformly distributed throughout the cytoplasm; such ova undergo *complete* division during the process of segmentation, and are therefore termed *holoblastic.* In the ova of birds, reptiles, and fishes where the nutritive yolk forms by far the larger portion of the egg, the cleavage is limited to the formative yolk, and is therefore only *partial;* such ova are termed *meroblastic.* Again, it has been observed, in some of the lower animals, that the pronuclei do not fuse but merely lie in apposition. At the commencement of the segmentation process the chromosomes of the two pronuclei group themselves around the equator of the nuclear spindle and then divide; an equal number of male and female chromosomes travel to the opposite poles of the spindle, and thus the male and female pronuclei contribute equal shares of chromatin to the nuclei of the two cells which result from the subdivision of the fertilized ovum. [back]

Note 6. The mode of formation of the germ layers in the human ovum has not yet been observed; in the youngest known human ovum (viz., that described by Bryce and Teacher), all three layers are already present and the mesoderm is split into its two layers. The extra-embryonic celom is of considerable size, and scattered mesodermal strands are seen stretching between the mesoderm of the yolk-sac and that of the chorion. [back]

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6. The Neural Groove and Tube

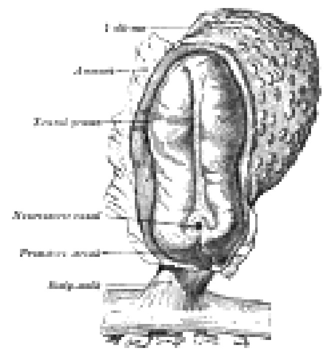

FIG. 17– Human embryo—length, 2 mm. Dorsal view, with the amnion laid open. X 30. (After Graf Spee.) (See enlarged image)

In front of the primitive streak two longitudinal ridges, caused by a folding up of the ectoderm, make their appearance, one on either side of the middle line (Fig. 16). These are named the **neural folds;** they commence some little distance behind the anterior end of the embryonic disk, where they are continuous with each other, and from there gradually extend backward, one on either side of the anterior end of the primitive streak. Between these folds is a shallow median groove, the **neural groove** (Figs. 16, 17). The groove gradually deepens as the neural folds become elevated, and ultimately the folds meet and coalesce in the middle line and convert the groove into a closed tube, the **neural tube** or **canal** (Fig. 18), the ectodermal wall of which forms the rudiment of the nervous system. After the coalescence of the neural folds over the anterior end of the primitive streak, the blastopore no longer opens on the surface but into the closed canal of the neural tube, and thus a transitory communication, the **neurenteric canal,** is established between the neural tube and the primitive digestive tube. The coalescence of the neural folds occurs first in the region of the hind-brain, and from there extends forward and backward; toward the end of the third week the front opening (anterior neuropore) of the tube finally closes at the anterior end of the future brain, and forms a recess which is in contact, for a time, with the overlying ectoderm; the hinder part of the neural groove presents for a time a rhomboidal shape, and to this expanded portion the term **sinus rhomboidalis** has been applied (Fig. 18). Before the neural groove is closed a ridge of ectodermal cells appears along the prominent margin of each neural fold; this is termed the **neural crest** or **ganglion ridge,** and from it the spinal and cranial nerve ganglia and the ganglia of the sympathetic nervous system are developed. By the upward growth of the mesoderm the neural tube is ultimately separated from the overlying ectoderm. *1*

FIG. 18– Chick embryo of thirty-three hours' incubation, viewed from the dorsal aspect. X 30. (From Duval's "Atlas d'Embryologie.") (See enlarged image)

The cephalic end of the neural groove exhibits several dilatations, which, when the tube is closed, assume the form of three vesicles; these constitute the three primary cerebral vesicles, and correspond respectively to the future **fore-brain** (*prosencephalon*), **mid-brain** (*mesencephalon*), and **hind-brain** (*rhombencephalon*) (Fig. 18). The walls of the vesicles are developed into the nervous tissue and neuroglia of the brain, and their cavities are modified to form its ventricles. The remainder of the tube forms the **medulla spinalis** or **spinal cord;** from its ectodermal wall the nervous and neuroglial elements of the medulla spinalis are developed while the cavity persists as the central canal. *2*

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7. The Notochord

The notochord (Fig. 19) consists of a rod of cells situated on the ventral aspect of the neural tube; it constitutes the foundation of the axial skeleton, since around it the segments of the vertebral column are formed. Its appearance synchronizes with that of the neural tube. On the ventral aspect of the neural groove an axial thickening of the entoderm takes place; this thickening assumes the appearance of a furrow—the **chordal furrow**—the margins of which come into contact, and so convert it into a solid rod of cells—the **notochord**—which is then separated from the entoderm. It extends throughout the entire length of the future vertebral column, and reaches as far as the anterior end of the mid-brain, where it ends in a hook-like extremity in the region of the future dorsum sellæ of the sphenoid bone. It lies at first between the neural tube and the entoderm of the yolk-sac, but soon becomes separated from them by the mesoderm, which grows medial-ward and surrounds it. From the mesoderm surrounding the neural tube and notochord, the skull and vertebral column, and the membranes of the brain and medulla spinalis are developed. 1

FIG. 19– Transverse section of a chick embryo of forty-five hours' incubation. (Balfour.) (See enlarged image)

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8. The Primitive Segments

Toward the end of the second week transverse segmentation of the paraxial mesoderm begins, and it is converted into a series of well-defined, more or less cubical masses, the **primitive segments** (Figs. 18, 19, 20), which occupy the entire length of the trunk on either side of the middle line from the occipital region of the head. Each segment contains a central cavity—**myocœl**—which, however, is soon filled with angular and spindle-shaped cells. 1

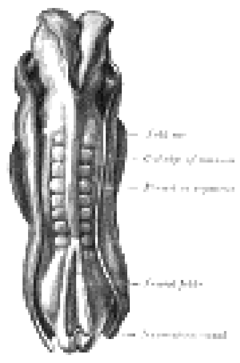

FIG. 20– Dorsum of human embryo, 2.11 mm. in length. (After Eternod.) (See enlarged image)

The primitive segments lie immediately under the ectoderm on the lateral aspect of the neural tube and notochord, and are connected to the lateral mesoderm by the **intermediate cell-mass.** Those of the trunk may be arranged in the following groups, viz.: cervical 8, thoracic 12, lumbar 5, sacral 5, and coccygeal from 5 to 8. Those of the occipital region of the head are usually described as being four in number. In mammals primitive segments of the head can be recognized only in the occipital region, but a study of the lower vertebrates leads to the belief that they are present also in the anterior part of the head, and that altogether nine segments are represented in the cephalic region. 2

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9. Separation of the Embryo

The embryo increases rapidly in size, but the circumference of the embryonic disk, or line of meeting of the embryonic and amniotic parts of the ectoderm, is of relatively slow growth and gradually comes to form a constriction between the embryo and the greater part of the yolk-sac. By means of this constriction, which corresponds to the future umbilicus, a small part of the yolk-sac is enclosed within the embryo and constitutes the primitive digestive tube. 1

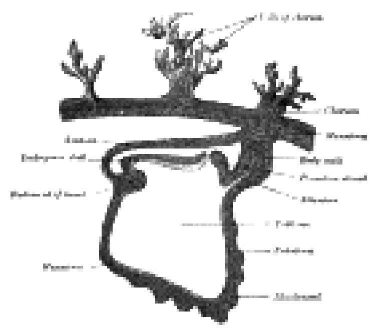

FIG. 21– Section through the embryo which is represented in Fig. 17. (After Graf Spee.) (See enlarged image)

The embryo increases more rapidly in length than in width, and its cephalic and caudal ends soon extend beyond the corresponding parts of the circumference of the embryonic disk and are bent in a ventral direction to form the **cephalic** and **caudal folds** respectively (Figs. 26 and 27). The cephalic fold is first formed, and as the proamniotic area (page 47) lying immediately in front of the pericardial area (page 47) forms the anterior limit of the circumference of the embryonic disk, the forward growth of the head necessarily carries with it the posterior end of the pericardial area, so that this area and the buccopharyngeal membrane are folded back under the head of the embryo which now encloses a diverticulum of the yolk-sac named the **fore-gut.** The caudal end of the embryo is at first connected to the chorion by a band of mesoderm called the **body-stalk,** but with the formation of the caudal fold the body-stalk assumes a ventral position; a diverticulum of the yolk-sac extends into the tail fold and is termed the **hind-gut.** Between the fore-gut and the hind-gut there exists for a time a wide opening into the yolk-sac, but the latter is gradually reduced to a small pear-shaped sac (sometimes termed the **umbilical vesicle**), and the channel of communication is at the same time narrowed and elongated to form a tube called the **vitelline duct.** 2

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10. The Yolk-sac

The yolk-sac (Figs. 22 and 23) is situated on the ventral aspect of the embryo; it is lined by entoderm, outside of which is a layer of mesoderm. It is filled with fluid, the **vitelline fluid,** which possibly may be utilized for the nourishment of the embryo during the earlier stages of its existence. Blood is conveyed to the wall of the sac by the primitive aortæ, and after circulating through a wide-meshed capillary plexus, is returned by the vitelline veins to the tubular heart of the embryo. This constitutes the **vitelline circulation,** and by means of it nutritive material is absorbed from the yolk-sac and conveyed to the embryo. At the end of the fourth week the yolk-sac presents the appearance of a small pear-shaped vesicle (umbilical vesicle) opening into the digestive tube by a long narrow tube, the **vitelline duct.** The vesicle can be seen in the after-birth as a small, somewhat oval-shaped body whose diameter varies from 1 mm. to 5 mm.; it is situated between the amnion and the chorion and may lie on or at a varying distance from the placenta. As a rule the duct undergoes complete obliteration during the seventh week, but in about three per cent. of cases its proximal part persists as a diverticulum from the small intestine, **Meckel's diverticulum,** which is situated about three or four feet above the ileocolic junction, and may be attached by a fibrous cord to the abdominal wall at the umbilicus. Sometimes a narrowing of the lumen of the ileum is seen opposite the site of attachment of the duct. 1

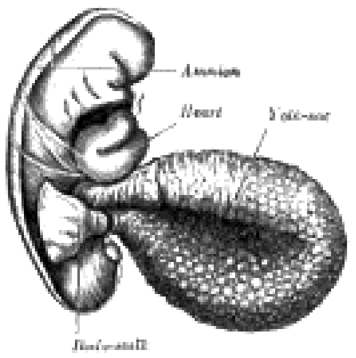

FIG. 22– Human embryo of 2.6 mm. (His.) (See enlarged image)

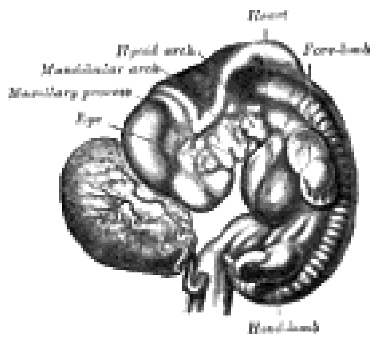

FIG. 23– Human embryo from thirty-one to thirty-four days. (His.) (See enlarged image)

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11. Development of the Fetal Membranes and Placenta

The Allantois **(Figs. 25 to 28).**—The allantois arises as a tubular diverticulum of the posterior part of the yolk-sac; when the hind-gut is developed the allantois is carried backward with it and then opens into the cloaca or terminal part of the hind-gut: it grows out into the body-stalk, a mass of mesoderm which lies below and around the tail end of the embryo. The diverticulum is lined by entoderm and covered by mesoderm, and in the latter are carried the allantoic or umbilical vessels. *1*

In reptiles, birds, and many mammals the allantois becomes expanded into a vesicle which projects into the extra-embryonic celom. If its further development be traced in the bird, it is seen to project to the right side of the embryo, and, gradually expanding, it spreads over its dorsal surface as a flattened sac between the amnion and the serosa, and extending in all directions, ultimately surrounds the yolk. Its outer wall becomes applied to and fuses with the serosa, which lies immediately inside the shell membrane. Blood is carried to the allantoic sac by the two allantoic or umbilical arteries, which are continuous with the primitive aortæ, and after circulating through the allantoic capillaries, is returned to the primitive heart by the two umbilical veins. In this way the allantoic circulation, which is of the utmost importance in connection with the respiration and nutrition of the chick, is established. Oxygen is taken from, and carbonic acid is given up to the atmosphere through the egg-shell, while nutritive materials are at the same time absorbed by the blood from the yolk. *2*

FIG. 24– Diagram showing earliest observed stage of human ovum. (See enlarged image)

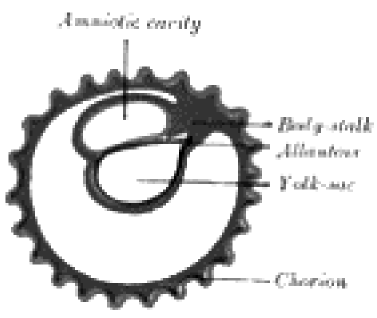

FIG. 25– Diagram illustrating early formation of allantois and differentiation of body-stalk. (See enlarged image)

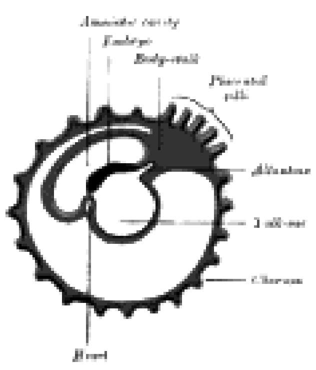

FIG. 26– Diagram showing later stage of allantoic development with commencing constriction of the yolk-sac. (See enlarged image)

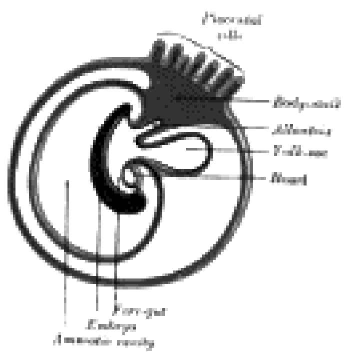

FIG. 27– Diagram showing the expansion of amnion and delimitation of the umbilicus. (See enlarged image)

In man and other primates the nature of the allantois is entirely different from that just described. Here it exists merely as a narrow, tubular diverticulum of the hind-gut, and never assumes the form of a vesicle outside the embryo. With the formation of the amnion the embryo is, in most animals, entirely separated from the chorion, and is only again united to it when the allantoic mesoderm spreads over and becomes applied to its inner surface. The human embryo, on the other hand, as was pointed out by His, is never wholly separated from the chorion, its tail end being from the first connected with the chorion by means of a thick band of mesoderm, named the **body-stalk** (Bauchstiel); into this stalk the tube of the allantois extends (Fig. 21). 3

The Amnion.—The amnion is a membranous sac which surrounds and protects the embryo. It is developed in reptiles, birds, and mammals, which are hence called “Amniota;” but not in amphibia and fishes, which are consequently termed “Anamnia.” 4

In the human embryo the earliest stages of the formation of the amnion have not been observed; in the youngest embryo which has been studied the amnion was already present as a closed sac (Figs. 24 and 32), and, as indicated on page 46, appears in the inner cell-mass as a cavity. This cavity is roofed in by a single stratum of flattened, ectodermal cells, the **amniotic ectoderm,** and its floor consists of the prismatic ectoderm of the embryonic disk—the continuity between the roof and floor being established at the margin of the embryonic disk. Outside the amniotic ectoderm is a thin layer of mesoderm, which is continuous with that of the somatopleure and is connected by the body-stalk with the mesodermal lining of the chorion. 5

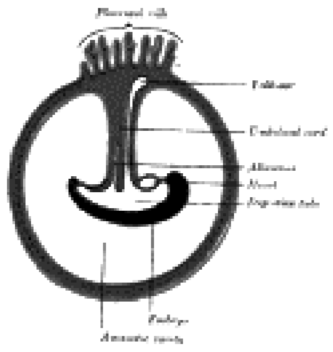

Fig. 28– Diagram illustrating a later stage in the development of the umbilical cord. (See enlarged image)

When first formed the amnion is in contact with the body of the embryo, but about the fourth or fifth week fluid (*liquor amnii*) begins to accumulate within it. This fluid increases in quantity and causes the amnion to expand and ultimately to adhere to the inner surface of the chorion, so that the extra-embryonic part of the celom is obliterated. The liquor amnii increases in quantity up to the sixth or seventh month of pregnancy, after which it diminishes somewhat; at the end of pregnancy it amounts to about 1 liter. It allows of the free movements of the fetus during the later stages of pregnancy, and also protects it by diminishing the risk of injury from without. It contains less than 2 per cent. of solids, consisting of urea and other extractives, inorganic salts, a small amount of protein, and frequently a trace of sugar. That some of the liquor amnii is swallowed by the fetus is proved by the fact that epidermal debris and hairs have been found among the contents of the fetal alimentary canal. 6

In reptiles, birds, and many mammals the amnion is developed in the following manner: At the point of constriction where the primitive digestive tube of the embryo joins the yolk-sac a reflection or folding upward of the somatopleure takes place. This, the **amniotic fold** (Fig. 29), first makes its appearance at the cephalic extremity, and subsequently at the caudal end and sides of the embryo, and gradually rising more and more, its different parts meet and fuse over the dorsal aspect of the embryo, and enclose a cavity, the **amniotic cavity.** After the fusion of the edges of the amniotic fold, the two layers of the fold become completely separated, the inner forming the **amnion,** the outer the **false amnion** or **serosa.** The space between the amnion and the serosa constitutes the extra-embryonic celom, and for a time communicates with the embryonic celom. 7

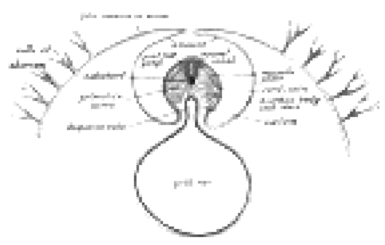

Fig. 29– Diagram of a transverse section, showing the mode of formation of the amnion in the chick. The amniotic folds have nearly united in the middle line. (From Quain’s Anatomy.) Ectoderm, blue; mesoderm, red; entoderm and notochord, black. (See enlarged image)

Fig. 30– Fetus of about eight weeks, enclosed in the amnion. Magnified a little over two diameters. (Drawn from stereoscopic photographs lent by Prof. A. Thomson, Oxford.) (See enlarged image)

The Umbilical Cord and Body-stalk.—The umbilical cord (Fig. 28) attaches the fetus to the placenta; its 8
length at full time, as a rule, is about equal to the length of the fetus, *i.e.,* about 50 cm., but it may be greatly diminished or increased. The rudiment of the umbilical cord is represented by the tissue which connects the rapidly growing embryo with the extra-embryonic area of the ovum. Included in this tissue are the body-stalk and the vitelline duct—the former containing the allantoic diverticulum and the umbilical vessels, the latter forming the communication between the digestive tube and the yolk-sac. The body-stalk is the posterior segment of the embryonic area, and is attached to the chorion. It consists of a plate of mesoderm covered by thickened ectoderm on which a trace of the neural groove can be seen, indicating its continuity with the embryo. Running through its mesoderm are the two umbilical arteries and the two umbilical veins, together with the canal of the allantois—the last being lined by entoderm (Fig. 31). Its dorsal surface is covered by the amnion, while its ventral surface is bounded by the extra-embryonic celom, and is in contact with the vitelline duct and yolk-sac. With the rapid elongation of the embryo and the formation of the tail fold, the body stalk comes to lie on the ventral surface of the embryo (Figs. 27 and 28), where its mesoderm blends with that of the yolk-sac and the vitelline duct. The lateral leaves of somatopleure then grow round on each side, and, meeting on the ventral aspect of the allantois, enclose the vitelline duct and vessels, together with a part of the extra-embryonic celom; the latter is ultimately obliterated. The cord is covered by a layer of ectoderm which is continuous with that of the amnion, and its various constitutents are enveloped by embryonic gelatinous tissue, **jelly of Wharton.** The vitelline vessels and duct, together with the right umbilical vein, undergo atrophy and disappear; and thus the cord, at birth, contains a pair of umbilical arteries and one (the left) umbilical vein.

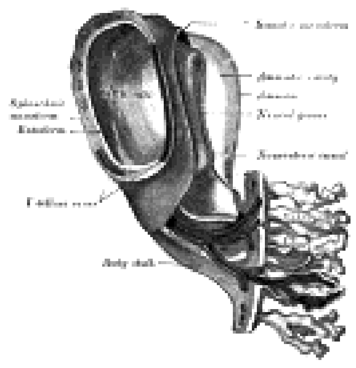

FIG. 31– Model of human embryo 1.3 mm. long. (After Eternod.) (See enlarged image)

Implantation or Imbedding of the Ovum.—As described (page 44), fertilization of the ovum occurs in the 9
lateral or ampullary end of the uterine tube and is immediately followed by segmentation. On reaching the cavity of the uterus the segmented ovum adheres like a parasite to the uterine mucous membrane, destroys the epithelium over the area of contact, and excavates for itself a cavity in the mucous membrane in which it becomes imbedded. In the ovum described by Bryce and Teacher [7] the point of entrance was visible as a small gap closed by a mass of fibrin and leucocytes; in the ovum described by Peters, [8] the opening was covered by a mushroom-shaped mass of fibrin and blood-clot (Fig. 32), the narrow stalk of which plugged the aperture in the mucous membrane. Soon, however, all trace of the opening is lost and the ovum is then completely surrounded by the uterine mucous membrane.

The structure actively concerned in the process of excavation is the trophoblast of the ovum, which 10
possesses the power of dissolving and absorbing the uterine tissues. The trophoblast proliferates rapidly and forms a network of branching processes which cover the entire ovum and invade and destroy the maternal tissues and open into the maternal bloodvessels, with the result that the spaces in the trophoblastic network are filled with maternal blood; these spaces communicate freely with one another and become greatly distended and form the **intervillous space.**

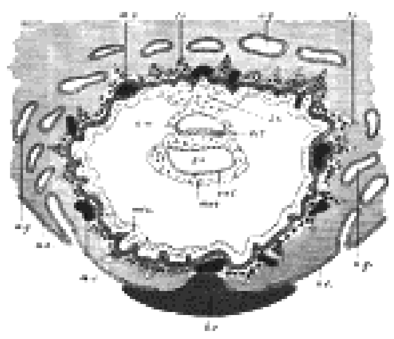

FIG. 32– Section through ovum imbedded in the uterine decidua. Semidiagrammatic. (After Peters.) *am.* Amniotic cavity. *b.c.* Blood-clot. *b.s.* Body-stalk. *ect.* Embryonic ectoderm. *ent.* Entoderm. *mes.* Mesoderm. *m.v.* Maternal vessels. *tr.* Trophoblast. *u.e.* Uterine epithelium. *u.g.* Uterine glands. *y.s.* Yolk-sac. (See enlarged image)

The Decidua.—Before the fertilized ovum reaches the uterus, the mucous membrane of the body of the 11
uterus undergoes important changes and is then known as the **decidua.** The thickness and vascularity of the mucous membrane are greatly increased; its glands are elongated and open on its free surface by funnel-shaped orifices, while their deeper portions are tortuous and dilated into irregular spaces. The interglandular tissue is also increased in quantity, and is crowded with large round, oval, or polygonal cells, termed **decidual cells.** These changes are well advanced by the second month of pregnancy, when the mucous membrane consists of the following strata (Fig. 33): (1) **stratum compactum,** next the free surface; in this the uterine glands are only slightly expanded, and are lined by columnar cells; (2) **stratum spongiosum,** in which the gland tubes are greatly dilated and very tortuous, and are ultimately separated from one another by only a small amount of interglandular tissue, while their lining cells are flattened or cubical; (3) a thin **unaltered** or **boundary layer,** next the uterine muscular fibers, containing the deepest parts of the uterine glands, which are not dilated, and are lined with columnar epithelium; it is from this epithelium that the epithelial lining of the uterus is regenerated after pregnancy. Distinctive names are applied to different portions of the decidua. The part which covers in the ovum is named the **decidua capsularis;** the portion which intervenes between the ovum and the uterine wall is named the **decidua basalis** or **decidua placentalis;** it is here that the placenta is subsequently developed. The part of the decidua which lines the remainder of the body of the uterus is known as the **decidua vera** or **decidua parietalis.**

Coincidently with the growth of the embryo, the decidua capsularis is thinned and extended (Fig. 34) and 12
the space between it and the decidua vera is gradually obliterated, so that by the third month of pregnancy the two are in contact. By the fifth month of pregnancy the decidua capsularis has practically disappeared, while during the succeeding months the decidua vera also undergoes atrophy, owing to the increased pressure. The glands of the stratum compactum are obliterated, and their epithelium is lost. In the stratum spongiosum the glands are compressed and appear as slit-like fissures, while their epithelium undergoes degeneration. In the unaltered or boundary layer, however, the glandular epithelium retains a columnar or cubical form.

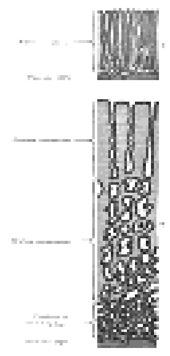

FIG. 33– Diagrammatic sections of the uterine mucous membrane: *A.* The non-pregnant uterus. *B.* The pregnant uterus, showing the thickened mucous membrane and the altered condition of the uterine glands. (Kundrat and Engelmann.) (See enlarged image)

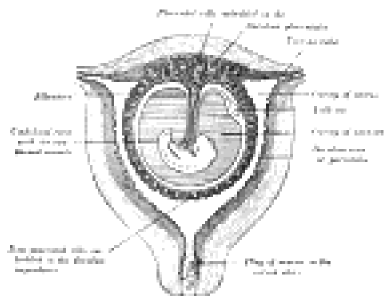

FIG. 34– Sectional plan of the gravid uterus in the third and fourth month. (Modified from Wagner.) (See enlarged image)

The Chorion (Figs. 23 to28).—The chorion consists of two layers: an outer formed by the primitive 13
ectoderm or trophoblast, and an inner by the somatic mesoderm; with this latter the amnion is in contact. The trophoblast is made up of an internal layer of cubical or prismatic cells, the **cytotrophoblast** or **layer of Langhans,** and an external layer of richly nucleated protoplasm devoid of cell boundaries, the **syncytiotrophoblast.** It undergoes rapid proliferation and forms numerous processes, the **chorionic villi,** which invade and destroy the uterine decidua and at the same time absorb from it nutritive materials for the growth of the embryo. The chorionic villi are at first small and non-vascular, and consist of trophoblast only, but they increase in size and ramify, while the mesoderm, carrying branches of the umbilical vessels, grows into them, and in this way they are vascularized. Blood is carried to the villi by the branches of the umbilical arteries, and after circulating through the capillaries of the villi, is returned to the embryo by the umbilical veins. Until about the end of the second month of pregnancy the villi cover the entire chorion, and are almost uniform in size (Fig. 25), but after this they develop unequally. The greater part of the chorion is in contact with the decidua capsularis (Fig. 34), and over this portion the villi, with their contained vessels, undergo atrophy, so that by the fourth month scarcely a trace of them is left, and hence this part of the chorion becomes smooth, and is named the **chorion læve;** as it takes no share in the formation of the placenta, it is also named the non-placental part of the chorion. On the other hand, the villi on that part of the chorion which is in contact with the decidua placentalis increase greatly in size and complexity, and hence this part is named the **chorion frondosum** (Fig. 28).

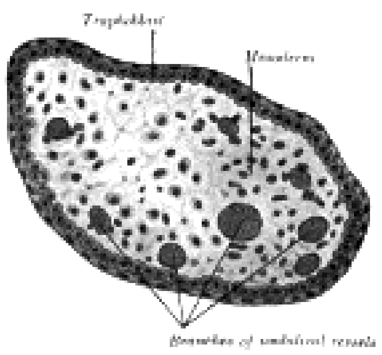

FIG. 35– Transverse section of a chorionic villus. (See enlarged image)

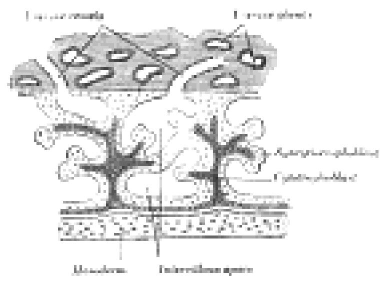

FIG. 36– Primary chorionic villi. Diagrammatic. (Modified from Bryce.) (See enlarged image)

The Placenta.—The placenta connects the fetus to the uterine wall, and is the organ by means of which the 14
nutritive, respiratory, and excretory functions of the fetus are carried on. It is composed of **fetal** and **maternal** portions.

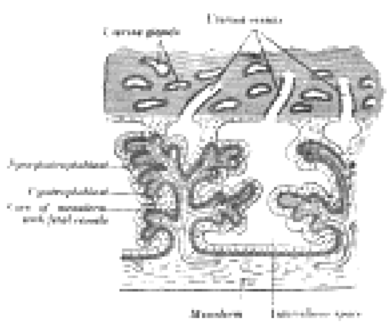

FIG. 37– Secondary chorionic villi. Diagrammatic. (Modified from Bryce.) (See enlarged image)

15 **Fetal Portion.**—The fetal portion of the placenta consists of the villi of the chorion frondosum; these branch repeatedly, and increase enormously in size. These greatly ramified villi are suspended in the intervillous space, and are bathed in maternal blood, which is conveyed to the space by the uterine arteries and carried away by the uterine veins. A branch of an umbilical artery enters each villus and ends in a capillary plexus from which the blood is drained by a tributary of the umbilical vein. The vessels of the villus are surrounded by a thin layer of mesoderm consisting of gelatinous connective tissue, which is covered by two strata of ectodermal cells derived from the trophoblast: the deeper stratum, next the mesodermic tissue, represents the cytotrophoblast or layer of Langhans; the superficial, in contact with the maternal blood, the syncytiotrophoblast (Figs. 36 and 37). After the fifth month the two strata of cells are replaced by a single layer of somewhat flattened cells.

16 **Maternal Portion.**—The maternal portion of the placenta is formed by the decidua placentalis containing the intervillous space. As already explained, this space is produced by the enlargement and intercommunication of the spaces in the trophoblastic network. The changes involve the disappearance of the greater portion of the stratum compactum, but the deeper part of this layer persists and is condensed to form what is known as the **basal plate.** Between this plate and the uterine muscular fibres are the stratum spongiosum and the boundary layer; through these and the basal plate the uterine arteries and veins pass to and from the intervillous space. The endothelial lining of the uterine vessels ceases at the point where they terminate in the intervillous space which is lined by the syncytiotrophoblast. Portions of the stratum compactum persist and are condensed to form a series of septa, which extend from the basal plate through the thickness of the placenta and subdivide it into the lobules or **cotyledons** seen on the uterine surface of the detached placenta.

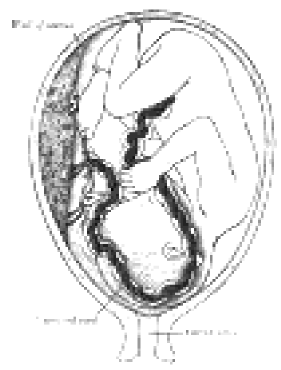

FIG. 38– Fetus in utero, between fifth and sixth months. (See enlarged image)

17 The fetal and maternal blood currents traverse the placenta, the former passing through the bloodvessels of the placental villi and the latter through the intervillous space (Fig. 39). The two currents do not intermingle, being separated from each other by the delicate walls of the villi. Nevertheless, the fetal blood is able to absorb, through the walls of the villi, oxygen and nutritive materials from the maternal blood, and give up to the latter its waste products. The blood, so purified, is carried back to the fetus by the umbilical vein. It will thus be seen that the placenta not only establishes a mechanical connection between the mother and the fetus, but subserves for the latter the purposes of nutrition, respiration, and excretion. In favor of the view that the placenta possesses certain selective powers may be mentioned the fact that glucose is more plentiful in the maternal than in the fetal blood. It is interesting to note also that the proportion of iron, and of lime and potash, in the fetus is increased during the last months of pregnancy. Further, there is evidence that the maternal leucocytes may migrate into the fetal blood, since leucocytes are much more numerous in the blood of the umbilical vein than in that of the umbilical arteries.

18 The placenta is usually attached near the fundus uteri, and more frequently on the posterior than on the anterior wall of the uterus. It may, however, occupy a lower position and, in rare cases, its site is close to the orificium internum uteri, which it may occlude, thus giving rise to the condition known as *placenta previa.*

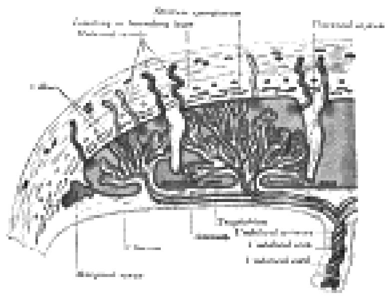

FIG. 39– Scheme of placental circulation. (See enlarged image)

19 **Separation of the Placenta.**—After the child is born, the placenta and membranes are expelled from the uterus as the **after-birth.** The separation of the placenta from the uterine wall takes place through the stratum spongiosum, and necessarily causes rupture of the uterine vessels. The orifices of the torn vessels are, however, closed by the firm contraction of the uterine muscular fibers, and thus *postpartum hemorrhage* is controlled. The epithelial lining of the uterus is regenerated by the proliferation and extension of the epithelium which lines the persistent portions of the uterine glands in the unaltered layer of the decidua.

20 The expelled placenta appears as a discoid mass which weighs about 450 gm. and has a diameter of from 15 to 20 cm. Its average thickness is about 3 cm., but this diminishes rapidly toward the circumference of the disk, which is continuous with the membranes. Its uterine surface is divided by a series of fissures into lobules or **cotyledons,** the fissures containing the remains of the septa which extended between the maternal and fetal portions. Most of these septa end in irregular or pointed processes; others, especially those near the edge of the placenta, pass through its thickness and are attached to the chorion. In the early months these septa convey branches of the uterine arteries which open into the intervillous space on the surfaces of the septa. The fetal surface of the placenta is smooth, being closely invested by the amnion. Seen through the latter, the chorion presents a mottled appearance, consisting of gray, purple, or yellowish areas. The umbilical cord is usually attached near the center of the placenta, but may be inserted anywhere between the center and the margin; in some cases it is inserted into the membranes, *i. e.,* the **velamentous insertion.** From the attachment of the cord the larger branches of the umbilical vessels radiate under the amnion, the veins being deeper and larger than the arteries. The remains of the vitelline duct and yolk-sac may be sometimes observed beneath the amnion, close to the cord, the former as an attenuated thread, the latter as a minute sac.

21 On section, the placenta presents a soft, spongy appearance, caused by the greatly branched villi; surrounding them is a varying amount of maternal blood giving the dark red color to the placenta. Many of the larger villi extend from the chorionic to the decidual surface, while others are attached to the septa which separate the cotyledons; but the great majority of the villi hang free in the intervillous space.

