SYLLABUS OF LECTURES

ON

HUMAN EMBRYOLOGY

AN INTRODUCTION TO THE STUDY OF OBSTETRICS AND GYNÆCOLOGY.

FOR MEDICAL STUDENTS AND PRACTITIONERS.

WITH A GLOSSARY OF EMBRYOLOGICAL TERMS.

BY

WALTER PORTER MANTON, M.D.,

PROFESSOR OF CLINICAL GYNÆCOLOGY AND LECTURER ON OBSTETRICS IN THE DETROIT COLLEGE OF MEDICINE; FELLOW OF THE ROYAL MICROSCOPICAL SOCIETY, OF THE BRITISH ZOOLOGICAL SOCIETY, AMERICAN MICROSCOPICAL SOCIETY, ETC., ETC.

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TO

O. BÜTSCHLI

AND

F. BLOCHMANN,

HEIDELBERG.

PREFACE.

THE object of this syllabus is to furnish to students of medicine and practitioners an outline of the principal facts in human Embryology; details and theories must be sought for in the works of reference and special monographs elsewhere mentioned.

The book has been so arranged that it may be used in the class-room, the printed headings serving as a guide during the elaboration of the subject by the teacher; notes of the lecture are to be taken down at the time on the blank pages provided. Sufficient space has been left around each outline cut so that the student may himself write down the names of the parts, thereby helping to fix them in his memory.

The general arrangement followed is that adopted in my lectures for the past ten years. In the revision of my notes the latest editions of the following works have been consulted: His: "Anatomie menschlicher Embryonen." Kölliker: "Entwickelungsgeschichte der Menchen und der Höheren Thieren." Von Baer: "Entwickelungsgeschichte." Bonnet: "Grundriss der Entwickelungsgeschichte der Haussaugethiere." O. Hertwig: "Lehrbuch d. Entwickelungsgeschichte d. Menchen und d. Wirbelthiere." Balfour: "A Treatise on Comparative Embryology." Foster and Balfour: "Elements of Embryology." Haddon: "An Introduction to the Study of Embryology." Minot: "Human Embryology."

Besides these, current medical literature and especially the "Journal of the Royal Microscopical Society," "Archiv für Gynakologie," "Zeitschrift für Geburtshulfe und Gynakologie," and works on zoölogy, anatomy, physiology, obstetrics, and diseases of women have been drawn upon.

For the benefit of those who may desire to read up on special subjects, reference foot-notes have been added.

The outline drawings, partly diagrammatic, have been taken from various sources, as far as possible acknowledged, and from the specimens in my own collection which are used for class illustration and demonstration.

I desire here to express my thanks to my friend, Dr. E. H. Sargent, Lecturer on Bacteriology in the Detroit College of Medicine, for many suggestions in the preparation of this syllabus.

W. P. M.

DETROIT, August 1, 1894.

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SOURCES FROM WHICH ILLUSTRATIONS HAVE BEEN DERIVED.

Balfour, Fig. 26.

Barnes, "Obstetric Medicine and Surgery," Fig. 35.

Bonnet, Figs. 30, 43, 47, 48, 49, 57.

Bumm, "Archiv für Gynakologie," Bd. xliii, Fig. 36.

Claus and Sedgwick, Figs. 2, 4.

Francis, Figs. 66, 67.

Henle's "Anatomie," Figs. 6, 7, 10, 11, 12.

Herting, O., Figs. 18, 19, 20, 33, 37, 55, 62, 64.

His, Frontispiece and Figs. 34, 38, 39, 40, 53, 59, 60, 61.

Kölliker, Figs. 42, 63.

Manton, Figs. 1, 8, 24, 29, 32, 44, 65, 68, 69.

Minot, Figs. 25, 45.

Packard's "Zoölogy," Fig. 3.

Quain's "Anatomy," Figs. 5, 15, 17, 22, 23, 31, 58.

Ranney, "Topographical Relations of the Female Pelvic Organs," Fig. 9.

Sutton, Bland, "Surgical Diseases of the Ovaries and Fallopian Tubes," Figs. 14, 16.