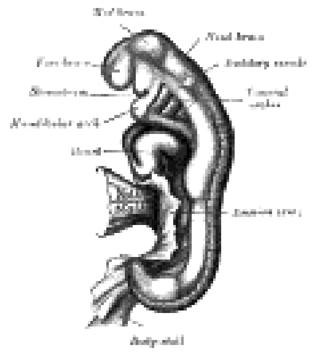

FIG. 40– Embryo between eighteen and twenty-one days. (His.) (See enlarged image)

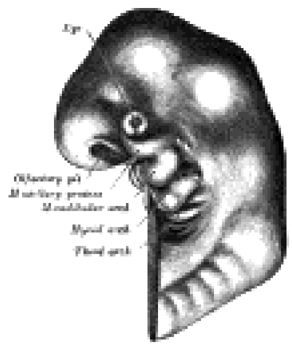

FIG. 41– Head end of human embryo, about the end of the fourth week. (From model by Peter.) (See enlarged image)

Note 7. Contribution to the study of the early development and imbedding of the human ovum, 1908. [back]

Note 8. Die Einbettung des menschlichen Eies, 1899. [back]

CONTENTS · BIBLIOGRAPHIC RECORD · ILLUSTRATIONS · SUBJECT INDEX

PREVIOUS NEXT

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

12. The Branchial Region

The Branchial or Visceral Arches and Pharyngeal Pouches.—In the lateral walls of the anterior part of the fore-gut five *pharyngeal pouches* appear (Fig. 42); each of the upper four pouches is prolonged into a dorsal and a ventral diverticulum. Over these pouches corresponding indentations of the ectoderm occur, forming what are known as the **branchial** or **outer pharyngeal grooves.** The intervening mesoderm is pressed aside and the ectoderm comes for a time into contact with the entodermal lining of the fore-gut, and the two layers unite along the floors of the grooves to form thin **closing membranes** between the fore-gut and the exterior. Later the mesoderm again penetrates between the entoderm and the ectoderm. In gill-bearing animals the closing membranes disappear, and the grooves become complete clefts, the **gill-clefts,** opening from the pharynx on to the exterior; perforation, however, does not occur in birds or mammals. The grooves separate a series of rounded bars or arches, the **branchial** or **visceral arches,** in which thickening of the mesoderm takes place (Figs. 40 and 41). The dorsal ends of these arches are attached to the sides of the head, while the ventral extremities ultimately meet in the middle line of the neck. In all, six arches make their appearance, but of these only the first four are visible externally. The first arch is named the mandibular, and the second the hyoid; the others have no distinctive names. In each arch a cartilaginous bar, consisting of right and left halves, is developed, and with each of these there is one of the primitive aortic arches. 1

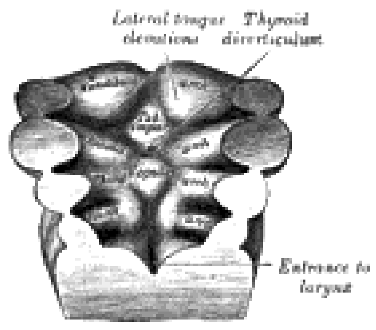

FIG. 42– Floor of pharynx of embryo shown in Fig. 40. (See enlarged image)

The **mandibular arch** lies between the first branchial groove and the stomodeum; from it are developed the lower lip, the mandible, the muscles of mastication, and the anterior part of the tongue. Its cartilaginous bar is formed by what are known as **Meckel's cartilages** (right and left) (Fig. 43); above this the incus is developed. The dorsal end of each cartilage is connected with the ear-capsule and is ossified to form the malleus; the ventral ends meet each other in the region of the symphysis menti, and are usually regarded as undergoing ossification to form that portion of the mandible which contains the incisor teeth. The intervening part of the cartilage disappears; the portion immediately adjacent to the malleus is replaced by fibrous membrane, which constitutes the spheno-mandibular ligament, while from the connective tissue covering the remainder of the cartilage the greater part of the mandible is ossified. From the dorsal ends of the mandibular arch a triangular process, the **maxillary process,** grows forward on either side and forms the cheek and lateral part of the upper lip. The **second** or **hyoid arch** assists in forming the side and front of the neck. From its cartilage are developed the styloid process, stylohyoid ligament, and lesser cornu of the hyoid bone. The stages probably arises in the upper part of this arch. The cartilage of the **third arch** gives origin to the greater cornu of the hyoid bone. The ventral ends of the second and third arches unite with those of the opposite side, and form a transverse band, from which the body of the hyoid bone and the posterior part of the tongue are developed. The ventral portions of the cartilages of the **fourth** and **fifth arches** unite to form the thyroid cartilage; from the cartilages of the **sixth arch** the cricoid and arytenoid cartilages and the cartilages of the trachea are developed. The mandibular and hyoid arches grow more rapidly than those behind them, with the result that the latter become, to a certain extent, telescoped within the former, and a deep depression, the **sinus cervicalis,** is formed on either side of the neck. This sinus is bounded in front by the hyoid arch, and behind by the thoracic wall; it is ultimately obliterated by the fusion of its walls. 2

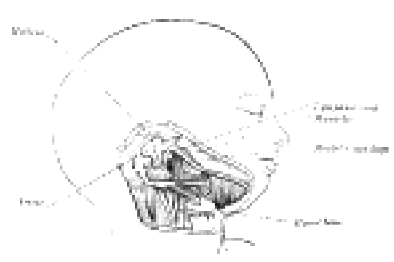

FIG. 43– Head and neck of a human embryo eighteen weeks old, with Meckel's cartilage and hyoid bar exposed. (After Kölliker.) (See enlarged image)

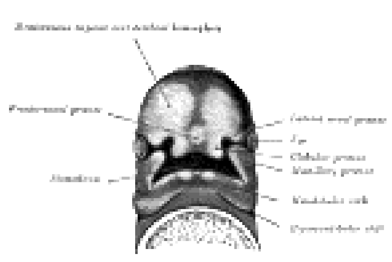

FIG. 44– Under surface of the head of a human embryo about twenty-nine days old. (After His.) (See enlarged image)

From the first branchial groove the concha auriculæ and external acoustic meatus are developed, while around the groove there appear, on the mandibular and hyoid arches, a number of swellings from which the auricula or pinna is formed. The first pharyngeal pouch is prolonged dorsally to form the auditory tube and the tympanic cavity; the closing membrane between the mandibular and hyoid arches is invaded by mesoderm, and forms the tympanic membrane. No traces of the second, third, and fourth branchial grooves persist. The inner part of the second pharyngeal pouch is named the **sinus tonsillaris;** in it the tonsil is developed, above which a trace of the sinus persists as the supratonsillar fossa. The fossa of Rosenmüller or lateral recess of the pharynx is by some regarded as a persistent part of the second pharyngeal pouch, but it is probably developed as a secondary formation. From the third pharyngeal pouch the thymus arises as an entodermal diverticulum on either side, and from the fourth pouches small diverticula project and become incorporated with the thymus, but in man these diverticula probably never form true thymus tissue. The parathyroids also arise as diverticula from the third and fourth pouches. From the fifth pouches the ultimobranchial bodies originate and are enveloped by the lateral prolongations of the median thyroid rudiment; they do not, however, form true thyroid tissue, nor are any traces of them found in the human adult. 3

The Nose and Face.—During the third week two areas of thickened ectoderm, the **olfactory areas,** appear immediately under the fore-brain in the anterior wall of the stomodeum, one on either side of a region termed the **fronto-nasal process** (Fig. 44). By the upgrowth of the surrounding parts these areas are converted into pits, the **olfactory pits,** which indent the fronto-nasal process and divide it into a **medial** and two **lateral nasal processes** (Fig. 45). The rounded lateral angles of the medial process constitute the **globular processes** of His. The olfactory pits form the rudiments of the nasal cavities, and from their ectodermal lining the epithelium of the nasal cavities, with the exception of that of the inferior meatuses, is derived. The globular processes are prolonged backward as plates, termed the **nasal laminæ:** these laminæ are at first some distance apart, but, gradually approaching, they ultimately fuse and form the nasal septum; the processes themselves meet in the middle line, and form the premaxillæ and the philtrum or central part of the upper lip (Fig. 48). The depressed part of the medial nasal process between the globular processes forms the lower part of the nasal septum or **columella;** while above this is seen a prominent angle, which becomes the future apex (Figs. 45, 46), and still higher a flat area, the future bridge, of the nose. The lateral nasal processes form the alæ of the nose. 4

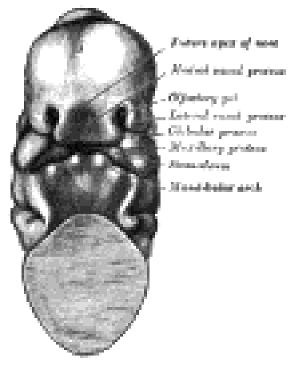

FIG. 45– Head end of human embryo of about thirty to thirty-one days. (From model by Peters.) (See enlarged image)

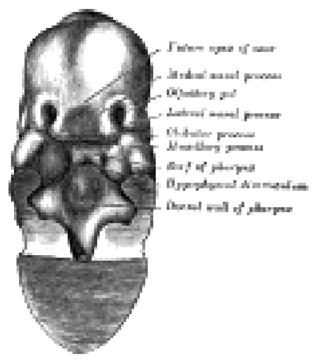

FIG. 46– Same embryo as shown in Fig. 45, with front wall of pharynx removed. (See enlarged image)

FIG. 47– Head of a human embryo of about eight weeks, in which the nose and mouth are formed. (His.) (See enlarged image)

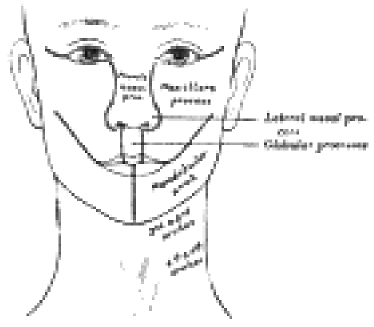

FIG. 48– Diagram showing the regions of the adult face and neck related to the fronto-nasal process and the branchial arches. (See enlarged image)

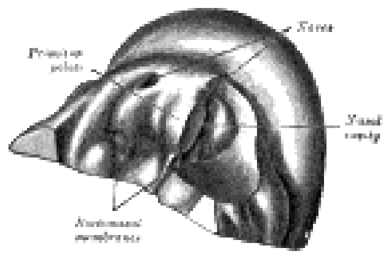

FIG. 49– Primitive palate of a human embryo of thirty-seven to thirty-eight days. (From model by Peters.) On the left side the lateral wall of the nasal cavity has been removed. (See enlarged image)

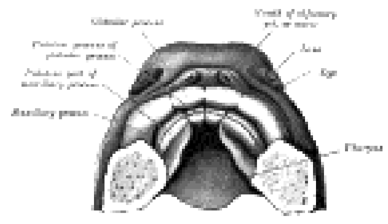

FIG. 50– The roof of the mouth of a human embryo, aged about two and a half months, showing the mode of formation of the palate. (His.) (See enlarged image)

Continuous with the dorsal end of the mandibular arch, and growing forward from its cephalic border, is a 5
triangular process, the **maxillary process,** the ventral extremity of which is separated from the mandibular arch by a > shaped notch (Fig. 44). The maxillary process forms the lateral wall and floor of the orbit, and in it are ossified the zygomatic bone and the greater part of the maxilla; it meets with the lateral nasal process, from which, however, it is separated for a time by a groove, the **naso-optic furrow,** that extends from the furrow encircling the eyeball to the olfactory pit. The maxillary processes ultimately fuse with the lateral nasal and globular processes, and form the lateral parts of the upper lip and the posterior boundaries of the nares (Figs. 47, 48). From the third to the fifth month the nares are filled by masses of epithelium, on the breaking down and disappearance of which the permanent openings are produced. The maxillary process also gives rise to the lower portion of the lateral wall of the nasal cavity. The roof of the nose and the remaining parts of the lateral wall, viz., the ethmoidal labyrinth, the inferior nasal concha, the lateral cartilage, and the lateral crus of the alar cartilage, are developed in the lateral nasal process. By the fusion of the maxillary and nasal processes in the roof of the stomodeum the **primitive palate** (Fig. 49) is formed, and the olfactory pits extend backward above it. The posterior end of each pit is closed by an epithelial membrane, the **bucco-nasal membrane,** formed by the apposition of the nasal and stomodeal epithelium. By the rupture of these membranes the **primitive choanæ** or openings between the olfactory pits and the stomodeum are established. The floor of the nasal cavity is completed by the development of a pair of shelf-like **palatine processes** which extend medial-ward from the maxillary processes (Figs. 50 and 51); these coalesce with each other in the middle line, and constitute the entire palate, except a small part in front which is formed by the premaxillary bones. Two apertures persist for a time between the palatine processes and the premaxillæ and represent the permanent channels which in the lower animals connect the nose and mouth. The union of the parts which form the palate commences in front, the premaxillary and palatine processes joining in the eighth week, while the region of the future hard palate is completed by the ninth, and that of the soft palate by the eleventh week. By the completion of the palate the **permanent choanæ** are formed and are situated a considerable distance behind the primitive choanæ. The deformity known as cleft palate results from a non-union of the palatine processes, and that of harelip through a non-union of the maxillary and globular processes (see page 199). The nasal cavity becomes divided by a vertical septum, which extends downward and backward from the medial nasal process and nasal laminæ, and unites below with the palatine processes. Into this septum a plate of cartilage extends from the under aspect of the ethmoid plate of the chodrocranium. The anterior part of this cartilaginous plate persists as the septal cartilage of the nose and the medial crus of the alar cartilage, but the posterior and upper parts are replaced by the vomer and perpendicular plate of the ethmoid. On either side of the nasal septum, at its lower and anterior part, the ectoderm is invaginated to form a blind pouch or diverticulum, which extends backward and upward into the nasal septum and is supported by a curved plate of cartilage. These pouches form the rudiments of the **vomero-nasal organs** of Jacobson, which open below, close to the junction of the premaxillary and maxillary bones.

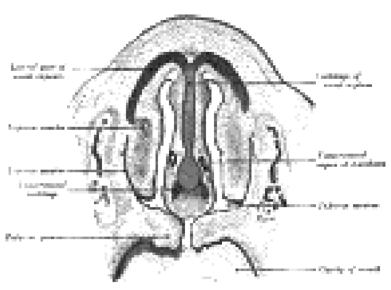

FIG. 51– Frontal section of nasal cavities of a human embryo 28 mm. long. (Kollmann.) (See enlarged image)

The Limbs.—The limbs begin to make their appearance in the third week as small elevations or buds at the side of the trunk (Fig. 52). Prolongations from the muscle- and cutis-plates of several primitive segments extend into each bud, and carry with them the anterior divisions of the corresponding spinal nerves. The nerves supplying the limbs indicate the number of primitive segments which contribute to their formation—the upper limb being derived from seven, viz., fourth cervical to second thoracic inclusive, and the lower limb from ten, viz., twelfth thoracic to fourth sacral inclusive. The axial part of the mesoderm of the limb-bud becomes condensed and converted into its cartilaginous skeleton, and by the ossification of this the bones of the limbs are formed. By the sixth week the three chief divisions of the limbs are marked off by furrows—the upper into arm, forearm, and hand; the lower into thigh, leg, and foot (Fig. 53). The limbs are at first directed backward nearly parallel to the long axis of the trunk, and each presents two surfaces and two borders. Of the surfaces, one—the future *flexor* surface of the limb—is directed ventrally; the other, the *extensor* surface, dorsally; one border, the *preaxial,* looks forward toward the cephalic end of the embryo, and the other, the *postaxial,* backward toward the caudal end. The lateral epicondyle of the humerus, the radius, and the thumb lie along the preaxial border of the upper limb; and the medial epicondyle of the femur, the tibia, and the great toe along the corresponding border of the lower limb. The preaxial part is derived from the anterior segments, the postaxial from the posterior segments of the limb-bud; and this explains, to a large extent, the innervation of the adult limb, the nerves of the more anterior segments being distributed along the preaxial (radial or tibial), and those of the more posterior along the postaxial (ulnar or fibular) border of the limb. The limbs next undergo a rotation or torsion through an angle of 90° around their long axes the rotation being effected almost entirely at the limb girdles. In the upper limb the rotation is outward and forward; in the lower limb, inward and backward. As a consequence of this rotation the preaxial (radial) border of the fore-limb is directed lateralward, and the preaxial (tibial) border of the hind-limb is directed medialward; thus the flexor surface of the fore-limb is turned forward, and that of the hind-limb backward.

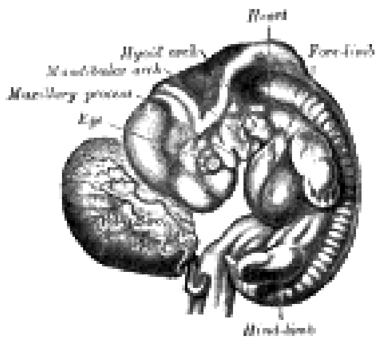

FIG. 52– Human embryo from thirty-one to thirty-four days. (His.) (See enlarged image)

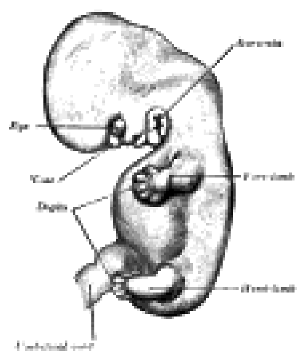

FIG. 53– Embryo of about six weeks. (His.) (See enlarged image)

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

13. Development of the Body Cavities

1 In the human embryo described by Peters the mesoderm outside the embryonic disk is split into two layers enclosing an extra-embryonic cœlom; there is no trace of an intra-embryonic cœlom. At a later stage four cavities are formed within the embryo, viz., one on either side within the mesoderm of the pericardial area, and one in either lateral mass of the general mesoderm. All these are at first independent of each other and of the extra-embryonic celom, but later they become continuous. The two cavities in the general mesoderm unite on the ventral aspect of the gut and form the pleuro-peritoneal cavity, which becomes continuous with the remains of the extra-embryonic celom around the umbilicus; the two cavities in the pericardial area rapidly join to form a single pericardial cavity, and this from two lateral diverticula extend caudalward to open into the pleuro-peritoneal cavity (Fig. 54).

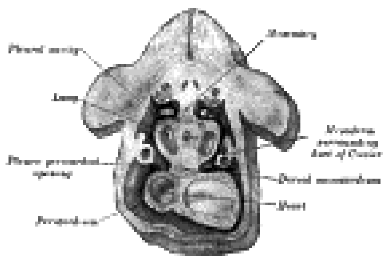

FIG. 54– Figure obtained by combining several successive sections of a human embryo of about the fourth week (From Kollmann.) The upper arrow is in the pleuroperitoneal opening, the lower in the pleuropericardial. (See enlarged image)

2 Between the two latter diverticula is a mass of mesoderm containing the ducts of Cuvier, and this is continuous ventrally with the mesoderm in which the umbilical veins are passing to the sinus venosus. A septum of mesoderm thus extends across the body of the embryo. It is attached in front to the body-wall between the pericardium and umbilicus; behind to the body-wall at the level of the second cervical segment; laterally it is deficient where the pericardial and pleuro-peritoneal cavities communicate, while it is perforated in the middle line by the foregut. This partition is termed the **septum transversum,** and is at first a bulky plate of tissue. As development proceeds the dorsal end of the septum is carried gradually caudalward, and when it reaches the fifth cervical segment muscular tissue with the phrenic nerve grows into it. It continues to recede, however, until it reaches the position of the adult diaphragm on the bodies of the upper lumbar vertebræ. The liver buds grow into the septum transversum and undergo development there.

3 The lung buds meantime have grown out from the fore-gut, and project laterally into the forepart of the pleuro-peritoneal cavity; the developing stomach and liver are imbedded in the septum transversum; caudal to this the intestines project into the back part of the pleuro-peritoneal cavity (Fig. 55). Owing to the descent of **the** dorsal end of the septum transversum the lung buds come to lie above the septum and thus pleural and peritoneal portions of the pleuro-peritoneal cavity (still, however, in free communication with one another) may be recognized; the pericardial cavity opens into the pleural part.

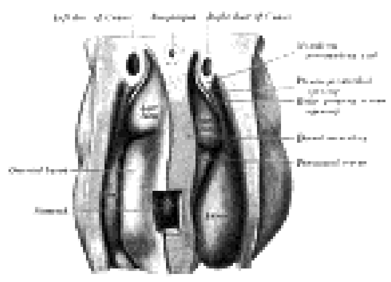

FIG. 55– Upper part of celom of human embryo of 6.8 mm., seen from behind. (From model by Piper.) (See enlarged image)

4 The ultimate separation of the permanent cavities from one another is effected by the growth of a ridge of tissue on either side from the mesoderm surrounding the duct of Cuvier (Figs. 54, 55). The front part of this ridge grows across and obliterates the pleuro-pericardial opening; the hinder part grows across the pleuro-peritoneal opening.

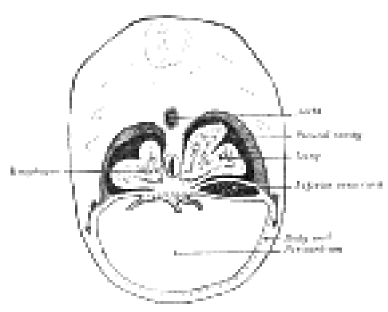

FIG. 56– Diagram of transverse section through rabbit embryo. (After Keith.) (See enlarged image)

5 With the continued growth of the lungs the pleural cavities are pushed forward in the body-wall toward the ventral median line, thus separating the pericardium from the lateral thoracic walls (Fig. 53). The further development of the peritoneal cavity has been described with the development of the digestive tube (page 168 *et seq.*).

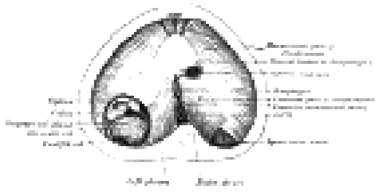

FIG. 57– The thoracic aspect of the diaphragm of a newly born child in which the communication between the peritoneum and pleura has not been closed on the left side; the position of the opening is marked on the right side by the spinocostal hiatus. (After Keith.) (See enlarged image)

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14. The Form of the Embryo at Different Stages of Its Growth

First Week.—During this period the ovum is in the uterine tube. Having been fertilized in the upper part of the tube, it slowly passes down, undergoing segmentation, and reaches the uterus. Peters 9 described a specimen, the age of which he reckoned as from three to four days. It was imbedded in the decidua on the posterior wall of the uterus and enveloped by a decidua capsularis, the central part of which, however, consisted merely of a layer of fibrin. The ovum was in the form of a sac, the outer wall of which consisted of a layer of trophoblast; inside this was a thin layer of mesoderm composed of round, oval, and spindle-shaped cells. Numerous villous processes—some consisting of trophoblast only, others possessing a core of mesoderm—projected from the surface of the ovum into the surrounding decidua. Inside this sac the rudiment of the embryo was found in the form of a patch of ectoderm, covered by a small but completely closed amnion. It possessed a minute yolk-sac and was surrounded by mesoderm, which was connected by a band to that lining the trophoblast (Fig. 32). 10 1

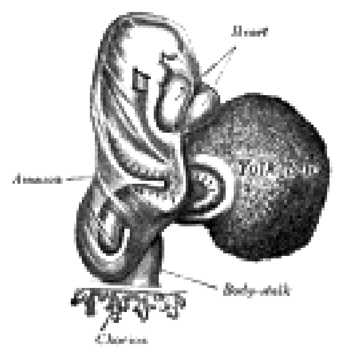

FIG. 58– Human embryo about fifteen days old. (His.) (See enlarged image)

Second Week.—By the end of this week the ovum has increased considerably in size, and the majority of its villi are vascularized. The embryo has assumed a definite form, and its cephalic and caudal extremities are easily distinguished. The neural folds are partly united. The embryo is more completely separated from the yolk-sac, and the paraxial mesoderm is being divided into the primitive segments (Fig. 58). 2

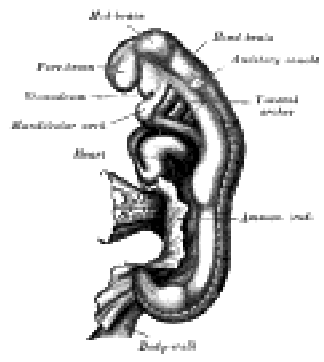

FIG. 59– Human embryo between eighteen and twenty-one days old. (His. (See enlarged image)

Third Week.—By the end of the third week the embryo is strongly curved, and the primitive segments number about thirty. The primary divisions of the brain are visible, and the optic and auditory vesicles are formed. Four branchial grooves are present: the stomodeum is well-marked, and the bucco-pharyngeal membrane has disappeared. The rudiments of the limbs are seen as short buds, and the Wolffian bodies are visible (Fig. 59). 3

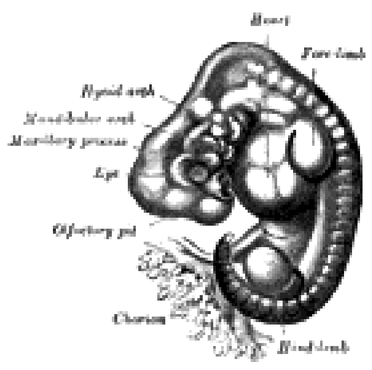

FIG. 60– Human embryo, twenty-seven to thirty days old. (His.) (See enlarged image)

Fourth Week.—The embryo is markedly curved on itself, and when viewed in profile is almost circular in outline. The cerebral hemispheres appear as hollow buds, and the elevations which form the rudiments of the auricula are visible. The limbs now appear as oval flattened projections (Fig. 60). 4

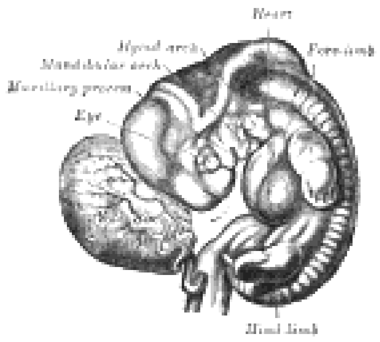

FIG. 61– Human embryo, thirty-one to thirty-four days old. (His.) (See enlarged image)

Fifth Week.—The embryo is less curved and the head is relatively of large size. Differentiation of the limbs into their segments occurs. The nose forms a short, flattened projection. The cloacal tubercle is evident (Fig. 61). 5

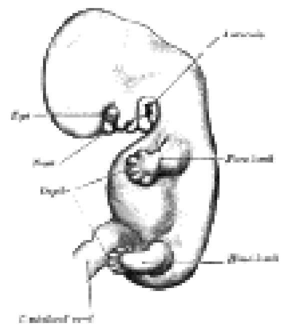

FIG. 62– Human embryo of about six weeks. (His.) (See enlarged image)

FIG. 63– Human embryo about eight and a half weeks old. (His.) (See enlarged image)

Sixth Week.—The curvature of the embryo is further diminished. The branchial grooves—except the first—have disappeared, and the rudiments of the fingers and toes can be recognized (Fig. 62). 6

Seventh and Eighth Weeks.—The flexure of the head is gradually reduced and the neck is somewhat lengthened. The upper lip is completed and the nose is more prominent. The nostrils are directed forward and the palate is not completely developed. The eyelids are present in the shape of folds above and below the eye, and the different parts of the auricula are distinguishable. By the end of the second month the fetus measures from 28 to 30 mm. in length (Fig. 63). 7

Third Month.—The head is extended and the neck is lengthened. The eyelids meet and fuse, remaining closed until the end of the sixth month. The limbs are well-developed and nails appear on the digits. The external generative organs are so far differentiated that it is possible to distinguish the sex. By the end of this month the length of the fetus is about 7 cm., but if the legs be included it is from 9 to 10 cm. 8

Fourth Month.—The loop of gut which projected into the umbilical cord is withdrawn within the fetus. The hairs begin to make their appearance. There is a general increase in size so that by the end of the fourth month the fetus is from 12 to 13 cm. in length, but if the legs be included it is from 16 to 20 cm. 9

Fifth Month.

—It is during this month that the first movements of the fetus are usually observed. The eruption of hair on the head commences, and the *vernix caseosa* begins to be deposited. By the end of this month the total length of the fetus, including the legs, is from 25 to 27 cm. 10

Sixth Month.—The body is covered by fine hairs (*lanugo*) and the deposit of vernix caseosa is considerable. The papillæ of the skin are developed and the free border of the nail projects from the corium of the dermis. Measured from vertex to heels, the total length of the fetus at the end of this month is from 30 to 32 cm. 11

Seventh Month.—The pupillary membrane atrophies and the eyelids are open. The testis descends with the vaginal sac of the peritoneum. From vertex to heels the total length at the end of the seventh month is from 35 to 36 cm. The weight is a little over three pounds. 12

Eighth Month.—The skin assumes a pink color and is now entirely coated with vernix caseosa, and the lanugo begins to disappear. Subcutaneous fat has been developed to a considerable extent, and the fetus presents a plump appearance. The total length, *i. e.,* from head to heels, at the end of the eighth month is about 40 cm., and the weight varies between four and one-half and five and one-half pounds. 13

Ninth Month.—The lanugo has largely disappeared from the trunk. The umbilicus is almost in the middle of the body and the testes are in the scrotum. At full time the fetus weighs from six and one-half to eight pounds, and measures from head to heels about 50 cm. 14

Note 9. Die Einbettung des menschlichen Eies, 1899. [back]

Note 10. Bryce and Teacher (*Early Development and Imbedding of the Human Ovum,* 1908) have described an ovum which they regard as thirteen to fourteen days old. In it the two vesicles, the amnion and yolk-sac, were present, but there was no trace of a layer of embryonic ectoderm. They are of opinion that the age of Peters' ovum has been understated, and estimate it as between thirteen and one-half and fourteen and one-half days. [back]

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II. Osteology

THE GENERAL framework of the body is built up mainly of a series of bones, supplemented, however, in certain regions by pieces of cartilage; the bony part of the framework constitutes the **skeleton.** 1

In the skeleton of the adult there are 206 distinct bones, as follows:— 2

Axial Skeleton	Vertebral column	26	
	Skull	22	
	Hyoid bone	1	
	Ribs and sternum	25	
		—	74
Appendicular Skeleton	Upper extremities	64	
	Lower extremities	62	
		—	126
Auditory ossicles			6
			—
	Total		206

The patellæ are included in this enumeration, but the smaller sesamoid bones are not reckoned. 3

Bones are divisible into four classes: *Long, Short, Flat, and Irregular.* 4

Long Bones.—The long bones are found in the limbs, and each consists of a body or shaft and two extremities. The **body,** or **diaphysis** is cylindrical, with a central cavity termed the **medullary canal;** the wall consists of dense, compact tissue of considerable thickness in the middle part of the body, but becoming thinner toward the extremities; within the medullary canal is some cancellous tissue, scanty in the middle of the body but greater in amount toward the ends. The *extremities* are generally expanded, for the purposes of articulation and to afford broad surfaces for muscular attachment. They are usually developed from separate centers of ossification termed **epiphyses,** and consist of cancellous tissue surrounded by thin compact bone. The medullary canal and the spaces in the cancellous tissue are filled with marrow. The long bones are not straight, but curved, the curve generally taking place in two planes, thus affording greater strength to the bone. The bones belonging to this class are: the **clavicle, humerus, radius, ulna, femur, tibia, fibula, metacarpals, metatarsals,** and **phalanges.** 5

Short Bones.—Where a part of the skeleton is intended for strength and compactness combined with limited movement, it is constructed of a number of short bones, as in the **carpus** and **tarsus.** These consist of cancellous tissue covered by a thin crust of compact substance. The **patellæ,** together with the other sesamoid bones, are by some regarded as short bones. 6

Flat Bones.—Where the principal requirement is either extensive protection or the provision of broad surfaces for muscular attachment, the bones are expanded into broad, flat plates, as in the **skull** and the **scapula.** These bones are composed of two thin layers of compact tissue enclosing between them a variable quantity of cancellous tissue. In the cranial bones, the layers of compact tissue are familiarly known as the **tables of the skull;** the outer one is thick and tough; the inner is thin, dense, and brittle, and hence is termed the **vitreous table.** The intervening cancellous tissue is called the **diploë,** and this, in certain regions of the skull, becomes absorbed so as to leave spaces filled with air (*air-sinuses*) between the two tables. The flat bones are: the **occipital, parietal, frontal, nasal, lacrimal, vomer, scapula, os coxæ** (*hip bone*), **sternum, ribs,** and, according to some, the **patella.** 7

Irregular Bones.—The irregular bones are such as, from their peculiar form, cannot be grouped under the preceding heads. They consist of cancellous tissue enclosed within a thin layer of compact bone. The irregular bones are: the **vertebræ, sacrum, coccyx, temporal, sphenoid, ethmoid, zygomatic, maxilla, mandible, palatine, inferior nasal concha,** and **hyoid.** 8

Surfaces of Bones.—If the surface of a bone be examined, certain eminences and depressions are seen. These eminences and depressions are of two kinds: articular and non-articular. Well-marked examples of **articular eminences** are found in the heads of the humerus and femur; and of **articular depressions** in the glenoid cavity of the scapula, and the acetabulum of the hip bone. **Non-articular eminences** are designated according to their form. Thus, a broad, rough, uneven elevation is called a **tuberosity, protuberance,** or **process,** a small, rough prominence, a **tubercle;** a sharp, slender pointed eminence, a **spine;** a narrow, rough elevation, running some way along the surface, a **ridge, crest,** or **line.** *Non-articular depressions* are also of variable form, and are described as **fossæ, pits, depressions, grooves, furrows, fissures, notches,** etc. These non-articular eminences and depressions serve to increase the extent of surface for the attachment of ligaments and muscles, and are usually well-marked in proportion to the muscularity of the subject. A short perforation is called a **foramen,** a longer passage a **canal.** 9

1. Development of the Skeleton

The Skeleton.—The skeleton is of mesodermal origin, and may be divided into (*a*) that of the trunk (**axial skeleton**), comprising the vertebral column, skull, ribs, and sternum, and (*b*) that of the limbs (**appendicular skeleton**). 10

The Vertebral Column.—The notochord (Fig. 19) is a temporary structure and forms a central axis, around which the segments of the vertebral column are developed. 11 It is derived from the entoderm, and consists of a rod of cells, which lies on the ventral aspect of the neural tube and reaches from the anterior end of the mid-brain to the extremity of the tail. On either side of it is a column of paraxial mesoderm which becomes subdivided into a number of more or less cubical segments, the **primitive segments** (Figs. 19 and 20). These are separated from one another by **intersegmental septa** and are arranged symmetrically on either side of the neural tube and notochord: to every segment a spinal nerve is distributed. At first each segment contains a central cavity, the **myocœl,** but this is soon filled with a core of angular and spindle-shaped cells. The cells of the segment become differentiated into three groups, which form respectively the cutis-plate or dermatome, the muscle-plate or myotome, and the sclerotome (Fig. 64). The **cutis-plate** is placed on the lateral and dorsal aspect of the myocœl, and from it the true skin of the corresponding segment is derived; the **muscle-plate** is situated on the medial side of the cutis-plate and furnishes the muscles of the segment. The cells of the **sclerotome** are largely derived from those forming the core of the myocœl, and lie next the notochord. Fusion of the individual sclerotomes in an antero-posterior direction soon takes place, and thus a continuous strand of cells, the **sclerotogenous layer,** is formed along the ventro-lateral aspects of the neural tube. The cells of this layer proliferate rapidly, and extending medialward surround the notochord; at the same time they grow backward on the lateral aspects of the neural tube and eventually surround it, and thus the notochord and neural tube are enveloped by a continuous sheath of mesoderm, which is termed the **membranous vertebral column.** In this mesoderm the original segments are still distinguishable, but each is now differentiated into two portions, an anterior, consisting of loosely arranged cells, and a posterior, of more condensed tissue (Fig. 65, *A* and *B*). Between the two portions the rudiment of the intervertebral fibrocartilage is laid down (Fig. 65, *C*). Cells from the posterior mass grow into the intervals between the myotomes (Fig. 65, *B* and *C*) of the corresponding and succeeding segments, and extend both dorsally and ventrally; the dorsal extensions surround the neural tube and represent the future vertebral arch, while the ventral extend into the body-wall as the costal processes. The hinder part of the posterior mass joins the anterior mass of the succeeding segment to form the vertebral body. Each vertebral body is therefore a composite of two segments, being formed from the posterior portion of one segment and the anterior part of that immediately behind it. The vertebral and costal arches are derivatives of the posterior part of the segment in front of the intersegmental septum with which they are associated.

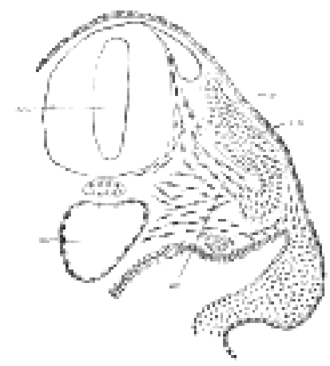

FIG. 64– Transverse section of a human embryo of the third week to show the differentiation of the primitive segment. (Kollmann.) *ao.* Aorta. *m.p.* Muscle-plate. *n.c.* Neural canal. *sc.* Sclerotome. *s.p.* cutis-plate. (See enlarged image)

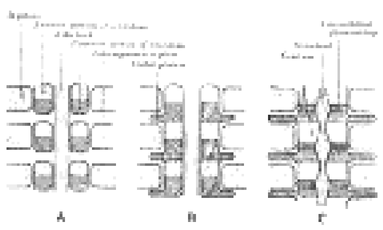

FIG. 65– Scheme showing the manner in which each vertebral centrum is developed from portions of two adjacent segments. (See enlarged image)

This stage is succeeded by that of the **cartilaginous vertebral column.** In the fourth week two cartilaginous centers make their appearance, one on either side of the notochord; these extend around the notochord and form the body of the cartilaginous vertebra. A second pair of cartilaginous foci appear in the lateral parts of the vertebral bow, and grow backward on either side of the neural tube to form the cartilaginous vertebral arch, and a separate cartilaginous center appears for each costal process. By the eighth week the cartilaginous arch has fused with the body, and in the fourth month the two halves of the arch are joined on the dorsal aspect of the neural tube. The spinous process is developed from the junction of the two halves of the vertebral arch. The transverse process grows out from the vertebral arch behind the costal process. 12

In the upper cervical vertebræ a band of mesodermal tissue connects the ends of the vertebral arches across the ventral surfaces of the intervertebral fibrocartilages. This is termed the **hypochordal bar** or **brace;** in all except the first it is transitory and disappears by fusing with the fibrocartilages. In the atlas, however, the entire bow persists and undergoes chondrification; it develops into the anterior arch of the bone, while the cartilage representing the body of the atlas forms the dens or odontoid process which fuses with the body of the second cervical vertebra. 13

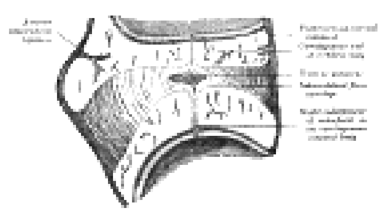

FIG. 66– Sagittal section through an intervertebral fibrocartilage and adjacent parts of two vertebræ of an advanced sheep's embryo. (Kölliker.) (See enlarged image)

The portions of the notochord which are surrounded by the bodies of the vertebræ atrophy, and ultimately disappear, while those which lie in the centers of the intervertebral fibrocartilages undergo enlargement, and persist throughout life as the central **nucleus pulposus** of the fibrocartilages (Fig. 66). 14

The Ribs.—The ribs are formed from the ventral or costal processes of the primitive vertebral bows, the processes extending between the muscle-plates. In the *thoracic region* of the vertebral column the costal processes grow lateralward to form a series of arches, the **primitive costal arches.** As already described, the transverse process grows out behind the vertebral end of each arch. It is at first connected to the costal process by continuous mesoderm, but this becomes differentiated later to form the costotransverse ligament; between the costal process and the tip of the transverse process the costotransverse joint is formed by absorption. The costal process becomes separated from the vertebral bow by the development of the costocentral joint. In the *cervical vertebrœ* (Fig. 67) the transverse process forms the posterior boundary of the foramen transversarium, while the costal process corresponding to the head and neck of the rib fuses with the body of the vertebra, and forms the antero-lateral boundary of the foramen. The distal portions of the primitive costal arches remain undeveloped; occasionally the arch of the seventh cervical vertebra undergoes greater development, and by the formation of costovertebral joints is separated off as a rib. In the *lumbar region* the distal portions of the primitive costal arches fail; the proximal portions fuse with the transverse processes to form the transverse processes of descriptive anatomy. Occasionally a movable rib is developed in connection with the first lumbar vertebra. In the *sacral region* costal processes are developed only in connection with the upper three, or it may be four, vertebræ the processes of adjacent segments fuse with one another to form the lateral parts of the sacrum. The *coccygeal vertebrœ* are devoid of costal processes. 15

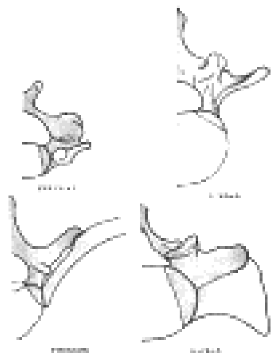

FIG. 67– Diagrams showing the portions of the adult vertebræ derived respectively from the bodies, vertebral arches, and costal processes of the embryonic vertebræ. The bodies are represented in yellow, the vertebral arches in red, and the costal processes in blue. (See enlarged image)

The Sternum.—The ventral ends of the ribs become united to one another by a longitudinal bar termed the **sternal plate,** and opposite the first seven pairs of ribs these sternal plates fuse in the middle line to form the manubrium and body of the sternum. The xiphoid process is formed by a backward extension of the sternal plates. 16

The Skull.—Up to a certain stage the development of the skull corresponds with that of the vertebral column; but it is modified later in association with the expansion of the brain-vesicles, the formation of the organs of smell, sight, and hearing, and the development of the mouth and pharynx. 17

The notochord extends as far forward as the anterior end of the mid-brain, and becomes partly surrounded by mesoderm (Fig. 68). The posterior part of this mesodermal investment corresponds with the basilar part of the occipital bone, and shows a subdivision into four segments, which are separated by the roots of the hypoglossal nerve. The mesoderm then extends over the brain-vesicles, and thus the entire brain is enclosed by a mesodermal investment, which is termed the **membranous cranium.** From the inner layer of this the bones of the skull and the membranes of the brain are developed; from the outer layer the muscles, bloodvessels, true skin, and subcutaneous tissues of the scalp. In the shark and dog-fish this membranous cranium undergoes complete chondrification, and forms the cartilaginous skull or **chondrocranium** of these animals. In mammals, on the other hand, the process of chondrification is limited to the base of the skull—the roof and sides being covered in by membrane. Thus the bones of the base of the skull are preceded by cartilage, those of the roof and sides by membrane. The posterior part of the base of the skull is developed around the notochord, and exhibits a segmented condition analogous to that of the vertebral column, while the anterior part arises in front of the notochord and shows no regular segmentation. The base of the skull may therefore be divided into (*a*) a **chordal** or **vertebral,** and (*b*) a **prechordal** or **prevertebral portion.** 18

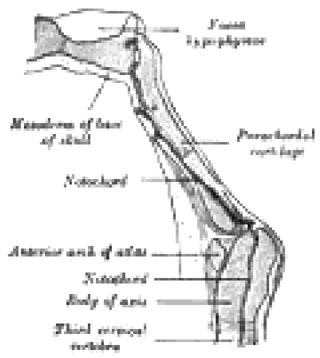

FIG. 68– Sagittal section of cephalic end of notochord. (Keibel.) (See enlarged image)

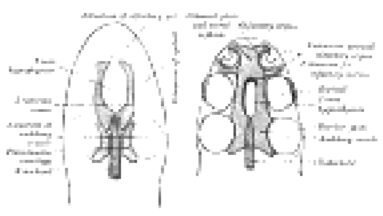

FIG. 69– Diagrams of the cartilaginous cranium. (Wiedersheim.) (See enlarged image)

In the lower vertebrates two pairs of cartilages are developed, viz., a pair of parachordal cartilages, one on either side of the notochord; and a pair of prechordal cartilages, the **trabeculæ cranii,** in front of the notochord (Fig. 66). The **parachordal cartilages** (Fig. 69) unite to form a basilar plate, from which the cartilaginous part of the occipital bone and the basi-sphenoid are developed. On the lateral aspects of the parachordal cartilages the auditory vesicles are situated, and the mesoderm enclosing them is soon converted into cartilage, forming the **cartilaginous ear-capsules.** These cartilaginous ear-capsules, which are of an oval shape, fuse with the sides of the basilar plate, and from them arise the petrous and mastoid portions of the temporal bones. **The trabeculæ cranii** (Fig. 69) are two curved bars of cartilage which embrace the hypophysis cerebri; their posterior ends soon unite with the basilar plate, while their anterior ends join to form the **ethmoidal plate,** which extends forward between the fore-brain and the olfactory pits. Later the trabeculæ meet and fuse below the hypophysis, forming the floor of the fossa hypophyseos and so cutting off the anterior lobe of the hypophysis from the stomodeum. The median part of the ethmoidal plate forms the bony and cartilaginous parts of the nasal septum. From the lateral margins of the trabeculæ cranii three processes grow out on either side. The anterior forms the ethmoidal labyrinth and the lateral and alar cartilages of the nose; the middle gives rise to the small wing of the sphenoid, while from the posterior the great wing and lateral pterygoid plate of the sphenoid are developed (Figs. 70, 71). The bones of the vault are of membranous formation, and are termed **dermal** or **covering bones.** They are partly developed from the mesoderm of the membranous cranium, and partly from that which lies outside the entoderm of the foregut. They comprise the upper part of the occipital squama (interparietal), the squamæ and tympanic parts of the temporals, the parietals, the frontal, the vomer, the medial pterygoid plates, and the bones of the face. Some of them remain distinct throughout life, *e.g.,* parietal and frontal, while others join with the bones of the chondrocranium, *e.g.,* interparietal, squamæ of temporals, and medial pterygoid plates. 19

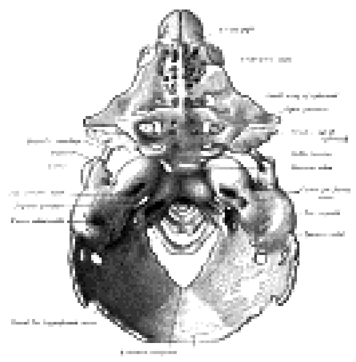

FIG. 70– Model of the chondrocranium of a human embryo, 8 cm. long. (Hertwig.) The membrane bones are not represented. (See enlarged image)

Recent observations have shown that, in mammals, the basi-cranial cartilage, both in the chordal and prechordal regions of the base of the skull, is developed as a single plate which extends from behind forward. In man, however, its posterior part shows an indication of being developed from two chondrifying centers which fuse rapidly in front and below. The anterior and posterior thirds of the cartilage surround the notochord, but its middle third lies on the dorsal aspect of the notochord, which in this region is placed between the cartilage and the wall of the pharynx. 20

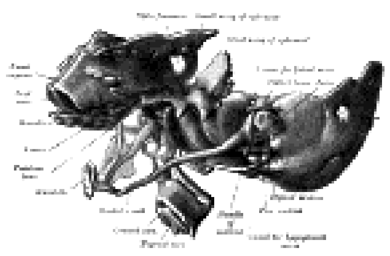

FIG. 71– The same model as shown in Fig. 70 from the left side. Certain of the membrane bones of the right side are represented in yellow. (Hertwig.) (See enlarged image)

Note 11. In the amphioxus the notochord persists and forms the only representative of a skeleton in that animal. [back]

2. Bone

Structure and Physical Properties.—Bone is one of the hardest structures of the animal body; it possesses 1
also a certain degree of toughness and elasticity. Its color, in a fresh state, is pinkish-white externally, and deep red within. On examining a section of any bone, it is seen to be composed of two kinds of tissue, one of which is dense in texture, like ivory, and is termed **compact tissue;** the other consists of slender fibers and lamellæ, which join to form a reticular structure; this, from its resemblance to lattice-work, is called **cancellous tissue.** The compact tissue is always placed on the exterior of the bone, the cancellous in the interior. The relative quantity of these two kinds of tissue varies in different bones, and in different parts of the same bone, according as strength or lightness is requisite. Close examination of the compact tissue shows it to be extremely porous, so that the difference in structure between it and the cancellous tissue depends merely upon the different amount of solid matter, and the size and number of spaces in each; the cavities are small in the compact tissue and the solid matter between them abundant, while in the cancellous tissue the spaces are large and the solid matter is in smaller quantity.

Bone during life is permeated by vessels, and is enclosed, except where it is coated with articular cartilage, 2
in a fibrous membrane, the **periosteum,** by means of which many of these vessels reach the hard tissue. If the periosteum be stripped from the surface of the living bone, small bleeding points are seen which mark the entrance of the periosteal vessels; and on section during life every part of the bone exudes blood from the minute vessels which ramify in it. The interior of each of the long bones of the limbs presents a cylindrical cavity filled with marrow and lined by a highly vascular areolar structure, called the **medullary membrane.**

THE STRENGTH OF BONE COMPARED WITH OTHER MATERIALS	Substance.	Weight in pounds per cubic foot.	Ultimate strength. Pounds per square inch.		
			Tension.	Compression.	Shear.
	Medium steel	490	65,000	60,000	40,000
	Granite	170	1,500	15,000	2,000
Oak, white	46	12,500 12	7,000	4,000 13	
Compact bone (low)	119	13,200	18,000	11,800	
Compact bone (high)	……	17,700	24,000	7,150	

Periosteum.—The periosteum adheres to the surface of each of the bones in nearly every part, but not to 3
cartilaginous extremities. When strong tendons or ligaments are attached to a bone, the periosteum is incorporated with them. It consists of two layers closely united together, the outer one formed chiefly of connective tissue, containing occasionally a few fat cells; the inner one, of elastic fibers of the finer kind, forming dense membranous networks, which again can be separated into several layers. In young bones the periosteum is thick and very vascular, and is intimately connected at either end of the bone with the epiphysial cartilage, but less closely with the body of the bone, from which it is separated by a layer of soft tissue, containing a number of **granular corpuscles** or **osteoblasts,** by which ossification proceeds on the exterior of the young bone. Later in life the periosteum is thinner and less vascular, and the osteoblasts are converted into an epithelioid layer on the deep surface of the periosteum. The periosteum serves as a nidus for the ramification of the vessels previous to their distribution in the bone; hence the liability of bone to exfoliation or necrosis when denuded of this membrane by injury or disease. Fine nerves and lymphatics, which generally accompany the arteries, may also be demonstrated in the periosteum.

Marrow.—The marrow not only fills up the cylindrical cavities in the bodies of the long bones, but also 4
occupies the spaces of the cancellous tissue and extends into the larger bony canals (Haversian canals) which contain the bloodvessels. It differs in composition in different bones. In the bodies of the long bones the marrow is of a *yellow* color, and contains, in 100 parts, 96 of fat, 1 of areolar tissue and vessels, and 3 of fluid with extractive matter; it consists of a basis of connective tissue supporting numerous bloodvessels and cells, most of which are fat cells but some are “marrow cells,” such as occur in the red marrow to be immediately described. In the flat and short bones, in the articular ends of the long bones, in the bodies of the vertebræ, in the cranial diploë, and in the sternum and ribs the marrow is of a *red* color, and contains, in 100 parts, 75 of water, and 25 of solid matter consisting of cell-globulin, nucleoprotein, extractives, salts, and only a small proportion of fat. The red marrow consists of a small quantity of connective tissue, bloodvessels, and numerous cells (Fig. 72), some few of which are fat cells, but the great majority are roundish nucleated cells, the true “marrow cells” of Kölliker. These marrow cells proper, or **myelocytes,** resemble in appearance lymphoid corpuscles, and like them are ameboid; they generally have a hyaline protoplasm, though some show granules either oxyphil or basophil in reaction. A number of eosinophil cells are also present. Among the marrow cells may be seen smaller cells, which possess a slightly pinkish hue; these are the **erythroblasts** or **normoblasts,** from which the red corpuscles of the adult are derived, and which may be regarded as descendants of the nucleated colored corpuscles of the embryo. **Giant cells** (*myeloplaxes, osteoclasts*), large, multinucleated, protoplasmic masses, are also to be found in both sorts of adult marrow, but more particularly in red marrow. They were believed by Kölliker to be concerned in the absorption of bone matrix, and hence the name which he gave to them—*osteoclasts.* They excavate in the bone small shallow pits or cavities, which are named **Howship's foveolæ,** and in these they are found lying.

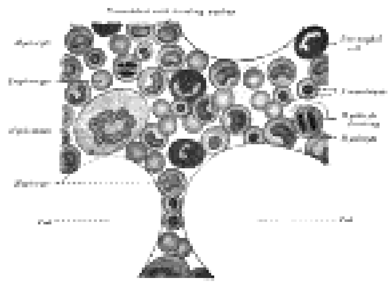

FIG. 72– Human bone marrow. Highly magnified. (See enlarged image)

Vessels and Nerves of Bone.—The **bloodvessels** of bone are very numerous. Those of the compact 5
tissue are derived from a close and dense network of vessels ramifying in the periosteum. From this membrane vessels pass into the minute orifices in the compact tissue, and run through the canals which traverse its substance. The cancellous tissue is supplied in a similar way, but by less numerous and larger vessels, which, perforating the outer compact tissue, are distributed to the cavities of the spongy portion of the bone. In the long bones, numerous apertures may be seen at the ends near the articular surfaces; some of these give passage to the arteries of the larger set of vessels referred to; but the most numerous and largest apertures are for some of the veins of the cancellous tissue, which emerge apart from the arteries. The marrow in the body of a long bone is supplied by one large artery (or sometimes more), which enters the bone at the nutrient foramen (situated in most cases near the center of the body), and perforates obliquely the compact structure. The *medullary* or *nutrient* artery, usually accompanied by one or two veins, sends branches upward and downward, which ramify in the medullary membrane, and give twigs to the adjoining canals. The ramifications of this vessel anastomose with the arteries of the cancellous and compact tissues. In most of the flat, and in many of the short spongy bones, one or more large apertures are observed, which transmit to the central parts of the bone vessels corresponding to the nutrient arteries and veins. The **veins** emerge from the long bones in three places (Kölliker): (1) one or two large veins accompany the artery; (2) numerous large and small veins emerge at the articular extremities; (3) many small veins pass out of the compact substance. In the flat cranial bones the veins are large, very numerous, and run in tortuous canals in the diploic tissue, the sides of the canals being formed by thin lamellæ of bone, perforated here and there for the passage of branches from the adjacent cancelli. The same condition is also found in all cancellous tissue, the veins being enclosed and supported by osseous material, and having exceedingly thin coats. When a bone is divided, the vessels remain patulous, and do not contract in the canals in which they are contained. **Lymphatic vessels,** in addition to those found in the periosteum, have been traced by Cruikshank into the substance of bone, and Klein describes them as running in the Haversian canals. **Nerves** are distributed freely to the periosteum, and accompany the nutrient arteries into the interior of the bone. They are said by Kölliker to be most numerous in the articular extremities of the long bones, in the vertebræ, and in the larger flat bones.

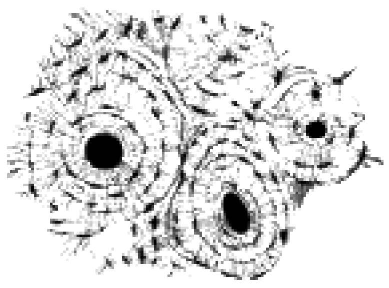

FIG. 73– Transverse section of compact tissue bone. Magnified. (Sharpey.) (See enlarged image)

Minute Anatomy.—A transverse section of dense bone may be cut with a saw and ground down until it is 6
sufficiently thin.

If this be examined with a rather low power the bone will be seen to be mapped out into a number of 7
circular districts each consisting of a central hole surrounded by a number of concentric rings. These districts are termed **Haversian systems;** the central hole is an **Haversian canal,** and the rings are layers of bony tissue arranged concentrically around the central canal, and termed **lamellæ.** Moreover, on closer examination it will be found that between these lamellæ, and therefore also arranged concentrically around the central canal, are a number of little dark spots, the **lacunæ,** and that these lacunæ are connected with each other and with the central Haversian canal by a number of fine dark lines, which radiate like the spokes of a wheel and are called **canaliculi.** Filling in the irregular intervals which are left between these circular systems are other lamellæ, with their lacunæ and canaliculi running in various directions, but more or less curved (Fig. 73); they are termed **interstitial lamellæ.** Again, other lamellæ, found on the surface of the bone, are arranged parallel to its circumference; they are termed **circumferential,** or by some authors **primary** or **fundamental lamellæ,** to distinguish them from those laid down around the axes of the Haversian canals, which are then termed **secondary** or **special lamellæ.**

The **Haversian canals,** seen in a transverse section of bone as round holes at or about the center of each 8
Haversian system, may be demonstrated to be true canals if a longitudinal section be made (Fig. 74). It will then be seen that the canals run parallel with the longitudinal axis of the bone for a short distance and then branch and communicate. They vary considerably in size, some being as much as 0.12 mm. in diameter; the average size is, however, about 0.05 mm. Near the medullary cavity the canals are larger than those near the surface of the bone. Each canal contains one or two bloodvessels, with a small quantity of delicate connective tissue and some nerve filaments. In the larger ones there are also lymphatic vessels, and cells with branching processes which communicate, through the canalculi, with the branched processes of certain bone cells in the substance of the bone. Those canals near the surface of the bone open upon it by minute orifices, and those near the medullary cavity open in the same way into this space, so that the whole of the bone is permeated by a system of bloodvessels running through the bony canals in the centers of the Haversian systems.

The **lamellæ** are thin plates of bony tissue encircling the central canal, and may be compared, for the sake 9
of illustration, to a number of sheets of paper pasted one over another around a central hollow cylinder. After macerating a piece of bone in dilute mineral acid, these lamellæ may be stripped off in a longitudinal direction as thin films. If one of these be examined with a high power of the microscope, it will be found to be composed of a finely reticular structure, made up of very slender transparent fibers, decussating obliquely; and coalescing at the points of intersection; these fibers are composed of fine fibrils identical with those of white connective tissue. The intercellular matrix between the fibers is impregnated by calcareous deposit which the acid dissolves. In many places the various lamellæ may be seen to be held together by tapering fibers, which run obliquely through them, pinning or bolting them together; they were first described by Sharpey, and were named by him **perforating fibers** (Fig. 75).

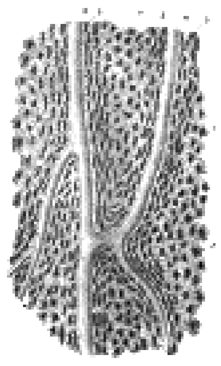

FIG. 74– Section parallel to the surface from the body of the femur. X 100. *a,* Haversian canals; *b,* lacunæ seen from the side; *c,* others seen from the surface in lamellæ, which are cut horizontally. (See enlarged image)

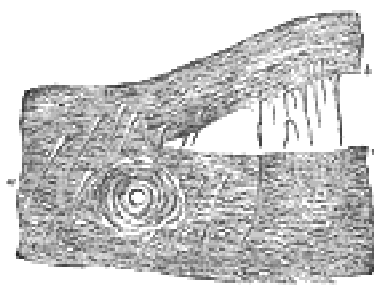

FIG. 75– Perforating fibers, human parietal bone, decalcified. (H. Müller.) *a,* perforating fibers *in situ; b,* fibres drawn out of their sockets; *c,* sockets. (See enlarged image)

10 The **Lacunæ** are situated between the lamellæ, and consist of a number of oblong spaces. In an ordinary microscopic section, viewed by transmitted light, they appear as fusiform opaque spots. Each lacuna is occupied during life by a branched cell, termed a **bone-cell** or **bone-corpuscle,** the processes from which extend into the canaliculi (Fig. 76).

11 The **Canaliculi** are exceedingly minute channels, crossing the lamellæ and connecting the lacunæ with neighboring lacunæ and also with the Haversian canal. From the Haversian canal a number of canaliculi are given off, which radiate from it, and open into the first set of lacunæ between the first and second lamellæ. From these lacunæ a second set of canaliculi is given off; these run outward to the next series of lacunæ, and so on until the periphery of the Haversian system is reached; here the canaliculi given off from the last series of lacunæ do not communicate with the lacunæ of neighboring Haversian systems, but after passing outward for a short distance form loops and return to their own lacunæ. Thus every part of an Haversian system is supplied with nutrient fluids derived from the vessels in the Haversian canal and distributed through the canaliculi and lacunæ.

12 The **bone cells** are contained in the lacunæ, which, however, they do not completely fill. They are flattened nucleated branched cells, homologous with those of connective tissue; the branches, especially in young bones, pass into the canaliculi from the lacunæ.

13 In thin plates of bone (as in the walls of the spaces of cancellous tissue) the Haversian canals are absent, and the canaliculi open into the spaces of the cancellous tissue (medullary spaces), which thus have the same function as the Haversian canals.

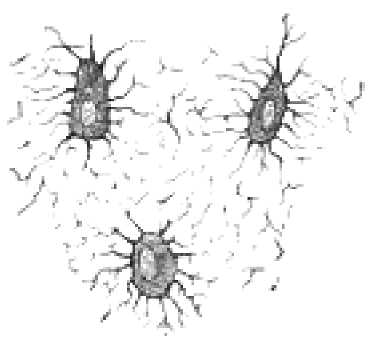

FIG. 76– Nucleated bone cells and their processes, contained in the bone lacunæ and their canaliculi respectively. From a section through the vertebra of an adult mouse. (Klein and Noble Smith.) (See enlarged image)

14 **Chemical Composition.**—Bone consists of an animal and an earthy part intimately combined together.

15 The animal part may be obtained by immersing a bone for a considerable time in dilute mineral acid, after which process the bone comes out exactly the same shape as before, but perfectly flexible, so that a long bone (one of the ribs, for example) can easily be tied in a knot. If now a transverse section is made (Fig. 77) the same general arrangement of the Haversian canals, lamellæ, lacunæ, and canaliculi is seen.

16 The earthy part may be separately obtained by calcination, by which the animal matter is completely burnt out. The bone will still retain its original form, but it will be white and brittle, will have lost about one-third of its original weight, and will crumble down with the slightest force. The earthy matter is composed chiefly of calcium phosphate, about 58 per cent. of the weight of the bone, calcium carbonate about 7 per cent., calcium fluoride and magnesium phosphate from 1 to 2 per cent. each and sodium chloride less than 1 per cent.; they confer on bone its hardness and rigidity, while the animal matter (*ossein*) determines its tenacity.

17 **Ossification.**—Some bones are preceded by membrane, such as those forming the roof and sides of the skull; others, such as the bones of the limbs, are preceded by rods of cartilage. Hence two kinds of ossification are described: the **intramembranous** and the **intracartilaginous.**

INTRAMEMBRANOUS OSSIFICATION.—In the case of bones which are developed in membrane, no 18 cartilaginous mould precedes the appearance of the bony tissue. The membrane which occupies the place of the future bone is of the nature of connective tissue, and ultimately forms the periosteum; it is composed of fibers and granular cells in a matrix. The peripheral portion is more fibrous, while, in the interior the cells or *osteoblasts* predominate; the whole tissue is richly supplied with blood vessels. At the outset of the process of bone formation a little network of spicules is noticed radiating from the point or center of ossification. These rays consist at their growing points of a network of fine clear fibers and granular corpuscles with an intervening ground substance (Fig. 78). The fibers are termed **osteogenetic fibers,** and are made up of fine fibrils differing little from those of white fibrous tissue. The membrane soon assumes a dark and granular appearance from the deposition of calcareous granules in the fibers and in the intervening matrix, and in the calcified material some of the granular corpuscles or osteoblasts are enclosed. By the fusion of the calcareous granules the tissue again assumes a more transparent appearance, but the fibers are no longer so distinctly seen. The involved osteoblasts from the corpuscles of the future bone, the spaces in which they are enclosed constituting the lacunæ. As the osteogenetic fibers grow out to the periphery they continue to calcify, and give rise to fresh bone spicules. Thus a network of bone is formed, the meshes of which contain the bloodvessels and a delicate connective tissue crowded with osteoblasts. The bony trabeculæ thicken by the addition of fresh layers of bone formed by the osteoblasts on their surface, and the meshes are correspondingly encroached upon. Subsequently successive layers of bony tissue are deposited under the periosteum and around the larger vascular channels which become the Haversian canals, so that the bone increases much in thickness.

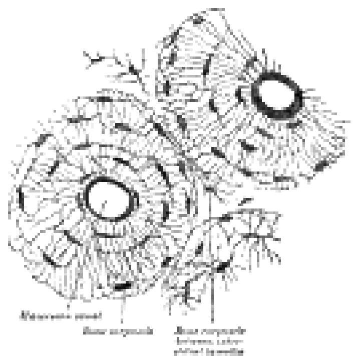

FIG. 77– Transverse section of body of human fibula, decalcified. X 250. (See enlarged image)

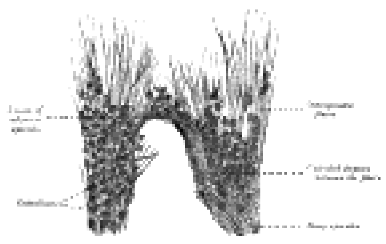

FIG. 78– Part of the growing edge of the developing parietal bone of a fetal cat. (After J. Lawrence.) (See enlarged image)

INTERCARTILAGINOUS OSSIFICATION.—Just before ossification begins the mass is entirely cartilaginous, and 19 in a long bone, which may be taken as an example, the process commences in the center and proceeds toward the extremities, which for some time remain cartilaginous. Subsequently a similar process commences in one or more places in those extremities and gradually extends through them. The extremities do not, however, become joined to the body of the bone by bony tissue until growth has ceased; between the body and either extremity a layer of cartilaginous tissue termed the **epiphysial cartilage** persists for a definite period.

The first step in the ossification of the cartilage is that the cartilage cells, at the point where ossification is 20 commencing and which is termed a **center of ossification,** enlarge and arrange themselves in rows (Fig. 79). The matrix in which they are imbedded increases in quantity, so that the cells become further separated from each other. A deposit of calcareous material now takes place in this matrix, between the rows of cells, so that they become separated from each other by longitudinal columns of calcified matrix, presenting a granular and opaque appearance. Here and there the matrix between two cells of the same row also becomes calcified, and transverse bars of calcified substance stretch across from one calcareous column to another. Thus there are longitudinal groups of the cartilage cells enclosed in oblong cavities, the walls of which are formed of calcified matrix which cuts off all nutrition from the cells; the cells, in consequence, atrophy, leaving spaces called the **primary areolæ.**

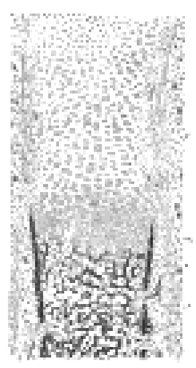

FIG. 79– Section of fetal bone of cat. *ir.* Irruption of the subperiosteal tissue. *p.* Fibrous layer of the periosteum. *o.* Layer of osteoblasts. *im.* Subperiosteal bony deposit. (From Quain’s “Anatomy,” E. A. Schäfer.) (See enlarged image)

21 At the same time that this process is going on in the center of the solid bar of cartilage, certain changes are taking place on its surface. This is covered by a very vascular membrane, the **perichondrium,** entirely similar to the embryonic connective tissue already described as constituting the basis of membrane bone; on the inner surface of this—that is to say, on the surface in contact with the cartilage—are gathered the formative cells, the **osteoblasts.** By the agency of these cells a thin layer of bony tissue is formed between the perichondrium and the cartilage, by the *intramembranous* mode of ossification just described. There are then, in this first stage of ossification, two processes going on simultaneously: in the center of the cartilage the formation of a number of oblong spaces, formed of calcified matrix and containing the withered cartilage cells, and on the surface of the cartilage the formation of a layer of true membrane bone. The second stage consists in the prolongation into the cartilage of processes of the deeper or osteogenetic layer of the perichondrium, which has now become periosteum (Fig. 79, *ir*). The processes consist of bloodvessels and cells—**osteoblasts,** or **bone-formers,** and **osteoclasts,** or **bone-destroyers.** The latter are similar to the giant cells (myeloplaxes) found in marrow, and they excavate passages through the new-formed bony layer by absorption, and pass through it into the calcified matrix (Fig. 80). Wherever these processes come in contact with the calcified walls of the primary areolæ they absorb them, and thus cause a fusion of the original cavities and the formation of larger spaces, which are termed the **secondary areolæ** or **medullary spaces.** These secondary spaces become filled with embryonic marrow, consisting of osteoblasts and vessels, derived, in the manner described above, from the osteogenetic layer of the periosteum (Fig. 80).

22 Thus far there has been traced the formation of enlarged spaces (secondary areolæ), the perforated walls of which are still formed by calcified cartilage matrix, containing an embryonic marrow derived from the processes sent in from the osteogenetic layer of the periosteum, and consisting of bloodvessels and osteoblasts. The walls of these secondary areolæ are at this time of only inconsiderable thickness, but they become thickened by the deposition of layers of true bone on their surface. This process takes place in the following manner: Some of the osteoblasts of the embryonic marrow, after undergoing rapid division, arrange themselves as an epithelioid layer on the surface of the wall of the space (Fig. 81). This layer of osteoblasts forms a bony stratum, and thus the wall of the space becomes gradually covered with a layer of true osseous substance in which some of the bone-forming cells are included as bone corpuscles. The next stage in the process consists in the removal of these primary bone spicules by the osteoclasts. One of these giant cells may be found lying in a Howship's foveola at the free end of each spicule. The removal of the primary spicules goes on *pari passu* with the formation of permanent bone by the periosteum, and in this way the medullary cavity of the body of the bone is formed.

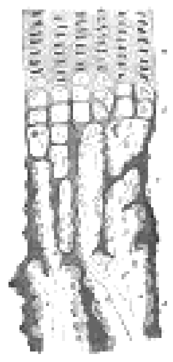

FIG. 80– Part of a longitudinal section of the developing femur of a rabbit. *a.* Flattened cartilage cells. *b.* Enlarged cartilage cells. *c, d.* Newly formed bone. *e.* Osteoblasts. *f.* Giant cells or osteoclasts. *g, h.* Shrunken cartilage cells. (From "Atlas of Histology," Klein and Noble Smith.) (See enlarged image)

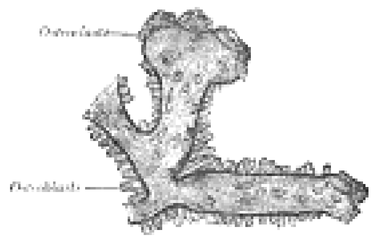

FIG. 81– Osteoblasts and osteoclasts on trabecula of lower jaw of calf embryo. (Kölliker.) (See enlarged image)

23 This series of changes has been gradually proceeding toward the end of the body of the bone, so that in the ossifying bone all the changes described above may be seen in different parts, from the true bone at the center of the body to the hyaline cartilage at the extremities.

24 While the ossification of the cartilaginous body is extending toward the articular ends, the cartilage immediately in advance of the osseous tissue continues to grow until the length of the adult bone is reached.

25 During the period of growth the articular end, or epiphysis, remains for some time entirely cartilaginous, then a bony center appears, and initiates in it the process of intracartilaginous ossification; but this process never extends to any great distance. The epiphysis remains separated from the body by a narrow cartilaginous layer for a definite time. This layer ultimately ossifies, the distinction between body and epiphysis is obliterated, and the bone assumes its completed form and shape. The same remarks also apply to such processes of bone as are separately ossified, *e.g.,* the trochanters of the femur. The bones therefore continue to grow until the body has acquired its full stature. They increase in length by ossification continuing to extend behind the epiphysial cartilage, which goes on growing in advance of the ossifying process. They increase in circumference by deposition of new bone, from the deeper layer of the periosteum, on their external surface, and at the same time an absorption takes place from within, by which the medullary cavities are increased.

26 The permanent bone formed by the periosteum when first laid down is cancellous in structure. Later the osteoblasts contained in its spaces become arranged in the concentric layers characteristic of the Haversian systems, and are included as bone corpuscles.

27 The number of ossific centers varies in different bones. In most of the short bones ossification commences at a single point near the center, and proceeds toward the surface. In the long bones there is a central point of ossification for the body or diaphysis: and one or more for each extremity, the epiphysis. That for the body is the first to appear. The times of union of the epiphyses with the body vary inversely with the dates at which their ossifications began (with the exception of the fibula) and regulate the direction of the nutrient arteries of the bones. Thus, the nutrient arteries of the bones of the arm and forearm are directed toward the elbow, since the epiphyses at this joint become united to the bodies before those at the opposite extremities. In the lower limb, on the other hand, the nutrient arteries are directed away from the knee: that is, upward in the femur, downward in the tibia and fibula; and in them it is observed that the upper epiphysis of the femur, and the lower epiphyses of the tibia and fibula, unite first with the bodies. Where there is only one epiphysis, the nutrient artery is directed toward the other end of the bone; as toward the acromial end of the clavicle, toward the distal ends of the metacarpal bone of the thumb and the metatarsal bone of the great toe, and toward the proximal ends of the other metacarpal and metatarsal bones.

Parsons 14 groups epiphyses under three headings, viz.: (1) **pressure epiphyses,** appearing at the articular ends of the bones and transmitting "the weight of the body from bone to bone;" (2) **traction epiphyses,** associated with the insertion of muscles and "originally sesamoid structures though not necessarily sesamoid bones;" and (3) **atavistic epiphyses,** representing parts of the skeleton, which at one time formed separate bones, but which have lost their function, "and only appear as separate ossifications in early life." 28

Note 12. Indicates stresses with the grain, *i.e.,* when the load is parallel to the long axis of the material, or parallel to the direction of the fibers of the material. [back]

Note 13. Indicates unit-stresses across the grain, *i.e.,* at right angles to the direction of the fibers of the material. [back]

Note 14. Jour. of Anat. and Phys., vols. xxxviii, xxxix, and xlii. [back]

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

3. The Vertebral Column

(Columna Vertebralis; Spinal Column). 1

The **vertebral column** is a flexuous and flexible column, formed of a series of bones called **vertebræ.**

The vertebræ are thirty-three in number, and are grouped under the names **cervical, thoracic, lumbar, sacral,** and **coccygeal,** according to the regions they occupy; there are seven in the cervical region, twelve in the thoracic, five in the lumbar, five in the sacral, and four in the coccygeal. 2

This number is sometimes increased by an additional vertebra in one region, or it may be diminished in one region, the deficiency often being supplied by an additional vertebra in another. The number of cervical vertebræ is, however, very rarely increased or diminished. 3

The vertebræ in the upper three regions of the column remain distinct throughout life, and are known as **true** or **movable** vertebræ; those of the sacral and coccygeal regions, on the other hand, are termed **false** or **fixed** vertebræ, because they are united with one another in the adult to form two bones—five forming the upper bone or **sacrum,** and four the terminal bone or **coccyx.** 4

With the exception of the first and second cervical, the true or movable vertebræ present certain common characteristics which are best studied by examining one from the middle of the thoracic region. 5

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

3a. General Characteristics of a Vertebra

A **typical vertebra** consists of two essential parts—viz., an anterior segment, the **body,** and a posterior part, the **vertebral** or **neural arch;** these enclose a foramen, the **vertebral foramen.** The vertebral arch consists of a pair of **pedicles** and a pair of **laminæ,** and supports **seven processes**—viz., four **articular,** two **transverse,** and one **spinous.** 1

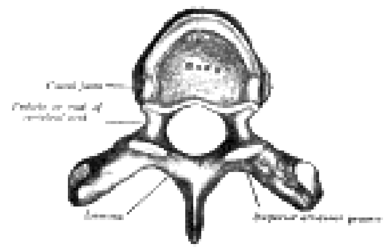

FIG. 82– A typical thoracic vertebra, viewed from above. (See enlarged image)

When the vertebræ are articulated with each other the bodies form a strong pillar for the support of the head and trunk, and the vertebral foramina constitute a canal for the protection of the medulla spinalis (*spinal cord*), while between every pair of vertebræ are two apertures, the **intervertebral foramina,** one on either side, for the transmission of the spinal nerves and vessels. 2

Body (*corpus vertebræ*).—The body is the largest part of a vertebra, and is more or less cylindrical in shape. Its upper and lower surfaces are flattened and rough, and give attachment to the intervertebral fibrocartilages, and each presents a rim around its circumference. In front, the body is convex from side to side and concave from above downward. Behind, it is flat from above downward and slightly concave from side to side. Its anterior surface presents a few small apertures, for the passage of nutrient vessels; on the posterior surface is a single large, irregular aperture, or occasionally more than one, for the exit of the basi-vertebral veins from the body of the vertebra. 3

Pedicles (*radices arci vertebræ*).—The pedicles are two short, thick processes, which project backward, one on either side, from the upper part of the body, at the junction of its posterior and lateral surfaces. The concavities above and below the pedicles are named the **vertebral notches;** and when the vertebræ are articulated, the notches of each contiguous pair of bones form the intervertebral foramina, already referred to. 4

Laminæ.—The laminæ are two broad plates directed backward and medialward from the pedicles. They fuse in the middle line posteriorly, and so complete the posterior boundary of the vertebral foramen. Their upper borders and the lower parts of their anterior surfaces are rough for the attachment of the ligamenta flava. 5

Processes.—Spinous Process (*processus spinosus*).—The spinous process is directed backward and downward from the junction of the laminæ, and serves for the attachment of muscles and ligaments. 6

Articular Processes.—The articular processes, two superior and two inferior, spring from the junctions of the pedicles and laminæ. The superior project upward, and their articular surfaces are directed more or less backward; the inferior project downward, and their surfaces look more or less forward. The articular surfaces are coated with hyaline cartilage. 7

Transverse Processes (*processus transversi*).—The transverse processes, two in number, project one at either side from the point where the lamina joins the pedicle, between the superior and inferior articular processes. They serve for the attachment of muscles and ligaments. 8

Structure of a Vertebra (Fig. 83).—The body is composed of cancellous tissue, covered by a thin coating of compact bone; the latter is perforated by numerous orifices, some of large size for the passage of vessels; the interior of the bone is traversed by one or two large canals, for the reception of veins, which converge toward a single large, irregular aperture, or several small apertures, at the posterior part of the body. The thin bony lamellæ of the cancellous tissue are more pronounced in lines perpendicular to the upper and lower surfaces and are developed in response to greater pressure in this direction (Fig. 83). The arch and processes projecting from it have thick coverings of compact tissue. 9

FIG. 83– Sagittal section of a lumbar vertebra. (See enlarged image)

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

3a. 1. The Cervical Vertebræ

(Vertebræ Cervicales). 1

cervical vertebræ (Fig. 84) are the smallest of the true vertebræ, and can be readily distinguished from those of the thoracic or lumbar regions by the presence of a foramen in each transverse process. The first, second, and seventh present exceptional features and must be separately described; the following characteristics are common to the remaining four.

The **body** is small, and broader from side to side than from before backward. The **anterior and posterior surfaces** are flattened and of equal depth; the former is placed on a lower level than the latter, and its inferior border is prolonged downward, so as to overlap the upper and forepart of the vertebra below. The **upper surface** is concave transversely, and presents a projecting lip on either side; the **lower surface** is concave from before backward, convex from side to side, and presents laterally shallow concavities which receive the corresponding projecting lips of the subjacent vertebra. The **pedicles** are directed lateralward and backward, and are attached to the body midway between its upper and lower borders, so that the superior vertebral notch is as deep as the inferior, but it is, at the same time, narrower. The **laminæ** are narrow, and thinner above than below; the **vertebral foramen** is large, and of a triangular form. The **spinous process** is short and bifid, the two divisions being often of unequal size. The **superior** and **inferior articular processes** on either side are fused to form an articular pillar, which projects lateralward from the junction of the pedicle and lamina. The articular facets are flat and of an oval form: the superior look backward, upward, and slightly medialward: the inferior forward, downward, and slightly lateralward. The **transverse processes** are each pierced by the **foramen transversarium,** which, in the upper six vertebræ, gives passage to the vertebral artery and vein and a plexus of sympathetic nerves. Each process consists of an anterior and a posterior part. The **anterior** portion is the homologue of the rib in the thoracic region, and is therefore named the **costal process** or **costal element:** it arises from the side of the body, is directed lateralward in front of the foramen, and ends in a tubercle, the **anterior tubercle.** The **posterior** part, the true transverse process, springs from the vertebral arch behind the foramen, and is directed forward and lateralward; it ends in a flattened vertical tubercle, the **posterior tubercle.** These two parts are joined, outside the foramen, by a bar of bone which exhibits a deep sulcus on its upper surface for the passage of the corresponding spinal nerve. 15 2

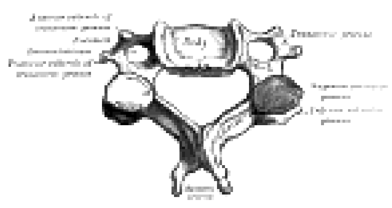

FIG. 84– A cervical vertebra. (See enlarged image)

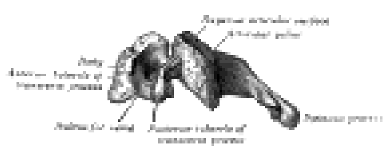

FIG. 85– Side view of a typical cervical vertebra. (See enlarged image)

First Cervical Vertebra.—The first cervical vertebra (Fig. 86) is named the **atlas** because it supports the globe of the head. Its chief peculiarity is that it has no body, and this is due to the fact that the body of the atlas has fused with that of the next vertebra. Its other peculiarities are that it has no spinous process, is ring-like, and consists of an anterior and a posterior arch and two lateral masses. The **anterior arch** forms about one-fifth of the ring: its anterior surface is convex, and presents at its center the **anterior tubercle** for the attachment of the Longus colli muscles; posteriorly it is concave, and marked by a smooth, oval or circular facet (*fovea dentis*), for articulation with the odontoid process (*dens*) of the axis. The upper and lower borders respectively give attachment to the anterior atlantooccipital membrane and the anterior atlantoaxial ligament; the former connects it with the occipital bone above, and the latter with the axis below. The **posterior arch** forms about two-fifths of the circumference of the ring: it ends behind in the **posterior tubercle,** which is the rudiment of a spinous process and gives origin to the Recti capitis posteriores minores. The diminutive size of this process prevents any interference with the movements between the atlas and the skull. The posterior part of the arch presents above and behind a rounded edge for the attachment of the posterior atlantoöccipital membrane, while immediately behind each superior articular process is a groove (*sulcus arteriæ vertebralis*), sometimes converted into a foramen by a delicate bony spiculum which arches backward from the posterior end of the superior articular process. This groove represents the superior vertebral notch, and serves for the transmission of the vertebral artery, which, after ascending through the foramen in the transverse process, winds around the lateral mass in a direction backward and medialward; it also transmits the suboccipital (first spinal) nerve. On the under surface of the posterior arch, behind the articular facets, are two shallow grooves, the **inferior vertebral notches.** The lower border gives attachment to the posterior atlantoaxial ligament, which connects it with the axis. The **lateral masses** are the most bulky and solid parts of the atlas, in order to support the weight of the head. Each carries two articular facets, a superior and an inferior. The **superior facets** are of large size, oval, concave, and approach each other in front, but diverge behind: they are directed upward, medialward, and a little backward, each forming a cup for the corresponding condyle of the occipital bone, and are admirably adapted to the nodding movements of the head. Not infrequently they are partially subdivided by indentations which encroach upon their margins. The **inferior articular facets** are circular in form, flattened or slightly convex and directed downward and medialward, articulating with the axis, and permitting the rotatory movements of the head. Just below the medial margin of each superior facet is a small tubercle, for the attachment of the transverse atlantal ligament which stretches across the ring of the atlas and divides the vertebral foramen into two unequal parts—the anterior or smaller receiving the odontoid process of the axis, the posterior transmitting the medulla spinalis and its membranes. This part of the vertebral canal is of considerable size, much greater than is required for the accommodation of the medulla spinalis, and hence lateral displacement of the atlas may occur without compression of this structure. The **transverse processes** are large; they project lateralward and downward from the lateral masses, and serve for the attachment of muscles which assist in rotating the head. They are long, and their anterior and posterior tubercles are fused into one mass; the foramen transversarium is directed from below, upward and backward. 3

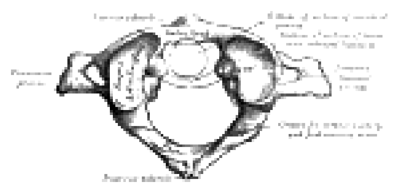

FIG. 86– First cervical vertebra, or atlas. (See enlarged image)

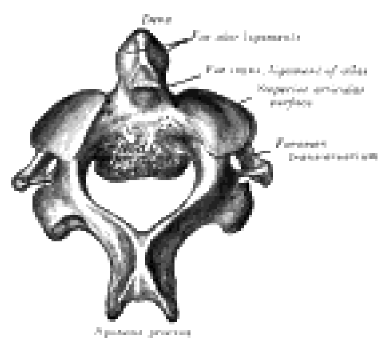

FIG. 87– Second cervical vertebra, or epistropheus, from above. (See enlarged image)

Second Cervical Vertebra.—The second cervical vertebra (Fig. 87 and 88) is named the **epistropheus** or **axis** because it forms the pivot upon which the first vertebra, carrying the head, rotates. The most distinctive characteristic of this bone is the strong odontoid process which rises perpendicularly from the upper surface of the body. The **body** is deeper in front than behind, and prolonged downward anteriorly so as to overlap the upper and fore part of the third vertebra. It presents in front a median longitudinal ridge, separating two lateral depressions for the attachment of the Longus colli muscles. Its under surface is concave from before backward and covex from side to side. The **dens** or **odontoid process** exhibits a slight constriction or neck, where it joins the body. On its anterior surface is an oval or nearly circular facet for articulation with that on the anterior arch of the atlas. On the back of the neck, and frequently extending on to its lateral surfaces, is a shallow groove for the transverse atlantal ligament which retains the process in position. The **apex** is pointed, and gives attachment to the apical odontoid ligament; below the apex the process is somewhat enlarged, and presents on either side a rough impression for the attachment of the alar ligament; these ligaments connect the process to the occipital bone. The internal structure of the odontoid process is more compact than that of the body. The **pedicles** are broad and strong, especially in front, where they coalesce with the sides of the body and the root of the odontoid process. They are covered above by the superior articular surfaces. The **laminæ** are thick and strong, and the vertebral foramen large, but smaller than that of the atlas. The **transverse processes** are very small, and each ends in a single tubercle; each is perforated by the foramen transversarium, which is directed obliquely upward and lateralward. The **superior articular surfaces** are round, slightly convex, directed upward and lateralward, and are supported on the body, pedicles, and transverse processes. The **inferior articular surfaces** have the same direction as those of the other cervical vertebræ. The **superior vertebral notches** are very shallow, and lie behind the articular processes; the **inferior** lie in front of the articular processes, as in the other cervical vertebræ. The **spinous process** is large, very strong, deeply channelled on its under surface, and presents a bifid, tuberculated extremity. 4

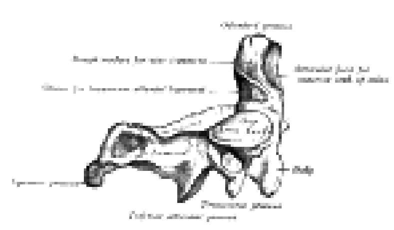

FIG. 88– Second cervical vertebra, epistropheus, or axis, from the side. (See enlarged image)

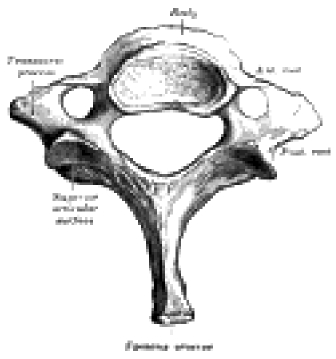

FIG. 89– Seventh cervical vertebra. (See enlarged image)

The Seventh Cervical Vertebra (Fig. 89).—The most distinctive characteristic of this vertebra is the existence of a long and prominent spinous process, hence the name **vertebra prominens.** This process is thick, nearly horizontal in direction, not bifurcated, but terminating in a tubercle to which the lower end of the ligamentum nuchæ is attached. The **transverse processes** are of considerable size, their posterior roots are large and prominent, while the anterior are small and faintly marked; the upper surface of each has usually a shallow sulcus for the eighth spinal nerve, and its extremity seldom presents more than a trace of bifurcation. The foramen transversarium may be as large as that in the other cervical vertebræ, but is generally smaller on one or both sides; occasionally it is double, sometimes it is absent. On the left side it occasionally gives passage to the vertebral artery; more frequently the vertebral vein traverses it on both sides; but the usual arrangement is for both artery and vein to pass in front of the transverse process, and not through the foramen. Sometimes the anterior root of the transverse process attains a large size and exists as a separate bone, which is known as a **cervical rib.** 5

Note 15. The *costal element* of a cervical vertebra not only includes the portion which springs from the side of the body, but the anterior and posterior tubercles and the bar of bone which connects them (Fig. 67). [back]

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

3a. 2. The Thoracic Vertebræ

(Vertebræ Thoracales). 1

The **thoracic vertebræ** (Fig. 90) are intermediate in size between those of the cervical and lumbar regions; they increase in size from above downward, the upper vertebræ being much smaller than those in the lower part of the region. They are distinguished by the presence of facets on the sides of the bodies for articulation with the heads of the ribs, and facets on the transverse processes of all, except the eleventh and twelfth, for articulation with the tubercles of the ribs.

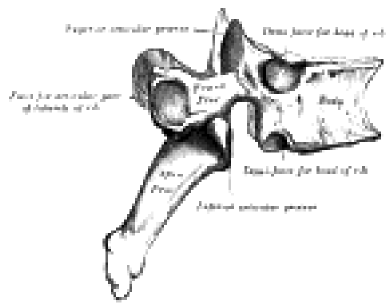

Fig. 90– A thoracic vertebra. (See enlarged image)

The **bodies** in the middle of the thoracic region are heart-shaped, and as broad in the antero-posterior as in the transverse direction. At the ends of the thoracic region they resemble respectively those of the cervical and lumbar vertebræ. They are slightly thicker behind than in front, flat above and below, convex from side to side in front, deeply concave behind, and slightly constricted laterally and in front. They present, on either side, two costal demi-facets, one above, near the root of the pedicle, the other below, in front of the inferior vertebral notch; these are covered with cartilage in the fresh state, and, when the vertebræ are articulated with one another, form, with the intervening intervertebral fibrocartilages, oval surfaces for the reception of the heads of the ribs. The **pedicles** are directed backward and slightly upward, and the inferior vertebral notches are of large size, and deeper than in any other region of the vertebral column. The **laminæ** are broad, thick, and imbricated—that is to say, they overlap those of subjacent vertebræ like tiles on a roof. The **vertebral foramen** is small, and of a circular form. The **spinous process** is long, triangular on coronal section, directed obliquely downward, and ends in a tuberculated extremity. These processes overlap from the fifth to the eighth, but are less oblique in direction above and below. The **superior articular processes** are thin plates of bone projecting upward from the junctions of the pedicles and laminæ; their articular facets are practically flat, and are directed backward and a little lateralward and upward. The **inferior articular processes** are fused to a considerable extent with the laminæ, and project but slightly beyond their lower borders; their facets are directed forward and a little medialward and downward. The **transverse processes** arise from the arch behind the superior articular processes and pedicles; they are thick, strong, and of considerable length, directed obliquely backward and lateralward, and each ends in a clubbed extremity, on the front of which is a small, concave surface, for articulation with the tubercle of a rib. The *first, ninth, tenth, eleventh,* and *twelfth* thoracic vertebræ present certain peculiarities, and must be specially considered (Fig. 91). 2

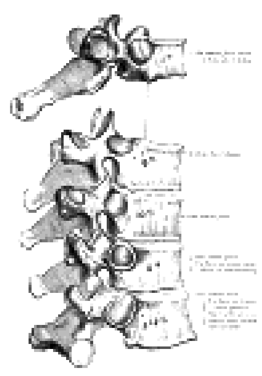

Fig. 91– Peculiar thoracic vertebræ. (See enlarged image)

The **First Thoracic Vertebra** has, on either side of the **body,** an entire articular facet for the head of the first rib, and a demi-facet for the upper half of the head of the second rib. The body is like that of a cervical vertebra, being broad transversely; its upper surface is concave, and lipped on either side. The **superior articular surfaces** are directed upward and backward; the **spinous process** is thick, long, and almost horizontal. The **transverse processes** are long, and the upper vertebral notches are deeper than those of the other thoracic vertebræ. 3

The **Ninth Thoracic Vertebra** may have no demi-facets below. In some subjects however, it has two demi-facets on either side; when this occurs the tenth has only demi-facets at the upper part. 4

The **Tenth Thoracic Vertebra** has (except in the cases just mentioned) an entire articular facet on either side, which is placed partly on the lateral surface of the pedicle. 5

In the **Eleventh Thoracic Vertebra** the **body** approaches in its form and size to that of the lumbar vertebræ. The articular facets for the heads of the ribs are of large size, and placed chiefly on the pedicles, which are thicker and stronger in this and the next vertebra than in any other part of the thoracic region. The **spinous process** is short, and nearly horizontal in direction. The **transverse processes** are very short, tuberculated at their extremities, and have no articular facets. 6

The **Twelfth Thoracic Vertebra** has the same general characteristics as the eleventh, but may be distinguished from it by its inferior articular surfaces being convex and directed lateralward, like those of the lumbar vertebræ; by the general form of the body, laminæ, and spinous process, in which it resembles the lumbar vertebræ; and by each transverse process being subdivided into three elevations, the superior, inferior, and lateral tubercles: the superior and inferior correspond to the mammillary and accessory processes of the lumbar vertebræ. Traces of similar elevations are found on the transverse processes of the tenth and eleventh thoracic vertebræ. 7

FIG. 92– A lumbar vertebra seen from the side. (See enlarged image)

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

3a. 3. The Lumbar Vertebræ

(Vertebræ Lumbales). 1

The **lumbar vertebræ** (Figs. 92 and 93) are the largest segments of the movable part of the vertebral column, and can be distinguished by the absence of a foramen in the transverse process, and by the absence of facets on the sides of the body.

The **body** is large, wider from side to side than from before backward, and a little thicker in front than behind. It is flattened or slightly concave above and below, concave behind, and deeply constricted in front and at the sides. The **pedicles** are very strong, directed backward from the upper part of the body; consequently, the inferior vertebral notches are of considerable depth. The **laminæ** are broad, short, and strong; the **vertebral foramen** is triangular, larger than in the thoracic, but smaller than in the cervical region. The **spinous process** is thick, broad, and somewhat quadrilateral; it projects backward and ends in a rough, uneven border, thickest below where it is occasionally notched. The **superior** and **inferior articular processes** are well-defined, projecting respectively upward and downward from the junctions of pedicles and laminæ. The facets on the superior processes are concave, and look backward and medialward; those on the inferior are convex, and are directed forward and lateralward. The former are wider apart than the latter, since in the articulated column the inferior articular processes are embraced by the superior processes of the subjacent vertebra. The **transverse processes** are long, slender, and horizontal in the upper three lumbar vertebræ; they incline a little upward in the lower two. In the upper three vertebræ they arise from the junctions of the pedicles and laminæ, but in the lower two they are set farther forward and spring from the pedicles and posterior parts of the bodies. They are situated in front of the articular processes instead of behind them as in the thoracic vertebræ, and are homologous with the ribs. Of the three tubercles noticed in connection with the transverse processes of the lower thoracic vertebræ, the superior one is connected in the lumbar region with the back part of the superior articular process, and is named the **mammillary process;** the inferior is situated at the back part of the base of the transverse process, and is called the **accessory process** (Fig. 93). 2

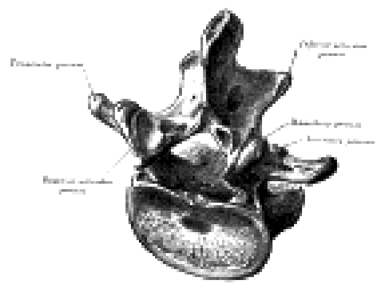

FIG. 93– A lumbar vertebra from above and behind. (See enlarged image)

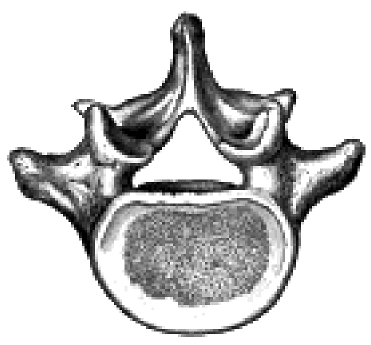

FIG. 94– Fifth lumbar vertebra, from above. (See enlarged image)

The **Fifth Lumbar Vertebra** (Fig. 94) is characterized by its body being much deeper in front than behind, which accords with the prominence of the sacrovertebral articulation; by the smaller size of its spinous process; by the wide interval between the inferior articular processes; and by the thickness of its transverse processes, which spring from the body as well as from the pedicles. 3

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

3a. 4. The Sacral and Coccygeal Vertebræ

The **sacral** and **coccygeal vertebræ** consist at an early period of life of nine separate segments which are united in the adult, so as to form two bones, five entering into the formation of the sacrum, four into that of the coccyx. Sometimes the coccyx consists of five bones; occasionally the number is reduced to three. 1

The Sacrum (*os sacrum*).—The sacrum is a large, triangular bone, situated in the lower part of the vertebral column and at the upper and back part of the pelvic cavity, where it is inserted like a wedge between the two hip bones; its upper part or base articulates with the last lumbar vertebra, its apex with the coccyx. It is curved upon itself and placed very obliquely, its base projecting forward and forming the **prominent sacrovertebral angle** when articulated with the last lumbar vertebra; its central part is projected backward, so as to give increased capacity to the pelvic cavity. 2

Pelvic Surface (*facies pelvina*).—The pelvic surface (Fig. 95) is concave from above downward, and slightly so from side to side. Its middle part is crossed by four **transverse ridges,** the positions of which correspond with the original planes of separation between the five segments of the bone. The portions of bone intervening between the ridges are the bodies of the sacral vertebræ. The body of the first segment is of large size, and in form resembles that of a lumbar vertebra; the succeeding ones diminish from above downward, are flattened from before backward, and curved so as to accommodate themselves to the form of the sacrum, being concave in front, convex behind. At the ends of the ridges are seen the **anterior sacral foramina,** four in number on either side, somewhat rounded in form, diminishing in size from above downward, and directed lateralward and forward; they give exit to the anterior divisions of the sacral nerves and entrance to the lateral sacral arteries. Lateral to these foramina are the **lateral parts of the sacrum,** each consisting of five separate segments at an early period of life; in the adult, these are blended with the bodies and with each other. Each lateral part is traversed by four broad, shallow grooves, which lodge the anterior divisions of the sacral nerves, and are separated by prominent ridges of bone which give origin to the Piriformis muscle. 3

If a sagittal section be made through the center of the sacrum (Fig. 99), the bodies are seen to be united at their circumferences by bone, wide intervals being left centrally, which, in the fresh state, are filled by the intervertebral fibrocartilages. In some bones this union is more complete between the lower than the upper segments. 4

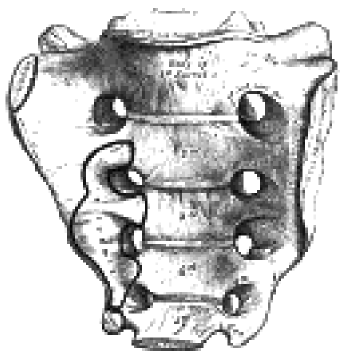

FIG. 95– Sacrum, pelvic surface. (See enlarged image)

Dorsal Surface (*facies dorsalis*).—The dorsal surface (Fig. 96) is convex and narrower than the pelvic. In the middle line it displays a crest, the **middle sacral crest,** surmounted by three or four tubercles, the rudimentary spinous processes of the upper three or four sacral vertebræ. On either side of the middle sacral crest is a shallow groove, the **sacral groove,** which gives origin to the Multifidus, the floor of the groove being formed by the united laminæ of the corresponding vertebræ. The laminæ of the fifth sacral vertebra, and sometimes those of the fourth, fail to meet behind, and thus a hiatus or deficiency occurs in the posterior wall of the sacral canal. On the lateral aspect of the sacral groove is a linear series of tubercles produced by the fusion of the articular processes which together form the indistinct **sacral articular crests.** The articular processes of the first sacral vertebra are large and oval in shape; their facets are concave from side to side, look backward and medialward, and articulate with the facets on the inferior processes of the fifth lumbar vertebra. The tubercles which represent the inferior articular processes of the fifth sacral vertebra are prolonged downward as rounded processes, which are named the **sacral cornua,** and are connected to the cornua of the coccyx. Lateral to the articular processes are the four **posterior sacral foramina;** they are smaller in size and less regular in form than the anterior, and transmit the posterior divisions of the sacral nerves. On the lateral side of the posterior sacral foramina is a series of tubercles, which represent the transverse processes of the sacral vertebræ, and form the **lateral crests** of the sacrum. The transverse tubercles of the first sacral vertebra are large and very distinct; they, together with the transverse tubercles of the second vertebra, give attachment to the horizontal parts of the posterior sacroiliac ligaments; those of the third vertebra give attachment to the oblique fasciculi of the posterior sacroiliac ligaments; and those of the fourth and fifth to the sacrotuberous ligaments. 5

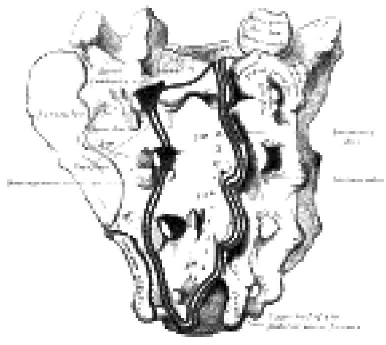

FIG. 96– Sacrum, dorsal surface. (See enlarged image)

Lateral Surface.—The lateral surface is broad above, but narrowed into a thin edge below. The upper half presents in front an ear-shaped surface, the **auricular surface,** covered with cartilage in the fresh state, for articulation with the ilium. Behind it is a rough surface, the **sacral tuberosity,** on which are three deep and uneven impressions, for the attachment of the posterior sacroiliac ligament. The lower half is thin, and ends in a projection called the **inferior lateral angle;** medial to this angle is a notch, which is converted into a foramen by the transverse process of the first piece of the coccyx, and transmits the anterior division of the fifth sacral nerve. The thin lower half of the lateral surface gives attachment to the sacrotuberous and sacrospinous ligaments, to some fibers of the Glutæus maximus behind, and to the Coccygeus in front. 6

FIG. 97– Lateral surfaces of sacrum and coccyx. (See enlarged image)

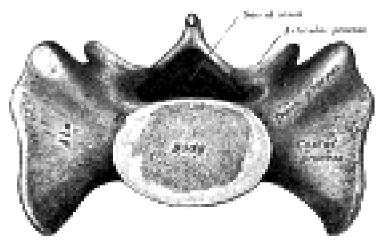

FIG. 98– Base of sacrum. (See enlarged image)

Base (*basis oss. sacri*).—The base of the sacrum, which is broad and expanded, is directed upward and forward. In the middle is a large oval articular surface, the upper surface of the body of the first sacral vertebra, which is connected with the under surface of the body of the last lumbar vertebra by an intervertebral fibrocartilage. Behind this is the large triangular orifice of the sacral canal, which is completed by the laminæ and spinous process of the first sacral vertebra. The superior articular processes project from it on either side; they are oval, concave, directed backward and medialward, like the superior articular processes of a lumbar vertebra. They are attached to the body of the first sacral vertebra and to the alæ by short thick pedicles; on the upper surface of each pedicle is a vertebral notch, which forms the lower part of the foramen between the last lumbar and first sacral vertebræ. On either side of the body is a large triangular surface, which supports the Psoas major and the lumbosacral trunk, and in the articulated pelvis is continuous with the iliac fossa. This is called the **ala;** it is slightly concave from side to side, convex from before backward, and gives attachment to a few of the fibers of the Iliacus. The posterior fourth of the ala represents the transverse process, and its anterior three-fourths the costal process of the first sacral segment. 7

FIG. 99– Median sagittal section of the sacrum. (See enlarged image)

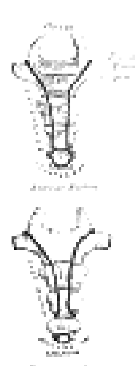

FIG. 100– Coccyx. (See enlarged image)

Apex (*apex oss. sacri*).—The apex is directed downward, and presents an oval facet for articulation with the coccyx. 8

Vertebral Canal (*canalis sacralis; sacral canal*).—The vertebral canal (Fig. 99) runs throughout the greater part of the bone; above, it is triangular in form; below, its posterior wall is incomplete, from the non-development of the laminæ and spinous processes. It lodges the sacral nerves, and its walls are perforated by the anterior and posterior sacral foramina through which these nerves pass out. 9

Structure.—The sacrum consists of cancellous tissue enveloped by a thin layer of compact bone. 10

Articulations.—The sacrum articulates with *four* bones; the last lumbar vertebra above, the coccyx below, and the hip bone on either side. 11

Differences in the Sacrum of the Male and Female.—In the female the sacrum is shorter and wider than in the male; the lower half forms a greater angle with the upper; the upper half is nearly straight, the lower half presenting the greatest amount of curvature. The bone is also directed more obliquely backward; this increases the size of the pelvic cavity and renders the sacrovertebral angle more prominent. In the male the curvature is more evenly distributed over the whole length of the bone, and is altogether greater than in the female. 12

Variations.—The sacrum, in some cases, consists of six pieces; occasionally the number is reduced to four. The bodies of the first and second vertebræ may fail to unite. Sometimes the uppermost transverse tubercles are not joined to the rest of the ala on one or both sides, or the sacral canal may be open throughout a considerable part of its length, in consequence of the imperfect development of the laminæ and spinous processes. The sacrum, also, varies considerably with respect to its degree of curvature. 13

The Coccyx (*os coccygis*).—The coccyx (Fig. 100) is usually formed of four rudimentary vertebræ; the number may however be increased to five or diminished to three. In each of the first three segments may be traced a rudimentary body and articular and transverse processes; the last piece (sometimes the third) is a mere nodule of bone. All the segments are destitute of pedicles, laminæ, and spinous processes. The first is the largest; it resembles the lowest sacral vertebra, and often exists as a separate piece; the last three diminish in size from above downward, and are usually fused with one another. 14

Surfaces.—The **anterior surface** is slightly concave, and marked with three transverse grooves which indicate the junctions of the different segments. It gives attachment to the anterior sacrococcygeal ligament and the Levatores ani, and supports part of the rectum. The **posterior surface** is convex, marked by transverse grooves similar to those on the anterior surface, and presents on either side a linear row of tubercles, the rudimentary articular processes of the coccygeal vertebræ. Of these, the superior pair are large, and are called the **coccygeal cornua;** they project upward, and articulate with the cornua of the sacrum, and on either side complete the foramen for the transmission of the posterior division of the fifth sacral nerve. 15

Borders.—The **lateral borders** are thin, and exhibit a series of small eminences, which represent the transverse processes of the coccygeal vertebræ. Of these, the first is the largest; it is flattened from before backward, and often ascends to join the lower part of the thin lateral edge of the sacrum, thus completing the foramen for the transmission of the anterior division of the fifth sacral nerve; the others diminish in size from above downward, and are often wanting. The borders of the coccyx are narrow, and give attachment on either side to the sacrotuberous and sacrospinous ligaments, to the Coccygeus in front of the ligaments, and to the Glutæus maximus behind them. 16

Base.—The base presents an oval surface for articulation with the sacrum. 17

Apex.—The apex is rounded, and has attached to it the tendon of the Sphincter ani externus. It may be bifid, and is sometimes deflected to one or other side. 18

Ossification of the Vertebral Column.—Each cartilaginous vertebra is ossified from three primary centers (Fig. 101), two for the vertebral arch and one for the body. 16 Ossification of the vertebral arches begins in the upper cervical vertebræ about the seventh or eighth week of fetal life, and gradually extends down the column. The ossific granules first appear in the situations where the transverse processes afterward project, and spread backward to the spinous process forward into the pedicles, and lateralward into the transverse and articular processes. Ossification of the bodies begins about the eighth week in the lower thoracic region, and subsequently extends upward and downward along the column. The center for the body does not give rise to the whole of the body of the adult vertebra, the postero-lateral portions of which are ossified by extensions from the vertebral arch centers. The body of the vertebra during the first few years of life shows, therefore, two synchondroses, **neurocentral synchondroses,** traversing it along the planes of junction of the three centers (Fig. 102). In the thoracic region, the facets for the heads of the ribs lie behind the neurocentral synchondroses and are ossified from the centers for the vertebral arch. At birth the vertebra consists of three pieces, the body and the halves of the vertebral arch. During the first year the halves of the arch unite behind, union taking place first in the lumbar region and then extending upward through the thoracic and cervical regions. About the third year the bodies of the upper cervical vertebræ are joined to the arches on either side; in the lower lumbar vertebræ the union is not completed until the sixth year. Before puberty, no other changes occur, excepting a gradual increase of these primary centers, the upper and under surfaces of the bodies and the ends of the transverse and spinous processes being cartilaginous. About the sixteenth year (Fig. 102), five secondary centers appear, one for the tip of each transverse process, one for the extremity of the spinous process, one for the upper and one for the lower surface of the body (Fig. 103). These fuse with the rest of the bone about the age of twenty-five. 19

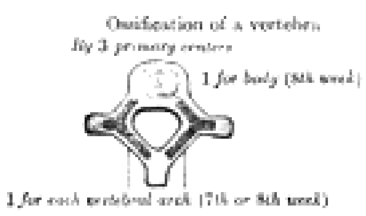

FIG. 101– Ossification of a vertebra (See enlarged image)

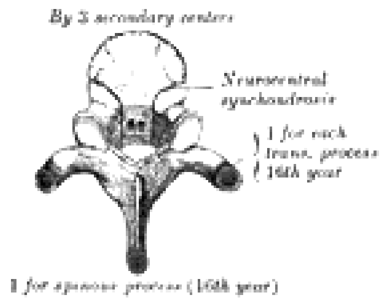

FIG. 102– No caption. (See enlarged image)

FIG. 103– No caption. (See enlarged image)

FIG. 104– Atlas. (See enlarged image)

FIG. 105– Axis. (See enlarged image)

FIG. 106– Lumbar vertebra. (See enlarged image)

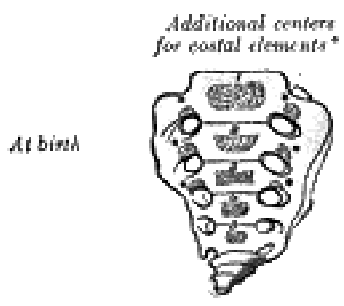

FIG. 107– No caption. (See enlarged image)

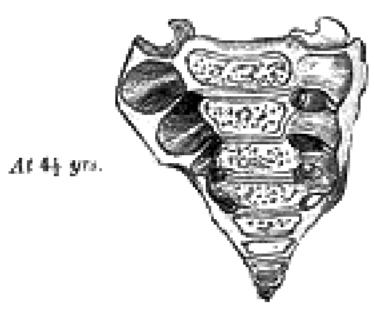

FIG. 108– No caption. (See enlarged image)

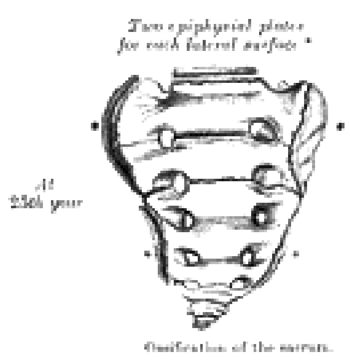

FIG. 109– Ossification of the sacrum. (See enlarged image)

Exceptions to this mode of development occur in the first, second, and seventh cervical vertebræ, and in the lumbar vertebræ. 20

Atlas.—The atlas is usually ossified from *three* centers (Fig. 104). Of these, one appears in each lateral mass about the seventh week of fetal life, and extends backward; at birth, these portions of bone are separated from one another behind by a narrow interval filled with cartilage. Between the third and fourth years they unite either directly or through the medium of a separate center developed in the cartilage. At birth, the anterior arch consists of cartilage; in this a separate center appears about the end of the first year after birth, and joins the lateral masses from the sixth to the eighth year—the lines of union extending across the anterior portions of the superior articular facets. Occasionally there is no separate center, the anterior arch being formed by the forward extension and ultimate junction of the two lateral masses; sometimes this arch is ossified from two centers, one on either side of the middle line. 21

Epistropheus or Axis.—The axis is ossified from *five* primary and *two* secondary centers (Fig. 105). The body and vertebral arch are ossified in the same manner as the corresponding parts in the other vertebræ, viz., one center for the body, and two for the vertebral arch. The centers for the arch appear about the seventh or eighth week of fetal life, that for the body about the fourth or fifth month. The dens or odontoid process consists originally of a continuation upward of the cartilaginous mass, in which the lower part of the body is formed. About the sixth month of fetal life, two centers make their appearance in the base of this process: they are placed laterally, and join before birth to form a conical bilobed mass deeply cleft above; the interval between the sides of the cleft and the summit of the process is formed by a wedge-shaped piece of cartilage. The base of the process is separated from the body by a cartilaginous disk, which gradually becomes ossified at its circumference, but remains cartilaginous in its center until advanced age. In this cartilage, rudiments of the lower epiphysial lamella of the atlas and the upper epiphysial lamella of the axis may sometimes be found. The apex of the odontoid process has a separate center which appears in the second and joins about the twelfth year; this is the upper epiphysial lamella of the atlas. In addition to these there is a secondary center for a thin epiphysial plate on the under surface of the body of the bone. 22

The Seventh Cervical Vertebra.—The anterior or costal part of the transverse process of this vertebra is sometimes ossified from a separate center which appears about the sixth month of fetal life, and joins the body and posterior part of the transverse process between the fifth and sixth years. Occasionally the costal part persists as a separate piece, and, becoming lengthened lateralward and forward, constitutes what is known as a *cervical rib.* Separate ossific centers have also been found in the costal processes of the fourth, fifth, and sixth cervical vertebræ. 23

Lumbar Vertebræ.—The lumbar vertebræ (Fig. 106) have each *two* additional centers, for the mammillary processes. The transverse process of the first lumbar is sometimes developed as a separate piece, which may remain permanently ununited with the rest of the bone, thus forming a lumbar rib—a peculiarity, however, rarely met with. 24

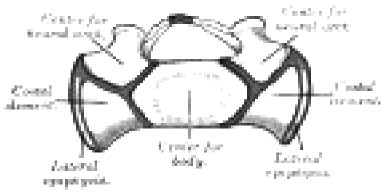

FIG. 110– Base of young sacrum. (See enlarged image)

Sacrum (Figs. 107 to 110).—The *body* of each sacral vertebra is ossified from a primary center and *two* epiphysial plates, one for its upper and another for its under surface, while each vertebral arch is ossified from two centers. 25

The anterior portions of the *lateral parts* have *six* additional centers, two for each of the first three vertebræ; these represent the costal elements, and make their appearance above and lateral to the anterior sacral foramina (Figs. 107, 108). 26

On each *lateral surface* two epiphysial plates are developed (Figs. 109, 110): one for the auricular surface, and another for the remaining part of the thin lateral edge of the bone. 17 27

PERIODS OF OSSIFICATION.—About the eighth or ninth week of fetal life, ossification of the central part of the body of the first sacral vertebra commences, and is rapidly followed by deposit of ossific matter in the second and third; ossification does not commence in the bodies of the lower two segments until between the fifth and eighth months of fetal life. Between the sixth and eighth months ossification of the vertebral arches takes place; and about the same time the costal centers for the lateral parts make their appearance. The junctions of the vertebral arches with the bodies take place in the lower vertebræ as early as the second year, but are not effected in the uppermost until the fifth or sixth year. About the sixteenth year the epiphysial plates for the upper and under surfaces of the bodies are formed; and between the eighteenth and twentieth years, those for the lateral surfaces make their appearance. The bodies of the sacral vertebræ are, during early life, separated from each other by intervertebral fibrocartilages, but about the eighteenth year the two lowest segments become united by bone, and the process of bony union gradually extends upward, with the result that between the twenty-fifth and thirtieth years of life all the segments are united. On examining a sagittal section of the sacrum, the situations of the intervertebral fibrocartilages are indicated by a series of oval cavities (Fig. 99). 28

Coccyx.—The coccyx is ossified from *four* centers, one for each segment. The ossific nuclei make their appearance in the following order: in the first segment between the first and fourth years; in the second between the fifth and tenth years; in the third between the tenth and fifteenth years; in the fourth between the fourteenth and twentieth years. As age advances, the segments unite with one another, the union between the first and second segments being frequently delayed until after the age of twenty-five or thirty. At a late period of life, especially in females, the coccyx often fuses with the sacrum. 29

Note 16. A vertebra is occasionally found in which the body consists of two lateral portions—a condition which proves that the body is sometimes ossified from *two* primary centers, one on either side of the middle line. [back]

Note 17. The ends of the spinous processes of the upper three sacral vertebræ are sometimes developed from separate epiphyses, and Fawcett (Anatomischer Anzeiger, 1907, Band xxx) states that a number of epiphysial nodules may be seen in the sacrum at the age of eighteen years. These are distributed as follows: One for each of the mammillary processes of the first sacral vertebra; twelve—six on either side—in connection with the costal elements (two each for the first and second and one each for the third and fourth) and eight for the transverse processes—four on either side—one each for the first, third, fourth, and fifth. He is further of opinion that the lower part of each lateral surface of the sacrum is formed by the extension and union of the third and fourth "costal" and fourth and fifth "transverse" epiphyses. [back]

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

3b. The Vertebral Column as a Whole

The vertebral column is situated in the median line, as the posterior part of the trunk; its average length in the male is about 71 cm. Of this length the cervical part measures 12.5 cm., the thoracic about 28 cm., the lumbar 18 cm., and the sacrum and coccyx 12.5 cm. The female column is about 61 cm. in length. *1*

Curves.—Viewed laterally (Fig. 111), the vertebral column presents several curves, which correspond to the different regions of the column, and are called cervical, thoracic, lumbar, and pelvic. The **cervical** curve, convex forward, begins at the apex of the odontoid process, and ends at the middle of the second thoracic vertebra; it is the least marked of all the curves. The **thoracic** curve, concave forward, begins at the middle of the second and ends at the middle of the twelfth thoracic vertebra. Its most prominent point behind corresponds to the spinous process of the seventh thoracic vertebra. The **lumbar** curve is more marked in the female than in the male; it begins at the middle of the last thoracic vertebra, and ends at the sacrovertebral angle. It is convex anteriorly, the convexity of the lower three vertebræ being much greater than that of the upper two. The **pelvic** curve begins at the sacrovertebral articulation, and ends at the point of the coccyx; its concavity is directed downward and forward. The thoracic and pelvic curves are termed primary curves, because they alone are present during fetal life. The cervical and lumbar curves are compensatory or secondary, and are developed after birth, the former when the child is able to hold up its head (at three or four months), and to sit upright (at nine months), the latter at twelve or eighteen months, when the child begins to walk. *2*

The vertebral column has also a slight **lateral** curvature, the convexity of which is directed toward the right side. This may be produced by muscular action, most persons using the right arm in preference to the left, especially in making long-continued efforts, when the body is curved to the right side. In support of this explanation it has been found that in one or two individuals who were left-handed, the convexity was to the left side. By others this curvature is regarded as being produced by the aortic arch and upper part of the descending thoracic aorta—a view which is supported by the fact that in cases where the viscera are transposed and the aorta is on the right side, the convexity of the curve is directed to the left side. *3*

Surfaces.—Anterior Surface.—When viewed from in front, the width of the bodies of the vertebræ is seen to increase from the second cervical to the first thoracic; there is then a slight diminution in the next three vertebræ; below this there is again a gradual and progressive increase in width as low as the sacrovertebral angle. From this point there is a rapid diminution, to the apex of the coccyx. *4*

Posterior Surface.—The posterior surface of the vertebral column presents in the median line the spinous processes. In the cervical region (with the exception of the second and seventh vertebræ) these are short and horizontal, with bifid extremities. In the upper part of the thoracic region they are directed obliquely downward; in the middle they are almost vertical, and in the lower part they are nearly horizontal. In the lumbar region they are nearly horizontal. The spinous processes are separated by considerable intervals in the lumbar region, by narrower intervals in the neck, and are closely approximated in the middle of the thoracic region. Occasionally one of these processes deviates a little from the median line—a fact to be remembered in practice, as irregularities of this sort are attendant also on fractures or displacements of the vertebral column. On either side of the spinous processes is the **vertebral groove** formed by the laminæ in the cervical and lumbar regions, where it is shallow, and by the laminæ and transverse processes in the thoracic region, where it is deep and broad; these grooves lodge the deep muscles of the back. Lateral to the vertebral grooves are the articular processes, and still more laterally the transverse processes. In the thoracic region, the transverse processes stand backward, on a plane considerably behind that of the same processes in the cervical and lumbar regions. In the cervical region, the transverse processes are placed in front of the articular processes, lateral to the pedicles and between the intervertebral foramina. In the thoracic region they are posterior to the pedicles, intervertebral foramina, and articular processes. In the lumbar region they are in front of the articular processes, but behind the intervertebral foramina. *5*

Lateral Surfaces.—The lateral surfaces are separated from the posterior surface by the articular processes in the cervical and lumbar regions, and by the transverse processes in the thoracic region. They present, in front, the sides of the bodies of the vertebræ, marked in the thoracic region by the facets for articulation with the heads of the ribs. More posteriorly are the intervertebral foramina, formed by the juxtaposition of the vertebral notches, oval in shape, smallest in the cervical and upper part of the thoracic regions, and gradually increasing in size to the last lumbar. They transmit the spinal nerves and are situated between the transverse processes in the cervical region, and in front of them in the thoracic and lumbar regions. *6*

FIG. 111– Lateral view of the vertebral column. (See enlarged image)

Vertebral Canal.—The vertebral canal follows the different curves of the column; it is large and triangular in those parts of the column which enjoy the greatest freedom of movement, viz., the cervical and lumbar regions; and is small and rounded in the thoracic region, where motion is more limited. *7*

Abnormalities.—Occasionally the coalescence of the laminæ is not completed, and consequently a cleft is left in the arches of the vertebræ, through which a protrusion of the spinal membranes (dura mater and arachnoid), and generally of the medulla spinalis itself, takes place, constituting the malformation known as *spina bifida.* This condition is most common in the lumbosacral region, but it may occur in the thoracic or cervical region, or the arches throughout the whole length of the canal may remain incomplete. *8*

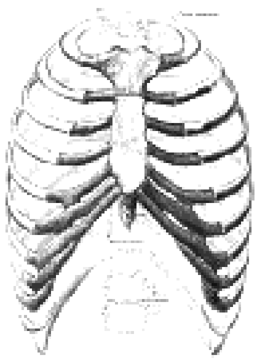

FIG. 112– The thorax from in front. (Spalteholz.) (See enlarged image)

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

4. The Thorax

The skeleton of the **thorax** or **chest** (Figs. 112, 113, 114) is an osseo-cartilaginous cage, containing and protecting the principal organs of respiration and circulation. It is conical in shape, being narrow above and broad below, flattened from before backward, and longer behind than in front. It is somewhat reniform on transverse section on account of the projection of the vertebral bodies into the cavity. 1

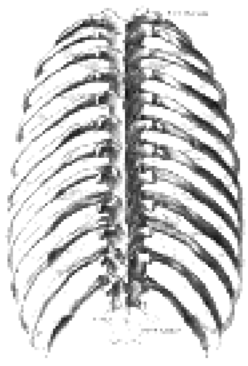

FIG. 113– The thorax from behind. (Spalteholz.) (See enlarged image)

Boundaries.—The **posterior surface** is formed by the twelve thoracic vertebræ and the posterior parts of the ribs. It is convex from above downward, and presents on either side of the middle line a deep groove, in consequence of the lateral and backward direction which the ribs take from their vertebral extremities to their angles. The **anterior surface,** formed by the sternum and costal cartilages, is flattened or slightly convex, and inclined from above downward and forward. The **lateral surfaces** are convex; they are formed by the ribs, separated from each other by the intercostal spaces, eleven in number, which are occupied by the Intercostal muscles and membranes. 2

The **upper opening** of the thorax is reniform in shape, being broader from side to side than from before backward. It is formed by the first thoracic vertebra behind, the upper margin of the sternum in front, and the first rib on either side. It slopes downward and forward, so that the anterior part of the opening is on a lower level than the posterior. Its antero-posterior diameter is about 5 cm., and its transverse diameter about 10 cm. The **lower opening** is formed by the twelfth thoracic vertebra behind, by the eleventh and twelfth ribs at the sides, and in front by the cartilages of the tenth, ninth, eighth, and seventh ribs, which ascend on either side and form an angle, the **subcostal angle,** into the apex of which the xiphoid process projects. The lower opening is wider transversely than from before backward, and slopes obliquely downward and backward, it is closed by the diaphragm which forms the floor of the thorax. 3

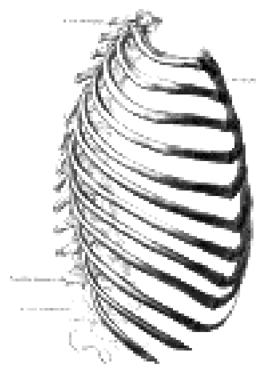

FIG. 114– The thorax from the right. (Spalteholz.) (See enlarged image)

The thorax of the female differs from that of the male as follows: 1. Its capacity is less. 2. The sternum is shorter. 3. The upper margin of the sternum is on a level with the lower part of the body of the third thoracic vertebra, whereas in the male it is on a level with the lower part of the body of the second. 4. The upper ribs are more movable, and so allow a greater enlargement of the upper part of the thorax. 4

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

4a. The Sternum

(Breast Bone) 1

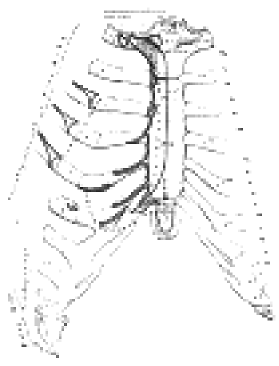

FIG. 115– Anterior surface of sternum and costa cartilages. (See enlarged image)

The **sternum** (Figs. 115 to 117) is an elongated, flattened bone, forming the middle portion of the anterior wall of the thorax. Its upper end supports the clavicles, and its margins articulate with the cartilages of the first seven **pairs** of ribs. It consists of three parts, named from above downward, the **manubrium,** the **body** or **gladiolus,** and the **xiphoid process;** in early life the body consists of four segments or *sternebrœ.* In its natural position the inclination of the bone is oblique from above, downward and forward. It is slightly convex in front and concave behind; broad above, becoming narrowed at the point where the manubrium joins the body, after which it again widens a little to below the middle of the body, and then narrows to its lower extremity. Its average length in the adult is about 17 cm., and is rather greater in the male than in the female. 2

Manubrium (*manubrium sterni*).—The manubrium is of a somewhat quadrangular form, broad and thick above, narrow below at its junction with the body. 3

Surfaces.—Its **anterior surface,** convex from side to side, concave from above downward, is smooth, and affords attachment on either side to the sternal origins of the Pectoralis major and Sternocleidomastoideus. Sometimes the ridges limiting the attachments of these muscles are very distinct. Its **posterior surface,** concave and smooth, affords attachment on either side to the Sternohyoideus and Sternothyreoideus. 4

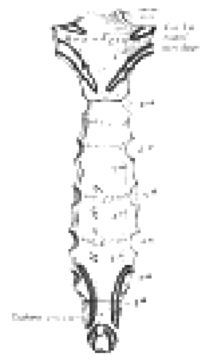

FIG. 116– Posterior surface of sternum. (See enlarged image)

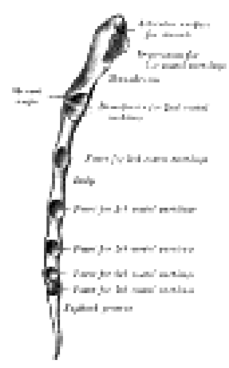

FIG. 117– Lateral border of sternum. (See enlarged image)

Borders.—The **superior border** is the thickest and presents at its center the **jugular** or **presternal notch;** on either side of the notch is an oval articular surface, directed upward, backward, and lateralward, for articulation with the sternal end of the clavicle. The **inferior border,** oval and rough, is covered in a fresh state with a thin layer of cartilage, for articulation with the body. The **lateral borders** are each marked above by a depression for the first costal cartilage, and below by a small facet, which, with a similar facet on the upper angle of the body, forms a notch for the reception of the costal cartilage of the second rib. Between the depression for the first costal cartilage and the demi-facet for the second is a narrow, curved edge, which slopes from above downward and medialward. 5

Body (*corpus sterni; gladiolus*).—The body, considerably longer, narrower, and thinner than the manubrium, attains its greatest breadth close to the lower end. 6

Surfaces.—Its **anterior surface** is nearly flat, directed upward and forward, and marked by three transverse 7
ridges which cross the bone opposite the third, fourth, and fifth articular depressions. [18] It affords attachment on either side to the sternal origin of the Pectoralis major. At the junction of the third and fourth pieces of the body is occasionally seen an orifice, the **sternal foramen,** of varying size and form. The **posterior surface,** slightly concave, is also marked by three transverse lines, less distinct, however, than those in front; from its lower part, on either side, the Transversus thoracis takes origin.

Borders.—The **superior border** is oval and articulates with the manubrium, the junction of the two forming 8
the **sternal angle** (*angulus Ludovici* [19]). The **inferior border** is narrow, and articulates with the xiphoid process. Each **lateral border** (Fig. 117), at its superior angle, has a small facet, which with a similar facet on the manubrium, forms a cavity for the cartilage of the second rib; below this are four angular depressions which receive the cartilages of the third, fourth, fifth, and sixth ribs, while the inferior angle has a small facet, which, with a corresponding one on the xiphoid process, forms a notch for the cartilage of the seventh rib. These articular depressions are separated by a series of curved interarticular intervals, which diminish in length from above downward, and correspond to the intercostal spaces. Most of the cartilages belonging to the true ribs, as will be seen from the foregoing description, articulate with the sternum at the lines of junction of its primitive component segments. This is well seen in many of the lower animals, where the parts of the bone remain ununited longer than in man.

Xiphoid Process (*processus xiphoideus; ensiform or xiphoid appendix*).—The xiphoid process is the 9
smallest of the three pieces: it is thin and elongated, cartilaginous in structure in youth, but more or less ossified at its upper part in the adult.

Surfaces.—Its **anterior surface** affords attachment on either side to the anterior costoxiphoid ligament and 10
a small part of the Rectus abdominis; its **posterior surface,** to the posterior costoxiphoid ligament and to some of the fibers of the diaphragm and Transversus thoracis, its **lateral borders,** to the aponeuroses of the abdominal muscles. Above, it articulates with the lower end of the body, and on the front of each superior angle presents a facet for part of the cartilage of the seventh rib; below, by its pointed extremity, it gives attachment to the linea alba. The xiphoid process varies much in form; it may be broad and thin, pointed, bifid, perforated, curved, or deflected considerably to one or other side.

Structure.—The sternum is composed of highly vascular cancellous tissue, covered by a thin layer of 11
compact bone which is thickest in the manubrium between the articular facets for the clavicles.

Ossification.—The sternum originally consists of two cartilaginous bars, situated one on either side of the 12
median plane and connected with the cartilages of the upper nine ribs of its own side. These two bars fuse with each other along the middle line to form the cartilaginous sternum which is ossified from *six* centers: one for the manubrium, four for the body, and one for the xiphoid process (Fig. 118). The ossific centers appear in the intervals between the articular depressions for the costal cartilages, in the following order: in the manubrium and first piece of the body, during the sixth month; in the second and third pieces of the body, during the seventh month of fetal life; in its fourth piece, during the first year after birth; and in the xiphoid process, between the fifth and eighteenth years. The centers make their appearance at the upper parts of the segments, and proceed gradually downward. [20] To these may be added the occasional existence of two small episternal centers, which make their appearance one on either side of the jugular notch; they are probably vestiges of the episternal bone of the monotremata and lizards. Occasionally some of the segments are formed from more than one center, the number and position of which vary (Fig. 120). Thus, the first piece may have two, three, or even six centers. When two are present, they are generally situated one above the other, the upper being the larger; the second piece has seldom more than one; the third, fourth, and fifth pieces are often formed from two centers placed laterally, the irregular union of which explains the rare occurrence of the sternal foramen (Fig. 121), or of the vertical fissure which occasionally intersects this part of the bone constituting the malformation known as *fissura sterni;* these conditions are further explained by the manner in which the cartilaginous sternum is formed. More rarely still the upper end of the sternum may be divided by a fissure. Union of the various centers of the body begins about puberty, and proceeds from below upward (Fig. 119); by the age of twenty-five they are all united. The xiphoid process may become joined to the body before the age of thirty, but this occurs more frequently after forty; on the other hand, it sometimes remains ununited in old age. In advanced life the manubrium is occasionally joined to the body by bone. When this takes place, however, the bony tissue is generally only superficial, the central portion of the intervening cartilage remaining unossified.

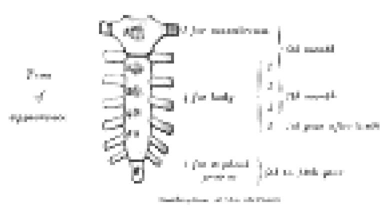

FIG. 118– Ossification of the sternum. (See enlarged image)

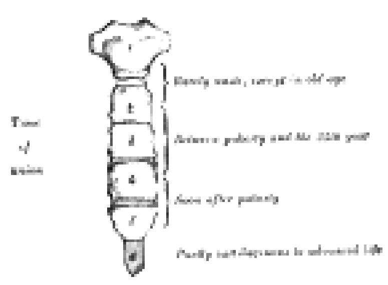

FIG. 119– No caption. (See enlarged image)

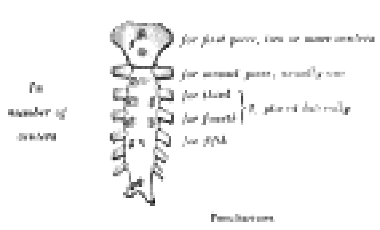

FIG. 120– Peculiarities. (See enlarged image)

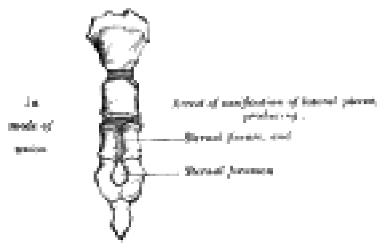

FIG. 121– No caption. (See enlarged image)

Articulations.—The sternum articulates on either side with the clavicle and upper seven costal cartilages. 13

Note 18. Paterson (The Human Sternum, 1904), who examined 524 specimens, points out that these ridges are altogether absent in 26.7 per cent.; that in 69 per cent. a ridge exists opposite the third costal attachment; in 39 per cent. opposite the fourth; and in 4 per cent. only, opposite the fifth. [back]

Note 19. Named after the French surgeon Antoine Louis, 1723–1792. The Latin name *angulus Ludovici* is not infrequently mistranslated into English as “the angle of Ludwig.” [back]

Note 20. Out of 141 sterna between the time of birth and the age of sixteen years, Paterson (*op. cit.*) found the fourth or lowest center for the body present only in thirty-eight cases— *i. e.,* 26.9 per cent. [back]

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

4b. The Ribs

(Costæ) 1

The **ribs** are elastic arches of bone, which form a large part of the thoracic skeleton. They are twelve in number on either side; but this number may be increased by the development of a cervical or lumbar rib, or may be diminished to eleven. The first seven are connected behind with the vertebral column, and in front, through the intervention of the costal cartilages, with the sternum (Fig. 115); they are called **true** or **vertebro-sternal ribs.** 21 The remaining five are **false ribs;** of these, the first three have their cartilages attached to the cartilage of the rib above (**vertebro-chondral**): the last two are free at their anterior extremities and are termed **floating** or **vertebral ribs.** The ribs vary in their direction, the upper ones being less oblique than the lower; the obliquity reaches its maximum at the ninth rib, and gradually decreases from that rib to the twelfth. The ribs are situated one below the other in such a manner that spaces called **intercostal spaces** are left between them. The length of each space corresponds to that of the adjacent ribs and their cartilages; the breadth is greater in front than behind, and between the upper than the lower ribs. The ribs increase in length from the first to the seventh, below which they diminish to the twelfth. In breadth they decrease from above downward; in the upper ten the greatest breadth is at the sternal extremity.

Common Characteristics of the Ribs (Figs. 122, 123).—A rib from the middle of the series should be taken in order to study the common characteristics of these bones. 2

Each rib has two extremities, a **posterior** or **vertebral,** and an **anterior** or **sternal,** and an intervening portion—the **body** or **shaft.** 3

Posterior Extremity.—The **posterior** or **vertebral extremity** presents for examination a head, neck, and tubercle. 4

The **head** is marked by a kidney-shaped articular surface, divided by a horizontal crest into two facets for articulation with the depression formed on the bodies of two adjacent thoracic vertebræ; the upper facet is the smaller; to the crest is attached the interarticular ligament. 5

The **neck** is the flattened portion which extends lateralward from the head; it is about 2.5 cm. long, and is placed in front of the transverse process of the lower of the two vertebræ with which the head articulates. Its **anterior surface** is flat and smooth, its **posterior** rough for the attachment of the ligament of the neck, and perforated by numerous foramina. Of its two borders the **superior** presents a rough crest (*crista colli costæ*) for the attachment of the anterior costotransverse ligament; its **inferior border** is rounded. On the posterior surface at the junction of the neck and body, and nearer the lower than the upper border, is an eminence—the **tubercle;** it consists of an articular and a non-articular portion. The *articular portion,* the lower and more medial of the two, presents a small, oval surface for articulation with the end of the transverse process of the lower of the two vertebræ to which the head is connected. The *non-articular portion* is a rough elevation, and affords attachment to the ligament of the tubercle. The tubercle is much more prominent in the upper than in the lower ribs. 6

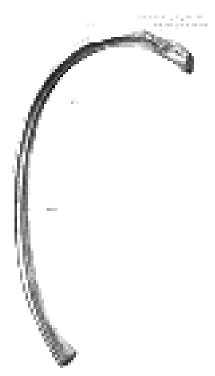

FIG. 122– A central rib of the left side. Inferior aspect. (See enlarged image)

7 **Body.**—The **body** or **shaft** is thin and flat, with two surfaces, an external and an internal; and two borders, a superior and an inferior. The **external surface** is convex, smooth, and marked, a little in front of the tubercle, by a prominent line, directed downward and lateralward; this gives attachment to a tendon of the Iliocostalis, and is called the **angle.** At this point the rib is bent in two directions, and at the same time twisted on its long axis. If the rib be laid upon its lower border, the portion of the body in front of the angle rests upon this border, while the portion behind the angle is bent medialward and at the same time tilted upward; as the result of the twisting, the external surface, behind the angle, looks downward, and in front of the angle, slightly upward. The distance between the angle and the tubercle is progressively greater from the second to the tenth ribs. The portion between the angle and the tubercle is rounded, rough, and irregular, and serves for the attachment of the Longissimus dorsi. The **internal surface** is concave, smooth, directed a little upward behind the angle, a little downward in front of it, and is marked by a ridge which commences at the lower extremity of the head; this ridge is strongly marked as far as the angle, and gradually becomes lost at the junction of the anterior and middle thirds of the bone. Between it and the inferior border is a groove, the **costal groove,** for the intercostal vessels and nerve. At the back part of the bone, this groove belongs to the inferior border, but just in front of the angle, where it is deepest and broadest, it is on the internal surface. The superior edge of the groove is rounded and serves for the attachment of an Intercostalis internus; the inferior edge corresponds to the lower margin of the rib, and gives attachment to an Intercostalis externus. Within the groove are seen the orifices of numerous small foramina for nutrient vessels which traverse the shaft obliquely from before backward. The **superior border,** thick and rounded, is marked by an external and an internal lip, more distinct behind than in front, which serve for the attachment of Intercostales externus and internus. The **inferior border** is thin, and has attached to it an Intercostalis externus.

8 **Anterior Extremity.**—The **anterior** or **sternal extremity** is flattened, and presents a porous, oval, concave depression, into which the costal cartilage is received.

9 **Peculiar Ribs.**—The first, second, tenth, eleventh, and twelfth ribs present certain variations from the common characteristics described above, and require special consideration.

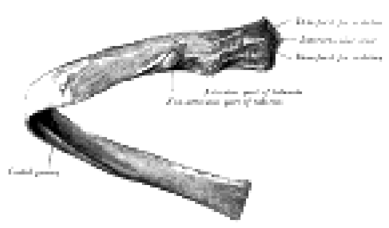

FIG. 123– A central rib of the left side, viewed from behind. (See enlarged image)

10 **First Rib.**—The first rib (Fig. 124) is the most curved and usually the shortest of all the ribs; it is broad and flat, its surfaces looking upward and downward, and its borders inward and outward. The **head** is small, rounded, and possesses only a single articular facet, for articulation with the body of the first thoracic vertebra. The **neck** is narrow and rounded. The **tubercle,** thick and prominent, is placed on the outer border. There is *no angle,* but at the tubercle the rib is slightly bent, with the convexity upward, so that the head of the bone is directed downward. The **upper surface** of the body is marked by two shallow grooves, separated from each other by a slight ridge prolonged internally into a tubercle, the **scalene tubercle,** for the attachment of the Scalenus anterior; the anterior groove transmits the subclavian vein, the posterior the subclavian artery and the lowest trunk of the brachial plexus. 22 Behind the posterior groove is a rough area for the attachment of the Scalenus medius. The **under surface** is smooth, and destitute of a costal groove. The **outer border** is convex, thick, and rounded, and at its posterior part gives attachment to the first digitation of the Serratus anterior; the **inner border** is concave, thin, and sharp, and marked about its center by the scalene tubercle. The **anterior extremity** is larger and thicker than that of any of the other ribs.

11 **Second Rib.**—The second rib (Fig. 125) is much longer than the first, but has a very similar curvature. The non-articular portion of the **tubercle** is occasionally only feebly marked. The **angle** is slight, and situated close to the tubercle. The **body** is not twisted, so that both ends touch any plane surface upon which it may be laid; but there is a bend, with its convexity upward, similar to, though smaller than that found in the first rib. The body is not flattened horizontally like that of the first rib. Its **external surface** is convex, and looks upward and a little outward; near the middle of it is a rough eminence for the origin of the lower part of the first and the whole of the second digitation of the Serratus anterior; behind and above this is attached the Scalenus posterior. The **internal surface,** smooth, and concave, is directed downward and a little inward: on its posterior part there is a short costal groove.

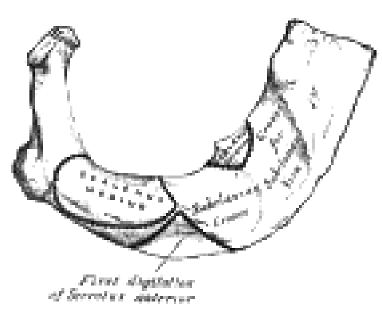

FIG. 124– Peculiar ribs. (See enlarged image)

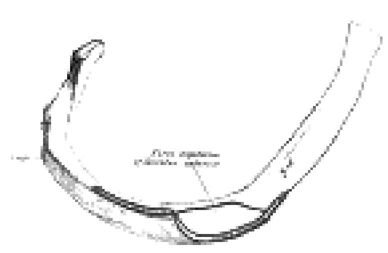

FIG. 125– Peculiar ribs. (See enlarged image)

FIG. 126– Peculiar ribs. (See enlarged image)

FIG. 127– Peculiar ribs. (See enlarged image)

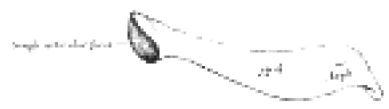

FIG. 128– Peculiar ribs. (See enlarged image)

Tenth Rib.—The tenth rib (Fig. 126) has only a single articular facet on its head. 12

Eleventh and Twelfth Ribs.—The eleventh and twelfth ribs (Figs. 127 and 128) have each a single articular 13
facet on the head, which is of rather large size; they have *no necks or tubercles,* and are pointed at their anterior ends. The eleventh has a slight angle and a shallow costal groove. The twelfth has neither; it is much shorter than the eleventh, and its head is inclined slightly downward. Sometimes the twelfth rib is even shorter than the first.

Structure.—The ribs consist of highly vascular cancellous tissue, enclosed in a thin layer of compact bone. 14

Ossification.—Each rib, with the exception of the last two, is ossified from *four* centers; a primary center for 15
the body, and three epiphysial centers, one for the head and one each for the articular and non-articular parts of the tubercle. The eleventh and twelfth ribs have each only *two* centers, those for the tubercles being wanting. Ossification begins near the angle toward the end of the second month of fetal life, and is seen first in the sixth and seventh ribs. The epiphyses for the head and tubercle make their appearance between the sixteenth and twentieth years, and are united to the body about the twenty-fifth year. Fawcett 23 states that "in all probability there is usually no epiphysis on the non-articular part of the tuberosity below the sixth or seventh rib.

Note 21. Sometimes the eighth rib cartilage articulates with the sternum; this condition occurs more frequently on the right than on the left side. [back]

Note 22. Anat. Anzeiger, 1910, Band xxxvi. [back]

Note 23. Journal of Anatomy and Physiology. vol. xlv. [back]

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

4c. The Costal Cartilages

(Cartilagines Costales) 1

The **costal cartilages** (Fig. 115) are bars of hyaline cartilage which serve to prolong the ribs forward and contribute very materially to the elasticity of the walls of the thorax. The first seven pairs are connected with the sternum; the next three are each articulated with the lower border of the cartilage of the preceding rib; the last two have pointed extremities, which end in the wall of the abdomen. Like the ribs, the costal cartilages vary in their length, breadth, and direction. They increase in length from the first to the seventh, then gradually decrease to the twelfth. Their breadth, as well as that of the intervals between them, diminishes from the first to the last. They are broad at their attachments to the ribs, and taper toward their sternal extremities, excepting the first two, which are of the same breadth throughout, and the sixth, seventh, and eighth, which are enlarged where their margins are in contact. They also vary in direction: the first descends a little, the second is horizontal, the third ascends slightly, while the others are angular, following the course of the ribs for a short distance, and then ascending to the sternum or preceding cartilage. Each costal cartilage presents two surfaces, two borders, and two extremities.

Surfaces.—The **anterior surface** is convex, and looks forward and upward: that of the first gives attachment to the costoclavicular ligament and the Subclavius muscle; those of the first six or seven at their sternal ends, to the Pectoralis major. The others are covered by, and give partial attachment to, some of the flat muscles of the abdomen. The **posterior surface** is concave, and directed backward and downward; that of the first gives attachment to the Sternothyroideus, those of the third to the sixth inclusive to the Transversus thoracis, and the six or seven inferior ones to the Transversus abdominis and the diaphragm. 2

Borders.—Of the two borders the **superior** is concave, the **inferior** convex; they afford attachment to the Intercostales interni: the upper border of the sixth gives attachment also to the Pectoralis major. The inferior borders of the sixth, seventh, eighth, and ninth cartilages present heel-like projections at the points of greatest convexity. These projections carry smooth oblong facets which articulate respectively with facets on slight projections from the upper borders of the seventh, eighth, ninth, and tenth cartilages. 3

Extremities.—The **lateral end** of each cartilage is continuous with the osseous tissue of the rib to which it belongs. The **medial end** of the first is continuous with the sternum; the medial ends of the six succeeding ones are rounded and are received into shallow concavities on the lateral margins of the sternum. The medial ends of the eighth, ninth, and tenth costal cartilages are pointed, and are connected each with the cartilage immediately above. Those of the eleventh and twelfth are pointed and free. In old age the costal cartilages are prone to undergo superficial ossification. 4

Cervical ribs derived from the seventh cervical vertebra (page 83) are of not infrequent occurrence, and are important clinically because they may give rise to obscure nervous or vascular symptoms. The cervical rib may be a mere epiphysis articulating only with the transverse process of the vertebra, but more commonly it consists of a defined head, neck, and tubercle, with or without a body. It extends lateralward, or forward and lateralward, into the posterior triangle of the neck, where it may terminate in a free end or may join the first thoracic rib, the first costal cartilage, or the sternum. 24 It varies much in shape, size, direction, and mobility. If it reach far enough forward, part of the brachial plexus and the subclavian artery and vein cross over it, and are apt to suffer compression in so doing. Pressure on the artery may obstruct the circulation so much that arterial thrombosis results, causing gangrene of the finger tips. Pressure on the nerves is commoner, and affects the eighth cervical and first thoracic nerves, causing paralysis of the muscles they supply, and neuralgic pains and paresthesia in the area of skin to which they are distributed: no oculopupillary changes are to be found. 5

The *thorax* is frequently found to be altered in shape in certain diseases. 6

In *rickets,* the ends of the ribs, where they join the costal cartilages, become enlarged, giving rise to the so-called "rickety rosary," which in mild cases is only found on the internal surface of the thorax. Lateral to these enlargements the softened ribs sink in, so as to present a groove passing downward and lateralward on either side of the sternum. This bone is forced forward by the bending of the ribs, and the antero-posterior diameter of the chest is increased. The ribs affected are the second to the eighth, the lower ones being prevented from falling in by the presence of the liver, stomach, and spleen; and when the abdomen is distended, as it often is in rickets, the lower ribs may be pushed outward, causing a transverse groove (Harrison's sulcus) just above the costal arch. This deformity or forward projection of the sternum, often asymmetrical, is known as *pigeon breast,* and may be taken as evidence of active or old rickets except in cases of primary spinal curvature. In many instances it is associated in children with obstruction in the upper air passages, due to enlarged tonsils or adenoid growths. In some rickety children or adults, and also in others who give no history or further evidence of having had rickets, an opposite condition obtains. The lower part of the sternum and often the xiphoid process as well are deeply depressed backward, producing an oval hollow in the lower sternal and upper epigastric regions. This is known as *funnel breast* (German, *Trichterbrust*); it never appears to produce the least disturbance of any of the vital functions. The *phthisical chest* is often long and narrow, and with great obliquity of the ribs and projection of the scapulæ. In *pulmonary emphysema* the chest is enlarged in all its diameters, and presents on section an almost circular outline. It has received the name of the *barrel-shaped chest.* In severe cases of *lateral curvature of the vertebral column* the thorax becomes much distorted. In consequence of the rotation of the bodies of the vertebræ which takes place in this disease, the ribs opposite the convexity of the dorsal curve become extremely convex behind, being thrown out and bulging, and at the same time flattened in front, so that the two ends of the same rib are almost parallel. Coincidently with this the ribs on the opposite side, on the concavity of the curve, are sunk and depressed behind, and bulging and convex in front. 7

Note 24. W. Thorburn, The Medical Chronicle, Manchester, 1907, 4th series, xiv, No. 3 [back]

5. The Skull

The **skull** is supported on the summit of the vertebral column, and is of an oval shape, wider behind than in front. It is composed of a series of flattened or irregular bones which, with one exception (the mandible), are immovably jointed together. It is divisible into two parts: (1) the **cranium,** which lodges and protects the brain, consists of eight bones, and (2) the **skeleton of the face,** of fourteen, as follows: 1

Skull, 22 bones	*Cranium,* 8 bones	Occipital. Two Parietals. Frontal. Two Temporals. Sphenoidal. Ethmoidal.
	Face, 14 bones	Two Nasals. Two Maxillæ. Two Lacrimals. Two Zygomatics. Two Palatines. Two Inferior Nasal Conchæ. Vomer. Mandible.

In the Basle nomenclature, certain bones developed in association with the nasal capsule, viz., the inferior nasal conchæ, the lacrimals, the nasals, and the vomer, are grouped as cranial and not as facial bones. 2

The hyoid bone, situated at the root of the tongue and attached to the base of the skull by ligaments, is described in this section. 3

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

5a. The Cranial Bones. 1. The Occipital Bone

(Ossa Cranii) & (Os Occipitale). 1

The **occipital bone** (Figs. 129, 130), situated at the back and lower part of the cranium, is trapezoid in shape and curved on itself. It is pierced by a large oval aperture, the **foramen magnum,** through which the cranial cavity communicates with the vertebral canal.

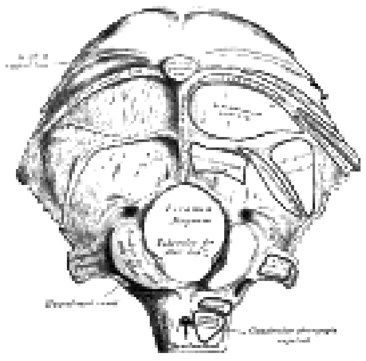

FIG. 129– Occipital bone. Outer surface. (See enlarged image)

The curved, expanded plate behind the foramen magnum is named the **squama;** the thick, somewhat quadrilateral piece in front of the foramen is called the **basilar part,** whilst on either side of the foramen is the **lateral portion.** 2

The Squama (*squama occipitalis*).—The squama, situated above and behind the foramen magnum, is curved from above downward and from side to side. 3

Surfaces.—The **external surface** is convex and presents midway between the summit of the bone and the foramen magnum a prominence, the **external occipital protuberance.** Extending lateralward from this on either side are two curved lines, one a little above the other. The upper, often faintly marked, is named the **highest nuchal line,** and to it the galea aponeurotica is attached. The lower is termed the **superior nuchal line.** That part of the squama which lies above the highest nuchal lines is named the **planum occipitale,** and is covered by the Occipitalis muscle; that below, termed the **planum nuchale,** is rough and irregular for the attachment of several muscles. From the external occipital protuberance a ridge or crest, the **median nuchal line,** often faintly marked, descends to the foramen magnum, and affords attachment to the ligamentum nuchæ; running from the middle of this line across either half of the nuchal plane is the **inferior nuchal line.** Several muscles are attached to the outer surface of the squama, thus: the superior nuchal line gives origin to the Occipitalis and Trapezius, and insertion to the Sternocleidomastoideus and Splenius capitis: into the surface between the superior and inferior nuchal lines the Semispinalis capitis and the Obliquus capitis superior are inserted, while the inferior nuchal line and the area below it receive the insertions of the Recti capitis posteriores major and minor. The posterior atlantoöccipital membrane is attached around the postero-lateral part of the foramen magnum, just outside the margin of the foramen. 4

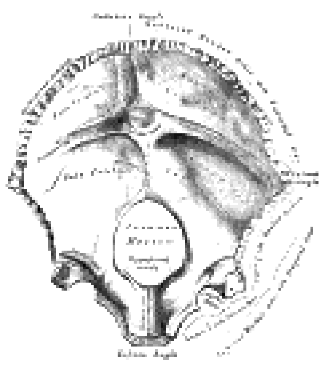

FIG. 130– Occipita bone. Inner surface. (See enlarged image)

The **internal surface** is deeply concave and divided into four fossæ by a **cruciate eminence.** The upper two fossæ are triangular and lodge the occipital lobes of the cerebrum; the lower two are quadrilateral and accommodate the hemispheres of the cerebellum. At the point of intersection of the four divisions of the cruciate eminence is the **internal occipital protuberance.** From this protuberance the upper division of the cruciate eminence runs to the superior angle of the bone, and on one side of it (generally the right) is a deep groove, the **sagittal sulcus,** which lodges the hinder part of the superior sagittal sinus; to the margins of this sulcus the falx cerebri is attached. The lower division of the cruciate eminence is prominent, and is named the **internal occipital crest;** it bifurcates near the foramen magnum and gives attachment to the falx cerebelli; in the attached margin of this falx is the occipital sinus, which is sometimes duplicated. In the upper part of the internal occipital crest, a small depression is sometimes distinguishable; it is termed the **vermian fossa** since it is occupied by part of the vermis of the cerebellum. Transverse grooves, one on either side, extend from the internal occipital protuberance to the lateral angles of the bone; those grooves accommodate the transverse sinuses, and their prominent margins give attachment to the tentorium cerebelli. The groove on the right side is usually larger than that on the left, and is continuous with that for the superior sagittal sinus. Exceptions to this condition are, however, not infrequent; the left may be larger than the right or the two may be almost equal in size. The angle of union of the superior sagittal and transverse sinuses is named the **confluence of the sinuses** (*torcular Herophili* 25), and its position is indicated by a depression situated on one or other side of the protuberance. 5

Lateral Parts (*pars lateralis*).—The lateral parts are situated at the sides of the foramen magnum; on their under surfaces are the **condyles** for articulation with the superior facets of the atlas. The condyles are oval or reniform in shape, and their anterior extremities, directed forward and medialward, are closer together than their posterior, and encroach on the basilar portion of the bone; the posterior extremities extend back to the level of the middle of the foramen magnum. The articular surfaces of the condyles are convex from before backward and from side to side, and look downward and lateralward. To their margins are attached the capsules of the atlantoöccipital articulations, and on the medial side of each is a rough impression or tubercle for the alar ligament. At the base of either condyle the bone is tunnelled by a short canal, the **hypoglossal canal** (*anterior condyloid foramen*). This begins on the cranial surface of the bone immediately above the foramen magnum, and is directed lateralward and forward above the condyle. It may be partially or completely divided into two by a spicule of bone; it gives exit to the hypoglossal or twelfth cerebral nerve, and entrance to a meningeal branch of the ascending pharyngeal artery. Behind either condyle is a depression, the **condyloid fossa,** which receives the posterior margin of the superior facet of the atlas when the head is bent backward; the floor of this fossa is sometimes perforated by the **condyloid canal,** through which an emissary vein passes from the transverse sinus. Extending lateralward from the posterior half of the condyle is a quadrilateral plate of bone, the **jugular process,** excavated in front by the **jugular notch,** which, in the articulated skull, forms the posterior part of the jugular foramen. The jugular notch may be divided into two by a bony spicule, the **intrajugular process,** which projects lateralward above the hypoglossal canal. The under surface of the jugular process is rough, and gives attachment to the Rectus capitis lateralis muscle and the lateral atlantoöccipital ligament; from this surface an eminence, the **paramastoid process,** sometimes projects downward, and may be of sufficient length to reach, and articulate with, the transverse process of the atlas. Laterally the jugular process presents a rough quadrilateral or triangular area which is joined to the jugular surface of the temporal bone by a plate of cartilage; after the age of twenty-five this plate tends to ossify. 6

The **upper surface** of the lateral part presents an oval eminence, the **jugular tubercle,** which overlies the hypoglossal canal and is sometimes crossed by an oblique groove for the glossopharyngeal, vagus, and accessory nerves. On the upper surface of the jugular process is a deep groove which curves medialward and forward and is continuous with the jugular notch. This groove lodges the terminal part of the transverse sinus, and opening into it, close to its medial margin, is the orifice of the condyloid canal. 7

Basilar Part (*pars basilaris*).—The basilar part extends forward and upward from the foramen magnum, and presents *in front* an area more or less quadrilateral in outline. In the young skull this area is rough and uneven, and is joined to the body of the sphenoid by a plate of cartilage. By the twenty-fifth year this cartilaginous plate is ossified, and the occipital and sphenoid form a continuous bone. 8

Surfaces.—On its **lower surface,** about 1 cm. in front of the foramen magnum, is the **pharyngeal tubercle** which gives attachment to the fibrous raphé of the pharynx. On either side of the middle line the Longus capitis and Rectus capitis anterior are inserted, and immediately in front of the foramen magnum the anterior atlantoöccipital membrane is attached. 9

The **upper surface** presents a broad, shallow groove which inclines upward and forward from the foramen magnum; it supports the medulla oblongata, and near the margin of the foramen magnum gives attachment to the membrana tectoria. On the lateral margins of this surface are faint grooves for the inferior petrosal sinuses. 10

Foramen Magnum.—The foramen magnum is a large oval aperture with its long diameter antero-posterior; it is wider behind than in front where it is encroached upon by the condyles. It transmits the medulla oblongata and its membranes, the accessory nerves, the vertebral arteries, the anterior and posterior spinal arteries, and the membrana tectoria and alar ligaments. 11

Angles.—The **superior angle** of the occipital bone articulates with the occipital angles of the parietal bones and, in the fetal skull, corresponds in position with the **posterior fontanelle.** The **inferior angle** is fused with the body of the sphenoid. The **lateral angles** are situated at the extremities of the grooves for the transverse sinuses: each is received into the interval between the mastoid angle of the parietal and the mastoid part of the temporal. 12

Borders.—The **superior borders** extend from the superior to the lateral angles: they are deeply serrated for articulation with the occipital borders of the parietals, and form by this union the **lambdoidal suture.** The **inferior borders** extend from the lateral angles to the inferior angle; the upper half of each articulates with the mastoid portion of the corresponding temporal, the lower half with the petrous part of the same bone. These two portions of the inferior border are separated from one another by the jugular process, the notch on the anterior surface of which forms the posterior part of the jugular foramen. 13

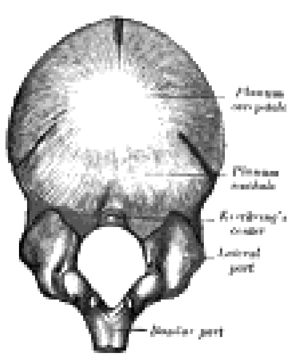

FIG. 131– Occipital bone at birth. (See enlarged image)

Structure.—The occipital, like the other cranial the *outer* and *inner tables,* between which is the cancellous 14
tissue or diploë; the bone is especially thick at the ridges, protuberances, condyles, and anterior part of the basilar part; in the inferior fossæ it is thin, semitransparent, and destitute of diploë.

Ossification (Fig. 131).—The planum occipitale of the squama is developed in membrane, and may remain 15
separate throughout life when it constitutes the *interparietal* bone; the rest of the bone is developed in cartilage. The number of nuclei for the planum occipitale is usually given as four, two appearing near the middle line about the second month, and two some little distance from the middle line about the third month of fetal life. The planum nuchale of the squama is ossified from two centers, which appear about the seventh week of fetal life and soon unite to form a single piece. Union of the upper and lower portions of the squama takes place in the third month of fetal life. An occasional center (Kerckring) appears in the posterior margin of the foramen magnum during the fifth month; this forms a separate ossicle (sometimes double) which unites with the rest of the squama before birth. Each of the lateral parts begins to ossify from a single center during the eighth week of fetal life. The basilar portion is ossified from two centers, one in front of the other; these appear about the sixth week of fetal life and rapidly coalesce. Mall 26 states that the planum occipitale is ossified from two centers and the basilar portion from one. About the fourth year the squama and the two lateral portions unite, and about the sixth year the bone consists of a single piece. Between the eighteenth and twenty-fifth years the occipital and sphenoid become united, forming a single bone.

Articulations.—The occipital articulates with *six* bones: the two parietals, the two temporals, the sphenoid, 16
and the atlas.

Note 25. The columns of blood coming in different directions were supposed to be pressed together at this point (*torcular,* a wine press). [back]

Note 26. American Journal of Anatomy, 1906, vol. v. [back]

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

5a. 2. The Parietal Bone

(Os Parietale) 1

The **parietal bones** form, by their union, the sides and roof of the cranium. Each bone is irregularly quadrilateral in form, and has two surfaces, four borders, and four angles.

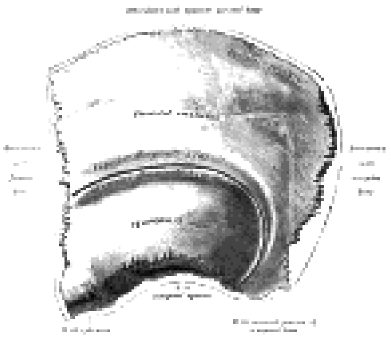

Fig. 132– Left parietal bone. Outer surface. (See enlarged image)

Surfaces.—The **external surface** (Fig. 132) is convex, smooth, and marked near the center by an eminence, the **parietal eminence** (*tuber parietale*), which indicates the point where ossification commenced. Crossing the middle of the bone in an arched direction are two curved lines, the **superior** and **inferior temporal lines;** the former gives attachment to the temporal fascia, and the latter indicates the upper limit of the muscular origin of the Temporalis. Above these lines the bone is covered by the galea aponeurotica; below them it forms part of the temporal fossa, and affords attachment to the Temporalis muscle. At the back part and close to the upper or sagittal border is the **parietal foramen,** which transmits a vein to the superior sagittal sinus, and sometimes a small branch of the occipital artery; it is not constantly present, and its size varies considerably. 2

The **internal surface** (Fig. 133) is concave; it presents depressions corresponding to the cerebral convolutions, and numerous furrows for the ramifications of the middle meningeal vessel; 27 the latter run upward and backward from the sphenoidal angle, and from the central and posterior part of the squamous border. Along the upper margin is a shallow groove, which, together with that on the opposite parietal, forms a channel, the **sagittal sulcus,** for the superior sagittal sinus; the edges of the sulcus afford attachment to the falx cerebri. Near the groove are several depressions, best marked in the skulls of old persons, for the **arachnoid granulations** (*Pacchionian bodies*). In the groove is the internal opening of the parietal foramen when that aperture exists. 3

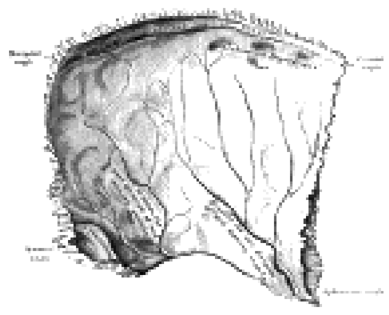

Fig. 133– Left parietal bone. Inner surface. (See enlarged image)

Borders.—The **sagittal border,** the longest and thickest, is dentated and articulates with its fellow of the opposite side, forming the sagittal suture. The **squamous border** is divided into three parts: of these, the anterior is thin and pointed, bevelled at the expense of the outer surface, and overlapped by the tip of the great wing of the sphenoid; the middle portion is arched, bevelled at the expense of the outer surface, and overlapped by the squama of the temporal; the posterior part is thick and serrated for articulation with the mastoid portion of the temporal. The **frontal border** is deeply serrated, and bevelled at the expense of the outer surface above and of the inner below; it articulates with the frontal bone, forming onehalf of the **coronal suture.** The **occipital border,** deeply denticulated, articulates with the occipital, forming one-half of the **lambdoidal suture.** 4

Angles.—The **frontal angle** is practically a right angle, and corresponds with the point of meeting of the sagittal and coronal sutures; this point is named the **bregma;** in the fetal skull and for about a year and a half after birth this region is membranous, and is called the **anterior fontanelle.** The **sphenoidal angle,** thin and acute, is received into the interval between the frontal bone and the great wing of the sphenoid. Its inner surface is marked by a deep groove, sometimes a canal, for the anterior divisions of the middle meningeal artery. The **occipital angle** is rounded and corresponds with the point of meeting of the sagittal and lambdoidal sutures—a point which is termed the **lambda;** in the fetus this part of the skull is membranous, and is called the **posterior fontanelle.** The **mastoid angle** is truncated; it articulates with the occipital bone and with the mastoid portion of the temporal, and presents on its inner surface a broad, shallow groove which lodges part of the transverse sinus. The point of meeting of this angle with the occipital and the mastoid part of the temporal is named the **asterion.** 5

Ossification.—The parietal bone is ossified in membrane from a single center, which appears at the parietal eminence about the eighth week of fetal life. Ossification gradually extends in a radial manner from the center toward the margins of the bone; the angles are consequently the parts last formed, and it is here that the fontanelles exist. Occasionally the parietal bone is divided into two parts, upper and lower, by an antero-posterior suture. *6*

Articulations.—The parietal articulates with *five* bones: the opposite parietal, the occipital, frontal, temporal, and sphenoid. *7*

Note 27. Journal of Anatomy and Physiology, 1912, vol. xlvi. [back]

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

5a. 3. The Frontal Bone

(Os Frontale) 1

The **frontal bone** resembles a cockle-shell in form, and consists of two portions—a **vertical** portion, the **squama,** corresponding with the region of the forehead; and an **orbital** or **horizontal** portion, which enters into the formation of the roofs of the orbital and nasal cavities.

Squama (*squama frontalis*).—Surfaces.—The **external surface** (Fig. 134) of this portion is convex and usually exhibits, in the lower part of the middle line, the remains of the **frontal** or **metopic suture;** in infancy this suture divides the bone into two, a condition which may persist throughout life. On either side of this suture, about 3 cm. above the supraorbital margin, is a rounded elevation, the **frontal eminence** (*tuber frontale*). These eminences vary in size in different individuals, are occasionally unsymmetrical, and are especially prominent in young skulls; the surface of the bone above them is smooth, and covered by the galea aponeurotica. Below the frontal eminences, and separated from them by a shallow groove, are two arched elevations, the **superciliary arches;** these are prominent medially, and are joined to one another by a smooth elevation named the **glabella.** They are larger in the male than in the female, and their degree of prominence depends to some extent on the size of the frontal air sinuses; 28 prominent ridges are, however, occasionally associated with small air sinuses. Beneath each superciliary arch is a curved and prominent margin, the **supraorbital margin,** which forms the upper boundary of the base of the orbit, and separates the squama from the orbital portion of the bone. The lateral part of this margin is sharp and prominent, affording to the eye, in that situation, considerable protection from injury; the medial part is rounded. At the junction of its medial and intermediate thirds is a notch, sometimes converted into a foramen, the **supraorbital notch** or **foramen,** which transmits the supraorbital vessels and nerve. A small aperture in the upper part of the notch transmits a vein from the diploë to join the supraorbital vein. The supraorbital margin ends laterally in the **zygomatic process,** which is strong and prominent, and articulates with the zygomatic bone. Running upward and backward from this process is a well-marked line, the **temporal line,** which divides into the **upper** and **lower temporal lines,** continuous, in the articulated skull, with the corresponding lines on the parietal bone. The area below and behind the temporal line forms the anterior part of the temporal fossa, and gives origin to the Temporalis muscle. Between the supraorbital margins the squama projects downward to a level below that of the zygomatic processes; this portion is known as the **nasal part** and presents a rough, uneven interval, the **nasal notch,** which articulates on either side of the middle line with the nasal bone, and laterally with the frontal process of the maxilla and with the lacrimal. The term **nasion** is applied to the middle of the frontonasal suture. From the center of the notch the **nasal process** projects downward and forward beneath the nasal bones and frontal processes of the maxillæ, and supports the bridge of the nose. The nasal process ends below in a sharp **spine,** and on either side of this is a small grooved surface which enters into the formation of the roof of the corresponding nasal cavity. The spine forms part of the septum of the nose, articulating in front with the crest of the nasal bones and behind with the perpendicular plate of the ethmoid. 2

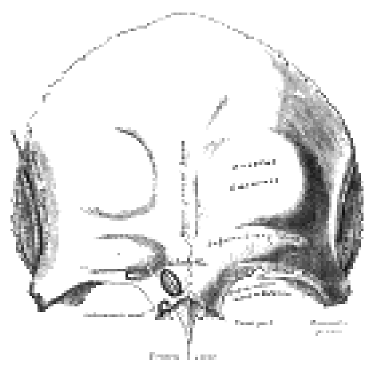

FIG. 134– Frontal bone. Outer surface. (See enlarged image)

The **internal surface** (Fig. 135) of the squama is concave and presents in the upper part of the middle line a vertical groove, the **sagittal sulcus,** the edges of which unite below to form a ridge, the **frontal crest;** the sulcus lodges the superior sagittal sinus, while its margins and the crest afford attachment to the falx cerebri. The crest ends below in a small notch which is converted into a foramen, the **foramen cecum,** by articulation with the ethmoid. This foramen varies in size in different subjects, and is frequently impervious; when open, it transmits a vein from the nose to the superior sagittal sinus. On either side of the middle line the bone presents depressions for the convolutions of the brain, and numerous small furrows for the anterior branches of the middle meningeal vessels. Several small, irregular fossæ may also be seen on either side of the sagittal sulcus, for the reception of the arachnoid granulations. 3

Orbital or Horizontal Part (*pars orbitalis*).—This portion consists of two thin triangular plates, the **orbital plates,** which form the vaults of the orbits, and are separated from one another by a median gap, the **ethmoidal notch.** 4

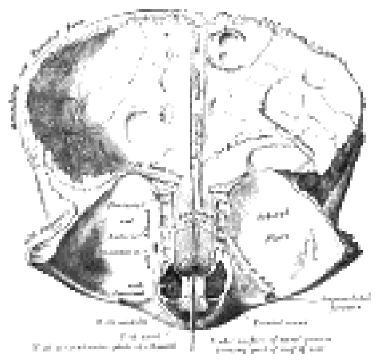

FIG. 135– Frontal bone. Inner surface. (See enlarged image)

Surfaces.—The **inferior surface** (Fig. 135) of each orbital plate is smooth and concave, and presents, laterally, under cover of the zygomatic process, a shallow depression, the **lacrimal fossa,** for the lacrimal gland; near the nasal part is a depression, the **fovea trochlearis,** or occasionally a small **trochlear spine,** for the attachment of the cartilaginous pulley of the Obliquus oculi superior. The **superior surface** is convex, and marked by depressions for the convolutions of the frontal lobes of the brain, and faint grooves for the meningeal branches of the ethmoidal vessels. *5*

The **ethmoidal notch** separates the two orbital plates; it is quadrilateral, and filled, in the articulated skull, by the cribriform plate of the ethmoid. The margins of the notch present several half-cells which, when united with corresponding half-cells on the upper surface of the ethmoid, complete the ethmoidal air cells. Two grooves cross these edges transversely; they are converted into the **anterior** and **posterior ethmoidal canals** by the ethmoid, and open on the medial wall of the orbit. The anterior canal transmits the nasociliary nerve and anterior ethmoidal vessels, the posterior, the posterior ethmoidal nerve and vessels. In front of the ethmoidal notch, on either side of the frontal spine, are the openings of the **frontal air sinuses.** These are two irregular cavities, which extend backward, upward, and lateralward for a variable distance between the two tables of the skull; they are separated from one another by a thin bony septum, which often deviates to one or other side, with the result that the sinuses are rarely symmetrical. Absent at birth, they are usually fairly well-developed between the seventh and eighth years, but only reach their full size after puberty. They vary in size in different persons, and are larger in men than in women. 29 They are lined by mucous membrane, and each communicates with the corresponding nasal cavity by means of a passage called the **frontonasal duct.** *6*

Borders.—The **border of the squama** is thick, strongly serrated, bevelled at the expense of the inner table above, where it rests upon the parietal bones, and at the expense of the outer table on either side, where it receives the lateral pressure of those bones; this border is continued below into a triangular, rough surface, which articulates with the great wing of the sphenoid. The **posterior borders of the orbital plates** are thin and serrated, and articulate with the small wings of the sphenoid. *7*

Structure.—The squama and the zygomatic processes are very thick, consisting of diploic tissue contained between two compact laminæ; the diploic tissue is absent in the regions occupied by the frontal air sinuses. The orbital portion is thin, translucent, and composed entirely of compact bone; hence the facility with which instruments can penetrate the cranium through this part of the orbit; when the frontal sinuses are exceptionally large they may extend backward for a considerable distance into the orbital portion, which in such cases also consists of only two tables. *8*

Ossification (Fig. 136).—The frontal bone is ossified in membrane from *two primary* centers, one for each half, which appear toward the end of the second month of fetal life, one above each supraorbital margin. From each of these centers ossification extends upward to form the corresponding half of the squama, and backward to form the orbital plate. The spine is ossified from a pair of *secondary* centers, on either side of the middle line; similar centers appear in the nasal part and zygomatic processes. At birth the bone consists of two pieces, separated by the frontal suture, which is usually obliterated, except at its lower part, by the eighth year, but occasionally persists throughout life. It is generally maintained that the development of the frontal sinuses begins at the end of the first or beginning of the second year, but Onodi's researches indicate that development begins at birth. The sinuses are of considerable size by the seventh or eighth year, but do not attain their full proportions until after puberty. *9*

Articulations.—The frontal articulates with *twelve* bones: the sphenoid, the ethmoid, the two parietals, the two nasals, the two maxillæ, the two lacrimals, and the two zygomatics. *10*

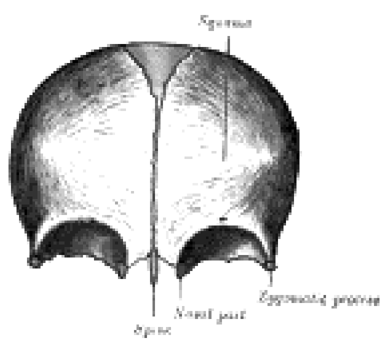

FIG. 136– Frontal bone at birth. (See enlarged image)

Note 28. Some confusion is occasioned to students commencing the study of anatomy by the name "sinus" having been given to two different kinds of space connected with the skull. It may be as well, therefore, to state here that the "sinuses" in the interior of the cranium which produce the grooves on the inner surfaces of the bones are venous channels which convey the blood from the brain, while the "sinuses" external to the cranial cavity (the frontal, sphenoidal, ethmoidal, and maxillary) are hollow spaces in the bones themselves; they communicate with the nasal cavities and contain air. [back]

Note 29. Aldren Turner (The Accessory Sinuses of the Nose, 1901) gives the following measurements for a sinus of average size: height, 1 1/4 inches; breadth, 1 inch; depth from before backward, 1 inch. [back]

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

5a. 4. The Temporal Bone

(Os Temporale) 1

The **temporal bones** are situated at the sides and base of the skull. Each consists of five parts, viz., the **squama,** the **petrous, mastoid,** and **tympanic parts,** and the **styloid process.**

The Squama (*squama temporalis*).—The squama forms the anterior and upper part of the bone, and is scale-like, thin, and translucent. 2

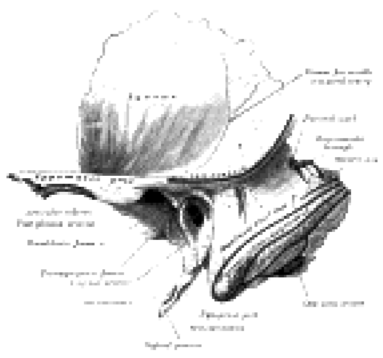

FIG. 137– Left temporal bone. Outer surface. (See enlarged image)

Surfaces.—Its **outer surface** (Fig. 137) is smooth and convex; it affords attachment to the Temporalis muscle, and forms part of the temporal fossa; on its hinder part is a vertical groove for the middle temporal artery. A curved line, the **temporal line,** or **supramastoid crest,** runs backward and upward across its posterior part; it serves for the attachment of the temporal fascia, and limits the origin of the Temporalis muscle. The boundary between the squama and the mastoid portion of the bone, as indicated by traces of the original suture, lies about 1 cm. below this line. Projecting from the lower part of the squama is a long, arched process, the **zygomatic process.** This process is at first directed lateralward, its two surfaces looking upward and downward; it then appears as if twisted inward upon itself, and runs forward, its surfaces now looking medialward and lateralward. The superior border is long, thin, and sharp, and serves for the attachment of the temporal fascia; the inferior, short, thick, and arched, has attached to it some fibers of the Masseter. The lateral surface is convex and subcutaneous; the medial is concave, and affords attachment to the Masseter. The anterior end is deeply serrated and articulates with the zygomatic bone. The posterior end is connected to the squama by two roots, the **anterior** and **posterior roots.** The posterior root, a prolongation of the upper border, is strongly marked; it runs backward above the external acoustic meatus, and is continuous with the temporal line. The anterior root, continuous with the lower border, is short but broad and strong; it is directed medialward and ends in a rounded eminence, the **articular tubercle** (*eminentia articularis*). This tubercle forms the front boundary of the mandibular fossa, and in the fresh state is covered with cartilage. In front of the articular tubercle is a small triangular area which assists in forming the infratemporal fossa; this area is separated from the outer surface of the squama by a ridge which is continuous behind with the anterior root of the zygomatic process, and in front, in the articulated skull, with the infratemporal crest on the great wing of the sphenoid. Between the posterior wall of the external acoustic meatus and the posterior root of the zygomatic process is the area called the **suprameatal triangle** (Macewen), or **mastoid fossa,** through which an instrument may be pushed into the tympanic antrum. At the junction of the anterior root with the zygomatic process is a projection for the attachment of the temporomandibular ligament; and behind the anterior root is an oval depression, forming part of the mandibular fossa, for the reception of the condyle of the mandible. The **mandibular fossa** (*glenoid fossa*) is bounded, in front, by the articular tubercle; behind, by the tympanic part of the bone, which separates it from the external acoustic meatus; it is divided into two parts by a narrow slit, the **petrotympanic fissure** (*Glaserian fissure*). The anterior part, formed by the squama, is smooth, covered in the fresh state with cartilage, and articulates with the condyle of the mandible. Behind this part of the fossa is a small conical eminence; this is the representative of a prominent tubercle which, in some mammals, descends behind the condyle of the mandible, and prevents its backward displacement. The posterior part of the mandibular fossa, formed by the tympanic part of the bone, is non-articular, and sometimes lodges a portion of the parotid gland. The petrotympanic fissure leads into the middle ear or tympanic cavity; it lodges the anterior process of the malleus, and transmits the tympanic branch of the internal maxillary artery. The chorda tympani nerve passes through a canal (*canal of Huguier*), separated from the anterior edge of the petrotympanic fissure by a thin scale of bone and situated on the lateral side of the auditory tube, in the retiring angle between the squama and the petrous portion of the temporal. 3

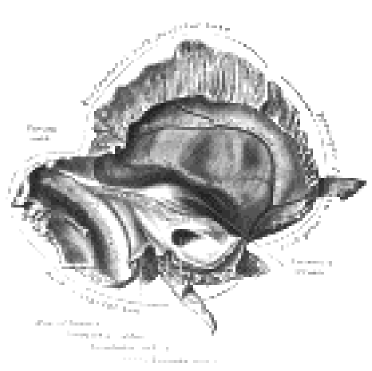

FIG. 138– Left temporal bone. Inner surface. (See enlarged image)

The **internal surface** of the squama (Fig. 138) is concave; it presents depressions corresponding to the 4
convolutions of the temporal lobe of the brain, and grooves for the branches of the middle meningeal vessels.

Borders.—The **superior border** is thin, and bevelled at the expense of the internal table, so as to overlap 5
the squamous border of the parietal bone, forming with it the squamosal suture. Posteriorly, the superior border forms an angle, the **parietal notch,** with the mastoid portion of the bone. The **antero-inferior border** is thick, serrated, and bevelled at the expense of the inner table above and of the outer below, for articulation with the great wing of the sphenoid.

Mastoid Portion (*pars mastoidea*).—The mastoid portion forms the posterior part of the bone. 6

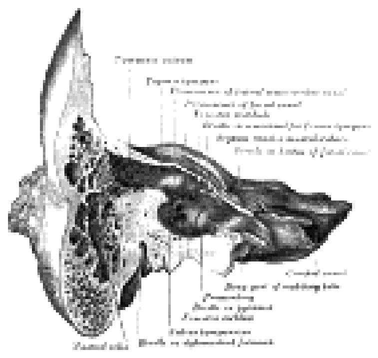

FIG. 139– Coronal section of right temporal bone. (See enlarged image)

Surfaces.—Its **outer surface** (Fig. 137) is rough, and gives attachment to the Occipitalis and Auricularis 7
posterior. It is perforated by numerous foramina; one of these, of large size, situated near the posterior border, is termed the **mastoid foramen;** it transmits a vein to the transverse sinus and a small branch of the occipital artery to the dura mater. The position and size of this foramen are very variable; it is not always present; sometimes it is situated in the occipital bone, or in the suture between the temporal and the occipital. The mastoid portion is continued below into a conical projection, the **mastoid process,** the size and form of which very somewhat; it is larger in the male than in the female. This process serves for the attachment of the Sternocleidomastoideus, Splenius capitis, and Longissimus capitis. On the medial side of the process is a deep groove, the **mastoid notch** (*digastric fossa*), for the attachment of the Digastricus; medial to this is a shallow furrow, the **occipital groove,** which lodges the occipital artery.

The **inner surface** of the mastoid portion presents a deep, curved groove, the **sigmoid sulcus,** which 8
lodges part of the transverse sinus; in it may be seen the opening of the mastoid foramen. The groove for the transverse sinus is separated from the innermost of the mastoid air cells by a very thin lamina of bone, and even this may be partly deficient.

Borders.—The **superior border** of the mastoid portion is broad and serrated, for articulation with the 9
mastoid angle of the parietal. The **posterior border,** also serrated, articulates with the inferior border of the occipital between the lateral angle and jugular process. Anteriorly the mastoid portion is fused with the descending process of the squama above; below it enters into the formation of the external acoustic meatus and the tympanic cavity.

A section of the mastoid process (Fig. 139) shows it to be hollowed out into a number of spaces, the 10
mastoid cells, which exhibit the greatest possible variety as to their size and number. At the upper and front part of the process they are large and irregular and contain air, but toward the lower part they diminish in size, while those at the apex of the process are frequently quite small and contain marrow; occasionally they are entirely absent, and the mastoid is then solid throughout. In addition to these a large irregular cavity is situated at the upper and front part of the bone. It is called the **tympanic antrum,** and must be distinguished from the mastoid cells, though it communicates with them. Like the mastoid cells it is filled with air and lined by a prolongation of the mucous membrane of the tympanic cavity, with which it communicates. The tympanic antrum is bounded above by a thin plate of bone, the **tegmen tympani,** which separates it from the middle fossa of the base of the skull; below by the mastoid process; laterally by the squama just below the temporal line, and medially by the lateral semicircular canal of the internal ear which projects into its cavity. It opens in front into that portion of the tympanic cavity which is known as the **attic** or **epitympanic recess.** The tympanic antrum is a cavity of some considerable size at the time of birth; the mastoid air cells may be regarded as diverticula from the antrum, and begin to appear at or before birth; by the fifth year they are well-marked, but their development is not completed until toward puberty.

Petrous Portion (*pars petrosa* [*pyramis*]).—The petrous portion or **pyramid** is pyramidal and is wedged in 11
at the base of the skull between the sphenoid and occipital. Directed medialward, forward, and a little upward, it presents for examination a base, an apex, three surfaces, and three angles, and contains, in its interior, the essential parts of the organ of hearing.

Base.—The base is fused with the internal surfaces of the squama and mastoid portion. 12

Apex.—The apex, rough and uneven, is received into the angular interval between the posterior border of 13
the great wing of the sphenoid and the basilar part of the occipital; it presents the anterior or internal orifice of the carotid canal, and forms the postero-lateral boundary of the foramen lacerum.

Surfaces.—The **anterior surface** forms the posterior part of the middle fossa of the base of the skull, and is 14
continuous with the inner surface of the squamous portion, to which it is united by the **petrosquamous suture,** remains of which are distinct even at a late period of life. It is marked by depressions for the convolutions of the brain, and presents six points for examination: (1) near the center, an **eminence** (*eminentia arcuata*) which indicates the situation of the superior semicircular canal; (2) in front of and a little lateral to this eminence, a depression indicating the position of the tympanic cavity: here the layer of bone which separates the tympanic from the cranial cavity is extremely thin, and is known as the **tegmen tympani;** (3) a shallow groove, sometimes double, leading lateralward and backward to an oblique opening, the **hiatus of the facial canal,** for the passage of the greater superficial petrosal nerve and the petrosal branch of the middle meningeal artery; (4) lateral to the hiatus, a smaller opening, occasionally seen, for the passage of the lesser superficial petrosal nerve; (5) near the apex of the bone, the termination of the carotid canal, the wall of which in this situation is deficient in front; (6) above this canal the shallow **trigeminal impression** for the reception of the semilunar ganglion.

The **posterior surface** (Fig. 138) forms the front part of the posterior fossa of the base of the skull, and is 15
continuous with the inner surface of the mastoid portion. Near the center is a large orifice, the **internal acoustic meatus,** the size of which varies considerably; its margins are smooth and rounded, and it leads into a short canal, about 1 cm. in length, which runs lateralward. It transmits the facial and acoustic nerves and the internal auditory branch of the basilar artery. The lateral end of the canal is closed by a vertical plate, which is divided by a horizontal crest, the **crista falciformis,** into two unequal portions (Fig. 140). Each portion is further subdivided by a vertical ridge into an anterior and a posterior part. In the portion beneath the crista falciformis are three sets of foramina; one group, just below the posterior part of the crest, situated in the **area cribrosa media,** consists of several small openings for the nerves to the saccule; below and behind this area is the **foramen singulare,** or opening for the nerve to the posterior semicircular duct; in front of and below the first is the **tractus spiralis foraminosus,** consisting of a number of small spirally arranged openings, which encircle the **canalis centralis cochleæ;** these openings together with this central canal transmit the nerves to the cochlea. The portion above the crista falciformis presents behind, the **area cribrosa superior,** pierced by a series of small openings, for the passage of the nerves to the utricle and the superior and lateral semicircular ducts, and, in front, the **area facians,** with one large opening, the commencement of the canal for the facial nerve (**aquæductus Fallopii**). Behind the internal acoustic meatus is a small slit almost hidden by a thin plate of bone, leading to a canal, the **aquæductus vestibuli,** which transmits the ductus endolymphaticus together with a small artery and vein. Above and between these two openings is an irregular depression which lodges a process of the dura mater and transmits a small vein; in the infant this depression is represented by a large fossa, the **subarcuate fossa,** which extends backward as a blind tunnel under the superior semicircular canal.

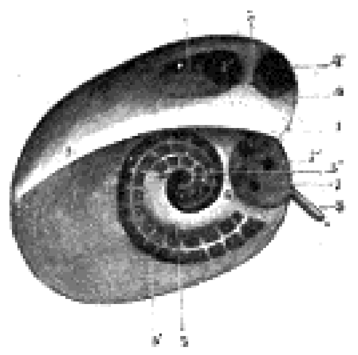

FIG. 140– Diagrammatic view of the fundus of the right internal acoustic meatus. (Testut.) 1. Crista falciformis. 2. Area facialis, with (2') internal opening of the facial canal. 3. Ridge separating the area facialis from the area cribrosa superior. 4. Area cribrosa superior, with (4') openings for nerve filaments. 5. Anterior inferior cribriform area, with (5') the tractus spiralis foraminosus, and (5'') the canalis centralis of the cochlea. 6. Ridge separating the tractus spiralis foraminosus from the area cribrosa media. 7. Area cribrosa media, with (7') orifices for nerves to saccule. 8. Foramen singulare. (See enlarged image)

The **inferior surface** (Fig. 141) is rough and irregular, and forms part of the exterior of the base of the skull. 16
It presents eleven points for examination: (1) near the apex is a rough surface, quadrilateral in form, which serves partly for the attachment of the Levator veli palatini and the cartilaginous portion of the auditory tube, and partly for connection with the basilar part of the occipital bone through the intervention of some dense fibrous tissue; (2) behind this is the large circular aperture of the **carotid canal,** which ascends at first vertically, and then, making a bend, runs horizontally forward and medialward; it transmits into the cranium the internal carotid artery, and the carotid plexus of nerves; (3) medial to the opening for the carotid canal and close to its posterior border, in front of the jugular fossa, is a triangular depression; at the apex of this is a small opening, the **aquæductus cochleæ,** which lodges a tubular prolongation of the dura mater establishing a communication between the perilymphatic space and the subarachnoid space, and transmits a vein from the cochlea to join the internal jugular; (4) behind these openings is a deep depression, the **jugular fossa,** of variable depth and size in different skulls; it lodges the bulb of the internal jugular vein; (5) in the bony ridge dividing the carotid canal from the jugular fossa is the small **inferior tympanic canaliculus** for the passage of the tympanic branch of the glossopharyngeal nerve; (6) in the lateral part of the jugular fossa is the **mastoid canaliculus** for the entrance of the auricular branch of the vagus nerve; (7) behind the jugular fossa is a quadrilateral area, the **jugular surface,** covered with cartilage in the fresh state, and articulating with the jugular process of the occipital bone; (8) extending backward from the carotid canal is the **vaginal process,** a sheath-like plate of bone, which divides behind into two laminæ; the lateral lamina is continuous with the tympanic part of the bone, the medial with the lateral margin of the jugular surface; (9) between these laminæ is the **styloid process,** a sharp spine, about 2.5 cm. in length; (10) between the styloid and mastoid processes is the **stylomastoid foramen;** it is the termination of the facial canal, and transmits the facial nerve and stylomastoid artery; (11) situated between the tympanic portion and the mastoid process is the tympanomastoid fissure, for the exit of the auricular branch of the vagus nerve.

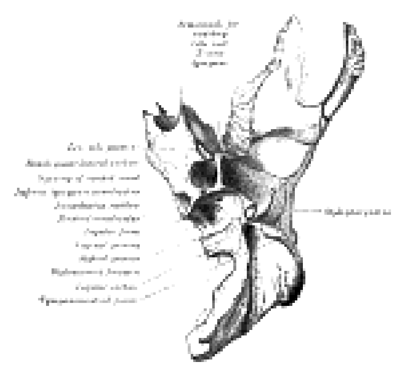

FIG. 141– Left temporal bone. Inferior surface. (See enlarged image)

Angles.—The **superior angle,** the longest, is grooved for the superior petrosal sinus, and gives attachment 17
to the tentorium cerebelli; at its medial extremity is a notch, in which the trigeminal nerve lies. The **posterior angle** is intermediate in length between the superior and the anterior. Its medial half is marked by a sulcus, which forms, with a corresponding sulcus on the occipital bone, the channel for the inferior petrosal sinus. Its lateral half presents an excavation—the **jugular fossa**—which, with the jugular notch on the occipital, forms the **jugular foramen;** an eminence occasionally projects from the center of the fossa, and divides the foramen into two. The **anterior angle** is divided into two parts—a lateral joined to the squama by a suture (*petrosquamous*), the remains of which are more or less distinct; a medial, free, which articulates with the spinous process of the sphenoid.

At the angle of junction of the petrous part and the squama are two canals, one above the other, and 18
separated by a thin plate of bone, the **septum canalis musculotubarii** (*processus cochleariformis*); both canals lead into the tympanic cavity. The upper one (*semicanalis m. tensoris tympani*) transmits the Tensor tympani, the lower one (*semicanalis tubæ auditivæ*) forms the bony part of the auditory tube.

The tympanic cavity, auditory ossicles, and internal ear, are described with the organ of hearing. 19

Tympanic Part (*pars tympanica*).—The tympanic part is a curved plate of bone lying below the squama and in front of the mastoid process. 20

Surfaces.—Its **postero-superior surface** is concave, and forms the anterior wall, the floor, and part of the posterior wall of the bony external acoustic meatus. Medially, it presents a narrow furrow, the **tympanic sulcus,** for the attachment of the tympanic membrane. Its **antero-inferior surface** is quadrilateral and slightly concave; it constitutes the posterior boundary of the mandibular fossa, and is in contact with the retromandibular part of the parotid gland. 21

Borders.—Its **lateral border** is free and rough, and gives attachment to the cartilaginous part of the external acoustic meatus. Internally, the tympanic part is fused with the petrous portion, and appears in the retreating angle between it and the squama, where it lies below and lateral to the orifice of the auditory tube. Posteriorly, it blends with the squama and mastoid part, and forms the anterior boundary of the tympanomastoid fissure. Its **upper border** fuses laterally with the back of the postglenoid process, while medially it bounds the petrotympanic fissure. The medial part of the **lower border** is thin and sharp; its lateral part splits to enclose the root of the styloid process, and is therefore named the **vaginal process.** The central portion of the tympanic part is thin, and in a considerable percentage of skulls is perforated by a hole, the **foramen of Huschke.** 22

The **external acoustic meatus** is nearly 2 cm. long and is directed inward and slightly forward: at the same time it forms a slight curve, so that the floor of the canal is convex upward. In sagittal section it presents an oval or elliptical shape with the long axis directed downward and slightly backward. Its anterior wall and floor and the lower part of its posterior wall are formed by the tympanic part; the roof and upper part of the posterior wall by the squama. Its inner end is closed, in the recent state, by the tympanic membrane; the upper limit of its outer orifice is formed by the posterior root of the zygomatic process, immediately below which there is sometimes seen a small spine, the **suprameatal spine,** situated at the upper and posterior part of the orifice. 23

Styloid Procéss (*processus styloideus*).—The styloid process is slender, pointed, and of varying length; it projects downward and forward, from the under surface of the temporal bone. Its proximal part (*tympanohyal*) is ensheathed by the vaginal process of the tympanic portion, while its distal part (*stylohyal*) gives attachment to the stylohyoid and stylomandibular ligaments, and to the Styloglossus, Stylohyoideus, and Stylopharyngeus muscles. The stylohyoid ligament extends from the apex of the process to the lesser cornu of the hyoid bone, and in some instances is partially, in others completely, ossified. 24

Structure.—The structure of the squama is like that of the other cranial bones: the mastoid portion is spongy, and the petrous portion dense and hard. 25

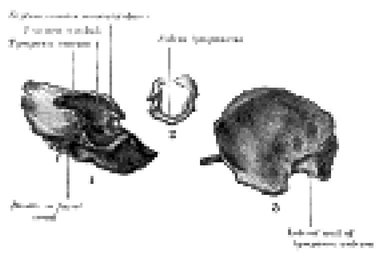

FIG. 142– The three principal parts of the tempora bone at birth. 1. Outer surface of petromastoid part. 2. Outer surface of tympanic ring. 3. Inner surface of squama. (See enlarged image)

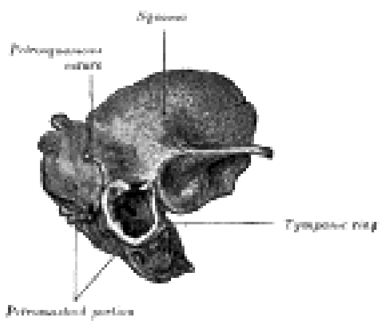

FIG. 143– Temporal bone at birth. Outer aspect. (See enlarged image)

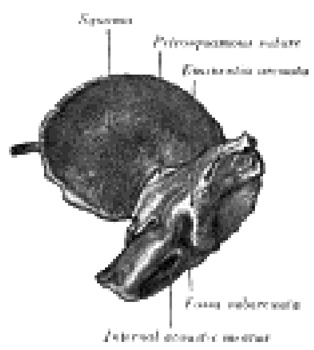

FIG. 144– Temporal bone at birth. Inner aspect. (See enlarged image)

Ossification.—The temporal bone is ossified from *eight* centers, exclusive of those for the internal ear and the tympanic ossicles, viz., one for the squama including the zygomatic process, one for the tympanic part, four for the petrous and mastoid parts, and two for the styloid process. Just before the close of fetal life (Fig. 142) the temporal bone consists of three principal parts: 1. The *squama* is ossified in membrane from a single nucleus, which appears near the root of the zygomatic process about the second month. 2. The *petromastoid* part is developed from four centers, which make their appearance in the cartilaginous ear capsule about the fifth or sixth month. One (*proötic*) appears in the neighborhood of the eminentia arcuata, spreads in front and above the internal acoustic meatus and extends to the apex of the bone; it forms part of the cochlea, vestibule, superior semicircular canal, and medial wall of the tympanic cavity. A second (*opisthotic*) appears at the promontory on the medial wall of the tympanic cavity and surrounds the fenestra cochleæ; it forms the floor of the tympanic cavity and vestibule, surrounds the carotid canal, invests the lateral and lower part of the cochlea, and spreads medially below the internal acoustic meatus. A third (*pterotic*) roofs in the tympanic cavity and antrum; while the fourth (*epiotic*) appears near the posterior semicircular canal and extends to form the mastoid process (Vrolik). 3. The *tympanic ring* is an incomplete circle, in the concavity of which is a groove, the tympanic sulcus, for the attachment of the circumference of the tympanic membrane. This ring expands to form the tympanic part, and is ossified in membrane from a single center which appears about the third month. The *styloid process* is developed from the proximal part of the cartilage of the second branchial or hyoid arch by two centers: one for the proximal part, the *tympanohyal,* appears before birth; the other, comprising the rest of the process, is named the *stylohyal,* and does not appear until after birth. The tympanic ring unites with the squama shortly before birth; the petromastoid part and squama join during the first year, and the tympanohyal portion of the styloid process about the same time (Figs. 143, 144). The stylohyal does not unite with the rest of the bone until after puberty, and in some skulls never at all. 26

The chief subsequent changes in the temporal bone apart from increase in size are: (1) The tympanic ring extends outward and backward to form the tympanic part. This extension does not, however, take place at an equal rate all around the circumference of the ring, but occurs most rapidly on its anterior and posterior portions, and these outgrowths meet and blend, and thus, for a time, there exists in the floor of the meatus a foramen, the *foramen of Huschke;* this foramen is usually closed about the fifth year, but may persist throughout life. (2) The mandibular fossa is at first extremely shallow, and looks lateralward as well as downward; it becomes deeper and is ultimately directed downward. Its change in direction is accounted for as follows. The part of the squama which forms the fossa lies at first below the level of the zygomatic process. As, however, the base of the skull increases in width, this lower part of the squama is directed horizontally inward to contribute to the middle fossa of the skull, and its surfaces therefore come to look upward and downward; the attached portion of the zygomatic process also becomes everted, and projects like a shelf at right angles to the squama. (3) The mastoid portion is at first quite flat, and the stylomastoid foramen and rudimentary styloid process lie immediately behind the tympanic ring. With the development of the air cells the outer part of the mastoid portion grows downward and forward to form the mastoid process, and the styloid process and stylomastoid foramen now come to lie on the under surface. The descent of the foramen is necessarily accompanied by a corresponding lengthening of the facial canal. (4) The downward and forward growth of the mastoid process also pushes forward the tympanic part, so that the portion of it which formed the original floor of the meatus and contained the foramen of Huschke is ultimately found in the anterior wall. (5) The fossa subarcuata becomes filled up and almost obliterated. 27

Articulations.—The temporal articulates with *five* bones: occipital, parietal, sphenoid, mandible and zygomatic. 28

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

5a. 5. The Sphenoid Bone

(Os Sphenoidale) 1

The **sphenoid bone** is situated at the base of the skull in front of the temporals and basilar part of the occipital. It somewhat resembles a bat with its wings extended, and is divided into a median portion or body, two great and two small wings extending outward from the sides of the body, and two pterygoid processes which project from it below.

Body (*corpus sphenoidale*).—The body, more or less cubical in shape, is hollowed out in its interior to form 2
two large cavities, the **sphenoidal air sinuses,** which are separated from each other by a septum.

Surfaces.—The **superior surface** of the body (Fig. 145) presents in front a prominent spine, the **ethmoidal** 3
spine, for articulation with the cribriform plate of the ethmoid; behind this is a smooth surface slightly raised in the middle line, and grooved on either side for the olfactory lobes of the brain. This surface is bounded behind by a ridge, which forms the anterior border of a narrow, transverse groove, the **chiasmatic groove** (*optic groove*), above and behind which lies the optic chiasma; the groove ends on either side in the **optic foramen,** which transmits the optic nerve and ophthalmic artery into the orbital cavity. Behind the chiasmatic groove is an elevation, the **tuberculum sellæ;** and still more posteriorly, a deep depression, the **sella turcica,** the deepest part of which lodges the hypophysis cerebri and is known as the **fossa hypophyseos.** The anterior boundary of the sella turcica is completed by two small eminences, one on either side, called the **middle clinoid processes,** while the posterior boundary is formed by a square-shaped plate of bone, the **dorsum sellæ,** ending at its superior angles in two tubercles, the **posterior clinoid processes,** the size and form of which vary considerably in different individuals. The posterior clinoid processes deepen the sella turcica, and give attachment to the tentorium cerebelli. On either side of the dorsum sellæ is a notch for the passage of the abducent nerve, and below the notch a sharp process, the **petrosal process,** which articulates with the apex of the petrous portion of the temporal bone, and forms the medial boundary of the foramen lacerum. Behind the dorsum sellæ is a shallow depression, the **clivus,** which slopes obliquely backward, and is continuous with the groove on the basilar portion of the occipital bone; it supports the upper part of the pons.

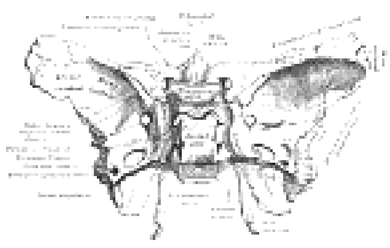

FIG. 145– Sphenoid bone. Upper surface. (See enlarged image)

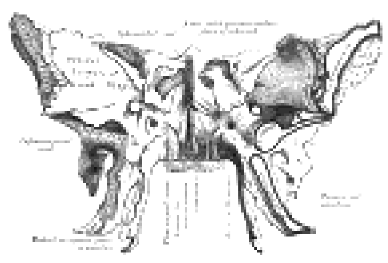

FIG. 146– Sphenoid bone. Anterior and inferior surfaces. (See enlarged image)

The **lateral surfaces** of the body are united with the great wings and the medial pterygoid plates. Above 4
the attachment of each great wing is a broad groove, curved something like the italic letter *f;* it lodges the internal carotid artery and the cavernous sinus, and is named the **carotid groove.** Along the posterior part of the lateral margin of this groove, in the angle between the body and great wing, is a ridge of bone, called the **lingula.**

The **posterior surface,** quadrilateral in form (Fig. 147), is joined, during infancy and adolescence, to the 5
basilar part of the occipital bone by a plate of cartilage. Between the eighteenth and twenty-fifth years this becomes ossified, ossification commencing above and extending downward.

6 The **anterior surface** of the body (Fig. 146) presents, in the middle line, a vertical crest, the **sphenoidal crest,** which articulates with the perpendicular plate of the ethmoid, and forms part of the septum of the nose. On either side of the crest is an irregular opening leading into the corresponding **sphenoidal air sinus.** These sinuses are two large, irregular cavities hollowed out of the interior of the body of the bone, and separated from one another by a bony septum, which is commonly bent to one or the other side. They vary considerably in form and size, 30 are seldom symmetrical, and are often partially subdivided by irregular bony laminæ. Occasionally, they extend into the basilar part of the occipital nearly as far as the foramen magnum. They begin to be developed before birth, and are of a considerable size by the age of six. They are partially closed, in front and below, by two thin, curved plates of bone, the **sphenoidal conchæ** (see page 152), leaving in the articulated skull a round opening at the upper part of each sinus by which it communicates with the upper and back part of the nasal cavity and occasionally with the posterior ethmoidal air cells. The lateral margin of the anterior surface is serrated, and articulates with the lamina papyracea of the ethmoid, completing the posterior ethmoidal cells; the lower margin articulates with the orbital process of the palatine bone, and the upper with the orbital plate of the frontal bone.

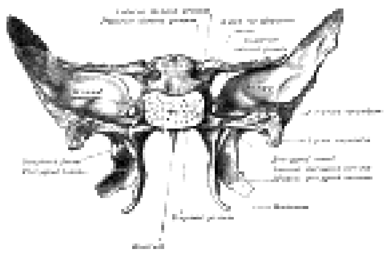

Fig. 147– Sphenoid bone. Upper and posterior surfaces. (See enlarged image)

7 The **inferior surface** presents, in the middle line, a triangular spine, the **sphenoidal rostrum,** which is continuous with the sphenoidal crest on the anterior surface, and is received in a deep fissure between the alæ of the vomer. On either side of the rostrum is a projecting lamina, the **vaginal process,** directed medialward from the base of the medial pterygoid plate, with which it will be described.

8 **The Great Wings (*alæ magnæ*).**—The great wings, or **ali-sphenoids,** are two strong processes of bone, which arise from the sides of the body, and are curved upward, lateralward, and backward; the posterior part of each projects as a triangular process which fits into the angle between the squama and the petrous portion of the temporal and presents at its apex a downwardly directed process, the **spina angularis** (*sphenoidal spine*).

9 **Surfaces.**—The **superior** or **cerebral surface** of each great wing (Fig. 145) forms part of the middle fossa of the skull; it is deeply concave, and presents depressions for the convolutions of the temporal lobe of the brain. At its anterior and medial part is a circular aperture, the **foramen rotundum,** for the transmission of the maxillary nerve. Behind and lateral to this is the **foramen ovale,** for the transmission of the mandibular nerve, the accessory meningeal artery, and sometimes the lesser superficial petrosal nerve. 31 Medial to the foramen ovale, a small aperture, the **foramen Vesalii,** may occasionally be seen opposite the root of the pterygoid process; it opens below near the scaphoid fossa, and transmits a small vein from the cavernous sinus. Lastly, in the posterior angle, near to and in front of the spine, is a short canal, sometimes double, the **foramen spinosum,** which transmits the middle meningeal vessels and a recurrent branch from the mandibular nerve.

10 The **lateral surface** (Fig. 146) is convex, and divided by a transverse ridge, the **infratemporal crest,** into two portions. The superior or temporal portion, convex from above downward, concave from before backward, forms a part of the temporal fossa, and gives attachment to the Temporalis; the inferior or infratemporal, smaller in size and concave, enters into the formation of the infratemporal fossa, and, together with the infratemporal crest, affords attachment to the Pterygoideus externus. It is pierced by the foramen ovale and foramen spinosum, and at its posterior part is the spina angularis, which is frequently grooved on its medial surface for the chorda tympani nerve. To the spina angularis are attached the sphenomandibular ligament and the Tensor veli palatini. Medial to the anterior extremity of the infratemporal crest is a triangular process which serves to increase the attachment of the Pterygoideus externus; extending downward and medialward from this process on to the front part of the lateral pterygoid plate is a ridge which forms the anterior limit of the infratemporal surface, and, in the articulated skull, the posterior boundary of the pterygomaxillary fissure.

11 The **orbital surface** of the great wing (Fig. 146), smooth, and quadrilateral in shape, is directed forward and medialward and forms the posterior part of the lateral wall of the orbit. Its upper serrated edge articulates with the orbital plate of the frontal. Its inferior rounded border forms the postero-lateral boundary of the inferior orbital fissure. Its medial sharp margin forms the lower boundary of the superior orbital fissure and has projecting from about its center a little tubercle which gives attachment to the inferior head of the Rectus lateralis oculi; at the upper part of this margin is a notch for the transmission of a recurrent branch of the lacrimal artery. Its lateral margin is serrated and articulates with the zygomatic bone. Below the medial end of the superior orbital fissure is a grooved surface, which forms the posterior wall of the pterygopalatine fossa, and is pierced by the foramen rotundum.

12 **Margin (Fig. 145).**—Commencing from behind, that portion of the circumference of the great wing which extends from the body to the spine is irregular. Its medial half forms the anterior boundary of the foramen lacerum, and presents the posterior aperture of the pterygoid canal for the passage of the corresponding nerve and artery. Its lateral half articulates, by means of a synchondrosis, with the petrous portion of the temporal, and between the two bones on the under surface of the skull, is a furrow, the **sulcus tubæ,** for the lodgement of the cartilaginous part of the auditory tube. In front of the spine the circumference presents a concave, serrated edge, bevelled at the expense of the inner table below, and of the outer table above, for articulation with the temporal squama. At the tip of the great wing is a triangular portion, bevelled at the expense of the internal surface, for articulation with the sphenoidal angle of the parietal bone; this region is named the **pterion.** Medial to this is a triangular, serrated surface, for articulation with the frontal bone; this surface is continuous medially with the sharp edge, which forms the lower boundary of the superior orbital fissure, and laterally with the serrated margin for articulation with the zygomatic bone.

13 **The Small Wings (*alæ parvæ*).**—The small wings or **orbito-sphenoids** are two thin triangular plates, which arise from the upper and anterior parts of the body, and, projecting lateralward, end in sharp points (Fig. 145).

Surfaces.—The **superior surface** of each is flat, and supports part of the frontal lobe of the brain. The **inferior surface** forms the back part of the roof of the orbit, and the upper boundary of the **superior orbital fissure.** This fissure is of a triangular form, and leads from the cavity of the cranium into that of the orbit: it is bounded *medially* by the body; *above,* by the small wing; *below,* by the medial margin of the orbital surface of the great wing; and is completed *laterally* by the frontal bone. It transmits the oculomotor, trochlear, and abducent nerves, the three branches of the ophthalmic division of the trigeminal nerve, some filaments from the cavernous plexus of the sympathetic, the orbital branch of the middle meningeal artery, a recurrent branch from the lacrimal artery to the dura mater, and the ophthalmic vein. 14

Borders.—The **anterior border** is serrated for articulation with the frontal bone. The **posterior border,** smooth and rounded, is received into the lateral fissure of the brain; the medial end of this border forms the **anterior clinoid process,** which gives attachment to the tentorium cerebelli; it is sometimes joined to the middle clinoid process by a spicule of bone, and when this occurs the termination of the groove for the internal carotid artery is converted into a foramen (*carotico-clinoid*). The small wing is connected to the body by two roots, the upper thin and flat, the lower thick and triangular; between the two roots is the **optic foramen,** for the transmission of the optic nerve and ophthalmic artery. 15

Pterygoid Processes (*processus pterygoidei*).—The pterygoid processes, one on either side, descend perpendicularly from the regions where the body and great wings unite. Each process consists of a medial and a lateral plate, the upper parts of which are fused anteriorly; a vertical sulcus, the **pterygopalatine groove,** descends on the front of the line of fusion. The plates are separated below by an angular cleft, the **pterygoid fissure,** the margins of which are rough for articulation with the pyramidal process of the palatine bone. The two plates diverge behind and enclose between them a V-shaped fossa, the **pterygoid fossa,** which contains the Pterygoideus internus and Tensor veli palatini. Above this fossa is a small, oval, shallow depression, the **scaphoid fossa,** which gives origin to the Tensor veli palatini. The anterior surface of the pterygoid process is broad and triangular near its root, where it forms the posterior wall of the pterygopalatine fossa and presents the anterior orifice of the pterygoid canal. 16

Lateral Pterygoid Plate.—The **lateral pterygoid plate** is broad, thin, and everted; its **lateral surface** forms part of the medial wall of the infratemporal fossa, and gives attachment to the Pterygoideus externus; its **medial surface** forms part of the pterygoid fossa, and gives attachment to the Pterygoideus internus. 17

Medial Pterygoid Plate.—The medial pterygoid plate is narrower and longer than the lateral; it curves lateralward at its lower extremity into a hook-like process, the **pterygoid hamulus,** around which the tendon of the Tensor veli palatini glides. The **lateral surface** of this plate forms part of the pterygoid fossa, the **medial surface** constitutes the lateral boundary of the choana or posterior aperture of the corresponding nasal cavity. Superiorly the medial plate is prolonged on to the under surface of the body as a thin lamina, named the **vaginal process,** which articulates in front with the sphenoidal process of the palatine and behind this with the ala of the vomer. The angular prominence between the posterior margin of the vaginal process and the medial border of the scaphoid fossa is named the **pterygoid tubercle,** and immediately above this is the posterior opening of the pterygoid canal. On the under surface of the vaginal process is a furrow, which is converted into a canal by the sphenoidal process of the palatine bone, for the transmission of the pharyngeal branch of the internal maxillary artery and the pharyngeal nerve from the sphenopalatine ganglion. The pharyngeal aponeurosis is attached to the entire length of the posterior edge of the medial plate, and the Constrictor pharyngis superior takes origin from its lower third. Projecting backward from near the middle of the posterior edge of this plate is an angular process, the **processus tubarius,** which supports the pharyngeal end of the auditory tube. The anterior margin of the plate articulates with the posterior border of the vertical part of the palatine bone. 18

The Sphenoidal Conchæ (*conchæ sphenoidales; sphenoidal turbinated processes*).—The sphenoidal conchæ are two thin, curved plates, situated at the anterior and lower part of the body of the sphenoid. An aperture of variable size exists in the anterior wall of each, and through this the sphenoidal sinus opens into the nasal cavity. Each is irregular in form, and tapers to a point behind, being broader and thinner in front. Its upper surface is concave, and looks toward the cavity of the sinus; its under surface is convex, and forms part of the roof of the corresponding nasal cavity. Each bone articulates in front with the ethmoid, laterally with the palatine; its pointed posterior extremity is placed above the vomer, and is received between the root of the pterygoid process laterally and the rostrum of the sphenoid medially. A small portion of the sphenoidal concha sometimes enters into the formation of the medial wall of the orbit, between the lamina papyracea of the ethmoid in front, the orbital plate of the palatine below, and the frontal bone above. 19

Ossification.—Until the seventh or eighth month of fetal life the body of the sphenoid consists of two parts, viz., one in front of the tuberculum sellæ, the *presphenoid,* with which the small wings are continuous; the other, comprising the sella turcica and dorsum sellæ, the *postsphenoid,* with which are associated the great wings, and pterygoid processes. The greater part of the bone is ossified in cartilage. There are fourteen centers in all, *six* for the presphenoid and *eight* for the postsphenoid. 20

FIG. 148– Sphenoid bone at birth. Posterior aspect. (See enlarged image)

Presphenoid.—About the ninth week of fetal life an ossific center appears for each of the small wings (orbitosphenoids) just lateral to the optic foramen; shortly afterward two nuclei appear in the presphenoid part of the body. The sphenoidal conchæ are each developed from a center which makes its appearance about the fifth month; 32 at birth they consist of small triangular laminæ, and it is not until the third year that they become hollowed out and coneshaped; about the fourth year they fuse with the labyrinths of the ethmoid, and between the ninth and twelfth years they unite with the sphenoid. 21

Postsphenoid.—The first ossific nuclei are those for the great wings (ali-sphenoids) 33. One makes its appearance in each wing between the foramen rotundum and foramen ovale about the eighth week. The orbital plate and that part of the sphenoid which is found in the temporal fossa, as well as the lateral pterygoid plate, are ossified in membrane (Fawcett) 34. Soon after, the centers for the postsphenoid part of the body appear, one on either side of the sella turcica, and become blended together about the middle of fetal life. Each medial pterygoid plate (with the exception of its hamulus) is ossified in membrane, and its center probably appears about the ninth or tenth week; the hamulus becomes chondrified during the third month, and almost at once undergoes ossification (Fawcett). 35 The medial joins the lateral pterygoid plate about the sixth month. About the fourth month a center appears for each lingula and speedily joins the rest of the bone. 22

The presphenoid is united to the postsphenoid about the eighth month, and at birth the bone is in three pieces (Fig. 148): a central, consisting of the body and small wings, and two lateral, each comprising a great wing and pterygoid process. In the first year after birth the great wings and body unite, and the small wings extend inward above the anterior part of the body, and, meeting with each other in the middle line, form an elevated smooth surface, termed the *jugum sphenoidale.* By the twenty-fifth year the sphenoid and occipital are completely fused. Between the pre- and postsphenoid there are occasionally seen the remains of a canal, the *canalis cranio-pharyngeus,* through which, in early fetal life, the hypophyseal diverticulum of the buccal ectoderm is transmitted. 23

The sphenoidal sinuses are present as minute cavities at the time of birth (Onodi), but do not attain their full size until after puberty. 24

Intrinsic Ligaments of the Sphenoid.—The more important of these are: the *pterygospinous,* stretching between the spina angularis and the lateral pterygoid plate (see *cervical fascia*); the *interclinoid,* a fibrous process joining the anterior to the posterior clinoid process; and the *caroticoclinoid,* connecting the anterior to the middle clinoid process. These ligaments occasionally ossify. 25

Articulations.—The sphenoid articulates with *twelve* bones: four single, the vomer, ethmoid, frontal, and occipital; and four paired, the parietal, temporal, zygomatic, and palatine. 36 26

Note 30. Aldren Turner (*op. cit.*) gives the following as their average measurements: vertical height, 7/8 inch; antero-posterior depth, 7/8 inch; transverse breadth, 3/4 inch. [back]

Note 31. The lesser superficial petrosal nerve sometimes passes through a special canal (*canaliculus innominatus* of Arnold) situated medial to the foramen spinosum. [back]

Note 32. According to Cleland, each sphenoidal concha is ossified from four centers. [back]

Note 33. Mall, Am. Jour. Anat., 1906, states that the pterygoid center appears first in an embryo fifty-seven days old. [back]

Note 34. Journal of Anatomy and Physiology, 1910, vol. xliv. [back]

Note 35. Anatomischer Anzeiger, March, 1905. [back]

Note 36. It also sometimes articulates with the tuberosity of the maxilla (see page 159). [back]

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

5a. 6. Ethmoid bone

(Os Ethmoidale) 1

The **ethmoid bone** is exceedingly light and spongy, and cubical in shape; it is situated at the anterior part of the base of the cranium, between the two orbits, at the roof of the nose, and contributes to each of these cavities. It consists of four parts: a **horizontal** or **cribriform plate,** forming part of the base of the cranium; a **perpendicular plate,** constituting part of the nasal septum; and two **lateral masses** or labyrinths.

Cribiform Plate (*lamina cribrosa; horizontal lamina*).—The cribriform plate (Fig. 149) is received into the ethmoidal notch of the frontal bone and roofs in the nasal cavities. Projecting upward from the middle line of this plate is a thick, smooth, triangular process, the **crista galli,** so called from its resemblance to a cock's comb. The long thin posterior border of the crista galli serves for the attachment of the falx cerebri. Its anterior border, short and thick, articulates with the frontal bone, and presents two small projecting **alæ,** which are received into corresponding depressions in the frontal bone and complete the foramen cecum. Its sides are smooth, and sometimes bulging from the presence of a small air sinus in the interior. On either side of the crista galli, the cribriform plate is narrow and deeply grooved; it supports the olfactory bulb and is perforated by foramina for the passage of the olfactory nerves. The foramina in the middle of the groove are small and transmit the nerves to the roof of the nasal cavity; those at the medial and lateral parts of the groove are larger—the former transmit the nerves to the upper part of the nasal septum, the latter those to the superior nasal concha. At the front part of the cribriform plate, on either side of the crista galli, is a small fissure which is occupied by a process of dura mater. Lateral to this fissure is a notch or foramen which transmits the nasociliary nerve; from this notch a groove extends backward to the anterior ethmoidal foramen. 2

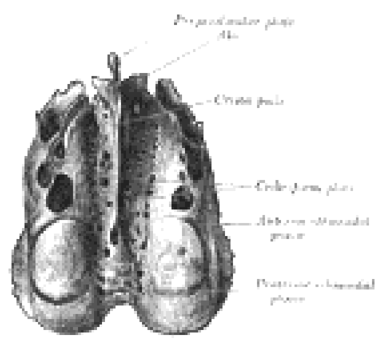

FIG. 149– Ethmoid bone from above. (See enlarged image)

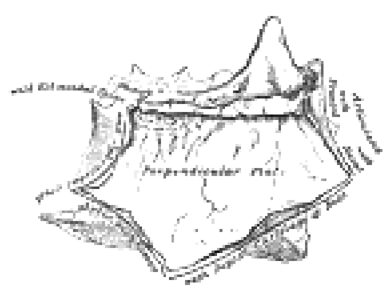

FIG. 150– Perpendicular plate of ethmoid. Shown by removing the right labyrinth. (See enlarged image)

Perpendicular Plate (*lamina perpendicularis; vertical plate*).—The perpendicular plate (Figs. 150, 151) is a thin, flattened lamina, polygonal in form, which descends from the under surface of the cribriform plate, and assists in forming the septum of the nose; it is generally deflected a little to one or other side. The **anterior border** articulates with the spine of the frontal bone and the crest of the nasal bones. The **posterior border** articulates by its upper half with the sphenoidal crest, by its lower with the vomer. The **inferior border** is thicker than the posterior, and serves for the attachment of the septal cartilage of the nose. The surfaces of the plate are smooth, except above, where numerous grooves and canals are seen; these lead from the medial foramina on the cribriform plate and lodge filaments of the olfactory nerves. 3

The **Labyrinth** or **Lateral Mass** (*labyrinthus ethmoidalis*) consists of a number of thin-walled cellular cavities, the **ethmoidal cells,** arranged in three groups, *anterior, middle,* and *posterior,* and interposed between two vertical plates of bone; the lateral plate forms part of the orbit, the medial, part of the corresponding nasal cavity. In the disarticulated bone many of these cells are opened into, but when the bones are articulated, they are closed in at every part, except where they open into the nasal cavity. 4

Surfaces.—The **upper surface** of the labyrinth (Fig. 149) presents a number of half-broken cells, the walls of which are completed, in the articulated skull, by the edges of the ethmoidal notch of the frontal bone. Crossing this surface are two grooves, converted into canals by articulation with the frontal; they are the **anterior** and **posterior ethmoidal canals,** and open on the inner wall of the orbit. The **posterior surface** presents large irregular cellular cavities, which are closed in by articulation with the sphenoidal concha and orbital process of the palatine. The **lateral surface** (Fig. 152) is formed of a thin, smooth, oblong plate, the **lamina papyracea** (*os planum*), which covers in the middle and posterior ethmoidal cells and forms a large part of the medial wall of the orbit; it articulates above with the orbital plate of the frontal bone, below with the maxilla and orbital process of the palatine, in front with the lacrimal, and behind with the sphenoid. 5

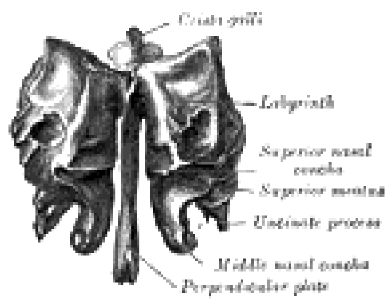

FIG. 151– Ethmoid bone from behind. (See enlarged image)

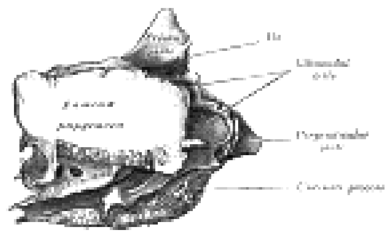

FIG. 152– Ethmoid bone from the right side. (See enlarged image)

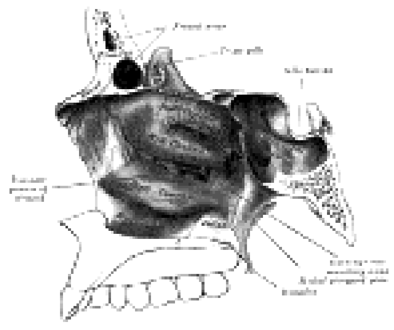

FIG. 153– Lateral wall of nasal cavity, showing ethmoid bone in position. (See enlarged image)

In front of the lamina papyracea are some broken air cells which are overlapped and completed by the lacrimal bone and the frontal process of the maxilla. A curved lamina, the **uncinate process,** projects downward and backward from this part of the labyrinth; it forms a small part of the medial wall of the maxillary sinus, and articulates with the ethmoidal process of the inferior nasal concha. *6*

The **medial surface** of the labyrinth (Fig. 153) forms part of the lateral wall of the corresponding nasal cavity. It consists of a thin lamella, which descends from the under surface of the cribriform plate, and ends below in a free, convoluted margin, the **middle nasal concha.** It is rough, and marked above by numerous grooves, directed nearly vertically downward from the cribriform plate; they lodge branches of the olfactory nerves, which are distributed to the mucous membrane covering the superior nasal concha. The back part of the surface is subdivided by a narrow oblique fissure, the **superior meatus** of the nose, bounded above by a thin, curved plate, the **superior nasal concha;** the posterior ethmoidal cells open into this meatus. Below, and in front of the superior meatus, is the convex surface of the middle nasal concha; it extends along the whole length of the medial surface of the labyrinth, and its lower margin is free and thick. The lateral surface of the middle concha is concave, and assists in forming the **middle meatus** of the nose. The middle ethmoidal cells open into the central part of this meatus, and a sinuous passage, termed the **infundibulum,** extends upward and forward through the labyrinth and communicates with the anterior ethmoidal cells, and in about 50 per cent. of skulls is continued upward as the frontonasal duct into the frontal sinus. *7*

Ossification.—The ethmoid is ossified in the cartilage of the nasal capsule by *three* centers: one for the perpendicular plate, and one for each labyrinth. *8*

The labyrinths are first developed, ossific granules making their appearance in the region of the lamina papyracea between the fourth and fifth months of fetal life, and extending into the conchæ. At birth, the bone consists of the two labyrinths, which are small and ill-developed. During the first year after birth, the perpendicular plate and crista galli begin to ossify from a single center, and are joined to the labyrinths about the beginning of the second year. The cribriform plate is ossified partly from the perpendicular plate and partly from the labyrinths. The development of the ethmoidal cells begins during fetal life. *9*

Articulations.—The ethmoid articulates with *fifteen* bones: four of the cranium—the frontal, the sphenoid, and the two sphenoidal conchæ; and eleven of the face—the two nasals, two maxillæ, two lacrimals, two palatines, two inferior nasal conchæ, and the vomer. *10*

Sutural or Wormian 37 Bones.—In addition to the usual centers of ossification of the cranium, others may occur in the course of the sutures, giving rise to irregular, isolated bones, termed *sutural* or *Wormian bones.* They occur most frequently in the course of the lambdoidal suture, but are occasionally seen at the fontanelles, especially the posterior. One, the *pterion ossicle,* sometimes exists between the sphenoidal angle of the parietal and the great wing of the sphenoid. They have a tendency to be more or less symmetrical on the two sides of the skull, and vary much in size. Their number is generally limited to two or three; but more than a hundred have been found in the skull of an adult hydrocephalic subject. *11*

Note 37. Ole Worm, Professor of Anatomy at Copenhagen, 1624–1639, was erroneously supposed to have given the first detailed description of these bones. [back]

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

5b. The Facial Bones. 1. The Nasal Bones

(Ossa Faciei) & (Ossa Nasalia) 1

The **nasal bones** are two small oblong bones, varying in size and form in different individuals; they are placed side by side at the middle and upper part of the face, and form, by their junction, "the bridge" of the nose (Fig. 190). Each has two surfaces and four borders.

Surfaces.—The **outer surface** (Fig. 155) is concavoconvex from above downward, convex from side to side; it is covered by the Procerus and Compressor naris, and perforated about its center by a foramen, for the transmission of a small vein. The **inner surface** (Fig. 156) is concave from side to side, and is traversed from above downward, by a groove for the passage of a branch of the nasociliary nerve. 2

Borders.—The **superior border** is narrow, thick, and serrated for articulation with the nasal notch of the frontal bone. The **inferior border** is thin, and gives attachment to the lateral cartilage of the nose; near its middle is a notch which marks the end of the groove just referred to. The **lateral border** is serrated, bevelled at the expense of the inner surface above, and of the outer below, to articulate with the frontal process of the maxilla. The **medial border,** thicker above than below, articulates with its fellow of the opposite side, and is prolonged behind into a vertical crest, which forms part of the nasal septum: this crest articulates, from above downward, with the spine of the frontal, the perpendicular plate of the ethmoid, and the septal cartilage of the nose. 3

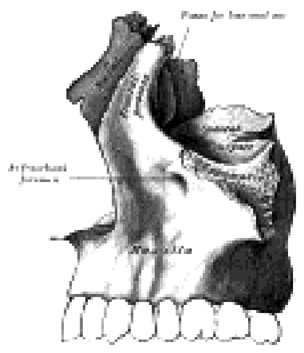

FIG. 154– Articulation of nasal and lacrimal bones with maxilla. (See enlarged image)

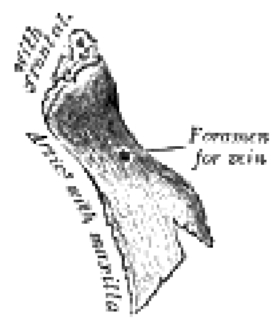

FIG. 155– Right nasal bone. Outer surface. (See enlarged image)

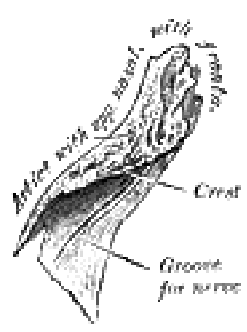

FIG. 156– Right nasal bone. Inner surface. (See enlarged image)

Ossification.—Each bone is ossified from *one* center, which appears at the beginning of the third month of fetal life in the membrane overlying the front part of the cartilaginous nasal capsule. 4

Articulations.—The nasal articulates with four bones: two of the cranium, the frontal and ethmoid, and two of the face, the opposite nasal and the maxilla. 5

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

5b. 2. The Maxillæ (Upper Jaw)

The **maxillæ** are the largest bones of the face, excepting the mandible, and form, by their union, the whole of the upper jaw. Each assists in forming the boundaries of three cavities, viz., the roof of the mouth, the floor and lateral wall of the nose and the floor of the orbit; it also enters into the formation of two fossæ, the infratemporal and pterygopalatine, and two fissures, the inferior orbital and pterygomaxillary. 1

Each bone consists of a body and four processes—zygomatic, frontal, alveolar, and palatine. 2

The Body (*corpus maxillæ*).—The body is somewhat pyramidal in shape, and contains a large cavity, the **maxillary sinus** (*antrum of Highmore*). It has four surfaces—an anterior, a posterior or infratemporal, a superior or orbital, and a medial or nasal. 3

Surfaces.—The **anterior surface** (Fig. 157) is directed forward and lateralward. It presents at its lower part a series of eminences corresponding to the positions of the roots of the teeth. Just above those of the incisor teeth is a depression, the **incisive fossa,** which gives origin to the Depressor alæ nasi; to the alveolar border below the fossa is attached a slip of the Orbicularis oris; above and a little lateral to it, the Nasalis arises. Lateral to the incisive fossa is another depression, the **canine fossa;** it is larger and deeper than the incisive fossa, and is separated from it by a vertical ridge, the **canine eminence,** corresponding to the socket of the canine tooth; the canine fossa gives origin to the Caninus. Above the fossa is the **infraorbital foramen,** the end of the infraorbital canal; it transmits the infraorbital vessels and nerve. Above the foramen is the margin of the orbit, which affords attachment to part of the Quadratus labii superioris. Medially, the anterior surface is limited by a deep concavity, the **nasal notch,** the margin of which gives attachment to the Dilatator naris posterior and ends below in a pointed process, which with its fellow of the opposite side forms the **anterior nasal spine.** 4

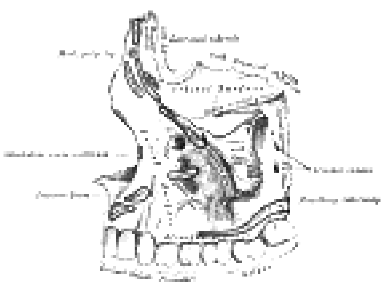

FIG. 157– Left maxilla. Outer surface. (See enlarged image)

The **infratemporal surface** (Fig. 157) is convex, directed backward and lateralward, and forms part of the infratemporal fossa. It is separated from the anterior surface by the zygomatic process and by a strong ridge, extending upward from the socket of the first molar tooth. It is pierced about its center by the apertures of the **alveolar canals,** which transmit the posterior superior alveolar vessels and nerves. At the lower part of this surface is a rounded eminence, the **maxillary tuberosity,** especially prominent after the growth of the wisdom tooth; it is rough on its lateral side for articulation with the pyramidal process of the palatine bone and in some cases articulates with the lateral pterygoid plate of the sphenoid. It gives origin to a few fibers of the Pterygoideus internus. Immediately above this is a smooth surface, which forms the anterior boundary of the pterygopalatine fossa, and presents a groove, for the maxillary nerve; this groove is directed lateralward and slightly upward, and is continuous with the infraorbital groove on the orbital surface. 5

The **orbital surface** (Fig. 157) is smooth and triangular, and forms the greater part of the floor of the orbit. It is bounded *medially* by an irregular margin which in front presents a notch, the **lacrimal notch;** behind this notch the margin articulates with the lacrimal, the lamina papyracea of the ethmoid and the orbital process of the palatine. It is bounded *behind* by a smooth rounded edge which forms the anterior margin of the inferior orbital fissure, and sometimes articulates at its lateral extremity with the orbital surface of the great wing of the sphenoid. 6

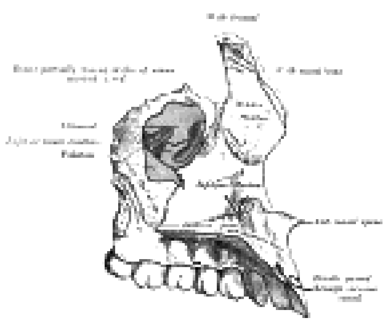

FIG. 158– Left maxilla. Nasal surface. (See enlarged image)

It is limited *in front* by part of the circumference of the orbit, which is continuous medially with the frontal 7
process, and laterally with the zygomatic process. Near the middle of the posterior part of the orbital surface is the **infraorbital groove,** for the passage of the infraorbital vessels and nerve. The groove begins at the middle of the posterior border, where it is continuous with that near the upper edge of the infratemporal surface, and, passing forward, ends in a canal, which subdivides into two branches. One of the canals, the **infraorbital canal,** opens just below the margin of the orbit; the other, which is smaller, runs downward in the substance of the anterior wall of the maxillary sinus, and transmits the anterior superior alveolar vessels and nerve to the front teeth of the maxilla. From the back part of the infraorbital canal, a second small canal is sometimes given off; it runs downward in the lateral wall of the sinus, and conveys the middle alveolar nerve to the premolar teeth. At the medial and forepart of the orbital surface just lateral to the lacrimal groove, is a depression, which gives origin to the Obliquus oculi inferior.

The **nasal surface** (Fig. 158) presents a large, irregular opening leading into the maxillary sinus. At the 8
upper border of this aperture are some broken air cells, which, in the articulated skull, are closed in by the ethmoid and lacrimal bones. Below the aperture is a smooth concavity which forms part of the inferior meatus of the nasal cavity, and behind it is a rough surface for articulation with the perpendicular part of the palatine bone; this surface is traversed by a groove, commencing near the middle of the posterior border and running obliquely downward and forward; the groove is converted into a canal, the **pterygopalatine canal,** by the palatine bone. In front of the opening of the sinus is a deep groove, the **lacrimal groove,** which is converted into the nasolacrimal canal, by the lacrimal bone and inferior nasal concha; this canal opens into the inferior meatus of the nose and transmits the nasolacrimal duct. More anteriorly is an oblique ridge, the **conchal crest,** for articulation with the inferior nasal concha. The shallow concavity above this ridge forms part of the atrium of the middle meatus of the nose, and that below it, part of the inferior meatus.

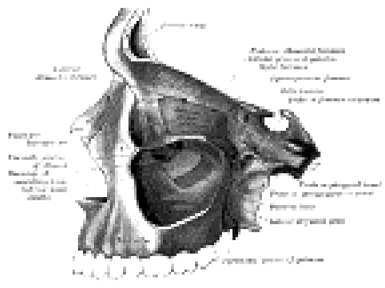

FIG. 159– Left maxillary sinus opened from the exterior. (See enlarged image)

The Maxillary Sinus or Antrum of Highmore (*sinus maxillaris*).—The maxillary sinus is a large pyramidal 9
cavity, within the body of the maxilla: its **apex,** directed lateralward, is formed by the zygomatic process; its **base,** directed medialward, by the lateral wall of the nose. Its walls are everywhere exceedingly thin, and correspond to the nasal orbital, anterior, and infratemporal surfaces of the body of the bone. Its **nasal wall,** or **base,** presents, in the disarticulated bone, a large, irregular aperture, communicating with the nasal cavity. In the articulated skull this aperture is much reduced in size by the following bones: the uncinate process of the ethmoid above, the ethmoidal process of the inferior nasal concha below, the vertical part of the palatine behind, and a small part of the lacrimal above and in front (Figs. 158, 159); the sinus communicates with the middle meatus of the nose, generally by two small apertures left between the above-mentioned bones. In the fresh state, usually only one small opening exists, near the upper part of the cavity; the other is closed by mucous membrane. On the **posterior wall** are the **alveolar canals,** transmitting the posterior superior alveolar vessels and nerves to the molar teeth. The **floor** is formed by the alveolar process of the maxilla, and, if the sinus be of an average size, is on a level with the floor of the nose; if the sinus be large it reaches below this level.

Projecting into the floor of the antrum are several conical processes, corresponding to the roots of the first 10
and second molar teeth; 38 in some cases the floor is perforated by the fangs of the teeth. The infraorbital canal usually projects into the cavity as a well-marked ridge extending from the roof to the anterior wall; additional ridges are sometimes seen in the posterior wall of the cavity, and are caused by the alveolar canals. The size of the cavity varies in different skulls, and even on the two sides of the same skull. 39

The Zygomatic Process (*processus zygomaticus; malar process*).—The zygomatic process is a rough 11
triangular eminence, situated at the angle of separation of the anterior, zygomatic, and orbital surfaces. *In front* it forms part of the anterior surface; *behind,* it is concave, and forms part of the infratemporal fossa; *above,* it is rough and serrated for articulation with the zygomatic bone; while *below,* it presents the prominent arched border which marks the division between the anterior and infratemporal surfaces.

The Frontal Process (*processus frontalis; nasal process*).—The frontal process is a strong plate, which 12
projects upward, medialward, and backward, by the side of the nose, forming part of its lateral boundary. Its *lateral surface* is smooth, continuous with the anterior surface of the body, and gives attachment to the Quadratus labii superioris, the Orbicularis oculi, and the medial palpebral ligament. Its *medial surface* forms part of the lateral wall of the nasal cavity; at its upper part is a rough, uneven area, which articulates with the ethmoid, closing in the anterior ethmoidal cells; below this is an oblique ridge, the **ethmoidal crest,** the posterior end of which articulates with the middle nasal concha, while the anterior part is termed the **agger nasi;** the crest forms the upper limit of the atrium of the middle meatus. The *upper border* articulates with the frontal bone and the *anterior* with the nasal; the *posterior border* is thick, and hollowed into a groove, which is continuous below with the lacrimal groove on the nasal surface of the body: by the articulation of the medial margin of the groove with the anterior border of the lacrimal a corresponding groove on the lacrimal is brought into continuity, and together they form the **lacrimal fossa** for the lodgement of the lacrimal sac. The lateral margin of the groove is named the **anterior lacrimal crest,** and is continuous below with the orbital margin; at its junction with the orbital surface is a small tubercle, the **lacrimal tubercle,** which serves as a guide to the position of the lacrimal sac.

The Alveolar Process (*processus alveolaris*).—The alveolar process is the thickest and most spongy part 13
of the bone. It is broader behind than in front, and excavated into deep cavities for the reception of the teeth. These cavities are eight in number, and vary in size and depth according to the teeth they contain. That for the canine tooth is the deepest; those for the molars are the widest, and are subdivided into minor cavities by septa; those for the incisors are single, but deep and narrow. The Buccinator arises from the outer surface of this process, as far forward as the first molar tooth. When the maxillæ are articulated with each other, their alveolar processes together form the **alveolar arch;** the center of the anterior margin of this arch is named the **alveolar point.**

The Palatine Process (*processus palatinus; palatal process*).—The palatine process, thick and strong, is horizontal and projects medialward from the nasal surface of the bone. It forms a considerable part of the floor of the nose and the roof of the mouth and is much thicker in front than behind. Its *inferior surface* (Fig. 160) is concave, rough and uneven, and forms, with the palatine process of the opposite bone, the anterior three-fourths of the hard plate. It is perforated by numerous foramina for the passage of the nutrient vessels; is channelled at the back part of its lateral border by a groove, sometimes a canal, for the transmission of the descending palatine vessels and the anterior palatine nerve from the spheno-palatine ganglion; and presents little depressions for the lodgement of the palatine glands. When the two maxillæ are articulated, a funnel-shaped opening, the **incisive foramen,** is seen in the middle line, immediately behind the incisor teeth. In this opening the orifices of two lateral canals are visible; they are named the **incisive canals** or **foramina of Stenson;** through each of them passes the terminal branch of the descending palatine artery and the nasopalatine nerve. Occasionally two additional canals are present in the middle line; they are termed the **foramina of Scarpa,** and when present transmit the nasopalatine nerves, the left passing through the anterior, and the right through the posterior canal. On the under surface of the palatine process, a delicate linear suture, well seen in young skulls, may sometimes be noticed extending lateralward and forward on either side from the incisive foramen to the interval between the lateral incisor and the canine tooth. The small part in front of this suture constitutes the **premaxilla** (*os incisivum*), which in most vertebrates forms an independent bone; it includes the whole thickness of the alveolus, the corresponding part of the floor of the nose and the anterior nasal spine, and contains the sockets of the incisor teeth. The *upper surface* of the palatine process is concave from side to side, smooth, and forms the greater part of the floor of the nasal cavity. It presents, close to its medial margin, the upper orifice of the incisive canal. The *lateral border* of the process is incorporated with the rest of the bone. The *medial border* is thicker in front than behind, and is raised above into a ridge, the **nasal crest,** which, with the corresponding ridge of the opposite bone, forms a groove for the reception of the vomer. The front part of this ridge rises to a considerable height, and is named the **incisor crest;** it is prolonged forward into a sharp process, which forms, together with a similar process of the opposite bone, the **anterior nasal spine.** The *posterior border* is serrated for articulation with the horizontal part of the palatine bone. 14

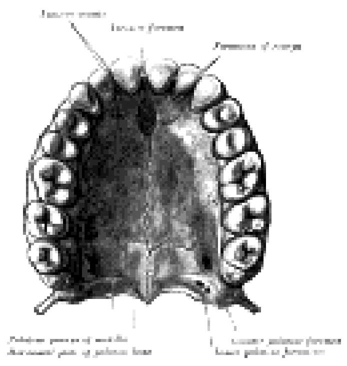

FIG. 160– The bony palate and alveolar arch. (See enlarged image)

Ossification.—The maxilla is ossified in membrane. Mall [40] and Fawcett [41] maintain that it is ossified from *two* centers only, one for the maxilla proper and one for the premaxilla. These centers appear during the sixth week of fetal life and unite in the beginning of the third month, but the suture between the two portions persists on the palate until nearly middle life. Mall states that the frontal process is developed from both centers. The maxillary sinus appears as a shallow groove on the nasal surface of the bone about the fourth month of fetal life, but does not reach its full size until after the second dentition. The maxilla was formerly described as ossifying from six centers, viz., one, the *orbitonasal,* forms that portion of the body of the bone which lies medial to the infraorbital canal, including the medial part of the floor of the orbit and the lateral wall of the nasal cavity; a second, the *zygomatic,* gives origin to the portion which lies lateral to the infraorbital canal, including the zygomatic process; from a third, the *palatine,* is developed the palatine process posterior to the incisive canal together with the adjoining part of the nasal wall; a fourth, the *premaxillary,* forms the incisive bone which carries the incisor teeth and corresponds to the premaxilla of the lower vertebrates; [42] a fifth, the *nasal,* gives rise to the frontal process and the portion above the canine tooth; and a sixth, the *infravomerine,* lies between the palatine and premaxillary centers and beneath the vomer; this center, together with the corresponding center of the opposite bone, separates the incisive canals from each other. 15

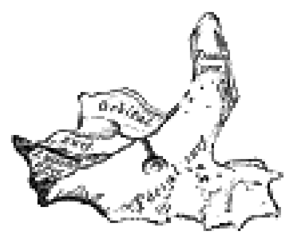

FIG. 161– Anterior surface of maxilla at birth. (See enlarged image)

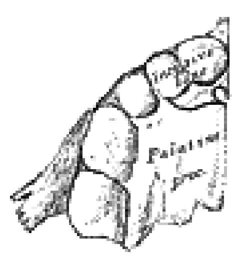

FIG. 162– Inferior surface of maxilla at birth. (See enlarged image)

Articulations.—The maxilla articulates with *nine* bones: two of the cranium, the frontal and ethmoid, and seven of the face, viz., the nasal, zygomatic, lacrimal, inferior nasal concha, palatine, vomer, and its fellow of the opposite side. Sometimes it articulates with the orbital surface, and sometimes with the lateral pterygoid plate of the sphenoid. 16

Changes Produced in the Maxilla by Age At birth the transverse and antero-posterior diameters of the bone are each greater than the vertical. The frontal process is well-marked and the body of the bone consists of little more than the alveolar process, the teeth sockets reaching almost to the floor of the orbit. The maxillary sinus presents the appearance of a furrow on the lateral wall of the nose. In the adult the vertical diameter is the greatest, owing to the development of the alveolar process and the increase in size of the sinus. In old age the bone reverts in some measure to the infantile condition; its height is diminished, and after the loss of the teeth the alveolar process is absorbed, and the lower part of the bone contracted and reduced in thickness. 17

Note 38. The number of teeth whose roots are in relation with the floor of the antrum is variable. The sinus "may extend so as to be in relation to all the teeth of the true maxilla, from the canine to the *dens sapientiæ.*" (Salter.) [back]

Note 39. Aldren Turner (*op. cit.*) gives the following measurements as those of an average sized sinus: vertical height opposite first molar tooth, 1 1/2 inch; transverse breadth, 1 inch; and antero-posterior depth, 1 1/4 inch. [back]

Note 40. American Journal of Anatomy, 1906, vol. v. [back]

Note 41. Journal of Anatomy and Physiology, 1911, vol. xlv. [back]

Note 42. Some anatomists believe that the premaxillary bone is ossified by two centers (see page 299). [back]

Henry Gray (1821–1865). Anatomy of the Human Body. 1918.

5b. 3. The Lacrimal Bone

(Os Lacrimale) 1

The **lacrimal bone,** the smallest and most fragile bone of the face, is situated at the front part of the medial wall of the orbit (Fig. 164). It has two surfaces and four borders.

Surfaces.—The **lateral** or **orbital surface** (Fig. 163) is divided by a vertical ridge, the **posterior lacrimal crest,** into two parts. In front of this crest is a longitudinal groove, the **lacrimal sulcus** (*sulcus lacrimalis*), the inner margin of which unites with the frontal process of the maxilla, and the lacrimal fossa is thus completed. The upper part of this fossa lodges the lacrimal sac, the lower part, the naso-lacrimal duct. The portion behind the crest is smooth, and forms part of the medial wall of the orbit. The crest, with a part of the orbital surface immediately behind it, gives origin to the lacrimal part of the Orbicularis oculi and ends below in a small, hook-like projection, the **lacrimal hamulus,** which articulates with the lacrimal tubercle of the maxilla, and completes the upper orifice of the lacrimal canal; it sometimes exists as a separate piece, and is then called the **lesser lacrimal bone.** 2

The **medial** or **nasal surface** presents a longitudinal furrow, corresponding to the crest on the lateral surface. The area in front of this furrow forms part of the middle meatus of the nose; that behind it articulates with the ethmoid, and completes some of the anterior ethmoidal cells. 3

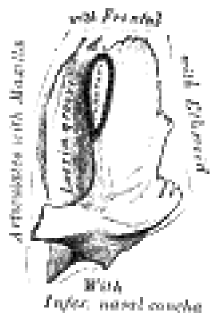

FIG. 163– Left lacrimal bone. Orbital surface. Enlarged. (See enlarged image)

Borders.—Of the *four borders* the **anterior** articulates with the frontal process of the maxilla; the **posterior** with the lamina papyracea of the ethmoid; the **superior** with the frontal bone. The **inferior** is divided by the lower edge of the posterior lacrimal crest into two parts: the posterior part articulates with the orbital plate of the maxilla; the anterior is prolonged downward as the **descending process,** which articulates with the lacrimal process of the inferior nasal concha, and assists in forming the canal for the nasolacrimal duct. 4

Ossification.—The lacrimal is ossified from a single center, which appears about the twelfth week in the membrane covering the cartilaginous nasal capsule. 5

Articulations.—The lacrimal articulates with *four* bones: two of the cranium, the frontal and ethmoid, and two of the face, the maxilla and the inferior nasal concha. 6