A SYLLABUS

OF

Lectures on Human Embryology.

SECTION I.

Introduction.

Embryology (Greek, εμβρυον, embryo, and λογος, a discussion) is an important subdivision of Biology treating of "those successive modifications through which the organism passes in its development from the germ to the adult form."[1] Alike important in the study of Natural History, Physiology, and Obstetrics.

The term *Embryo*, later *Fœtus*, is applied to the unborn young, which at birth may resemble the parent form,—*e.g.*, mammals; or, as in some of the lower orders of life, must undergo a series of changes and modifications before attaining to the adult state,—*e.g.*, frog.

The study of Embryology is divided into two parts, one of which, called "*Ontogeny*" (ων, existence, and γεναω, to beget), deals with the history of the individual and the development of the animal and its various parts; the other, called "*Phylogeny*" (φυλος, race, and γεναω, to beget), compares the development of different animals, and "attempts therefrom to deduce or reconstruct the evolution of the Animal Kingdom."

The Animal Kingdom is composed of *Protozoa*, or unicellular animals,—*e.g.*, Amœba; and *Metazoa*, or

[1] Spencer's Biology, vol. i, p. 97.

animals composed of many cells so united as to form tissues,—*e.g.*, all animals,—and which alone produce eggs (ova).

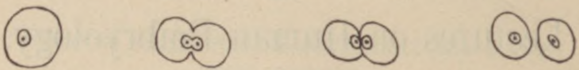

FIG. 1.

Propagation of Species.—Four methods: (a) *Fission.* The organism divides into two similar parts,—*e.g.*, the amœba; white blood-corpuscle.

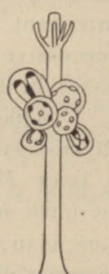

FIG. 2.

(b) *Budding*, or *Gemmation.* The organism develops outgrowths, which finally become separated from

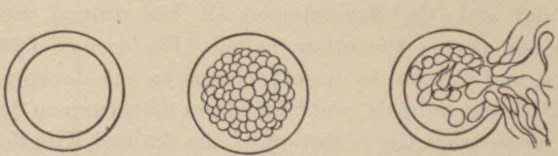

FIG. 3.

the parent, and carry on a separate existence,—*e.g.*, hydra.

(c) *Spore Formation.* The organism breaks up into a considerable number of parts, each of which resembles the parent form,—*e.g.*, protomyxa.

(d) *Conjugation* and *Fusion.* The uniting and fusion

FIG. 4.

of two dissimilar organisms,—*e.g.*, ovum and spermatozoön.

Sexual Development.—*Puberty:* Twelfth to fifteenth year in the female, usually somewhat later in the male.

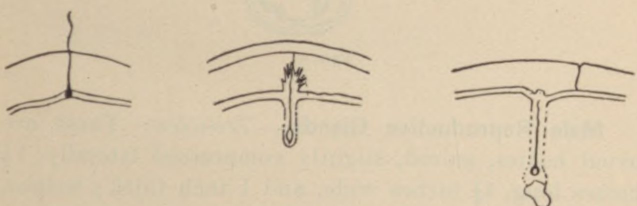

FIG. 5.

Changes in the Organism.—Male: Growth of pubic, abdominal, and axillary hair; change in pitch and volume of voice; sexual activity; formation and ejaculation of spermatic fluid with spermatozoa. *Female:* Change in figure, rounding of limbs, development of mammary glands; growth of pubic hair; sexual activity, monthly discharge from genitals (menstruation), periodical discharge of ova.

Function of the Male.—Production of fertilizing cell for conjugation and fusion with the female egg-cell. The term *Genoblast* is applied to the mature element of either sex.

FIG. 6.

Male Reproductive Glands.—*Testicles:* These are ovoid bodies, paired, slightly compressed laterally, 1½ inches long, 1¼ inches wide, and 1 inch thick; weight, ¾ to 1 ounce. The left is usually larger than the right. They are suspended in the scrotum by the spermatic cord and membranes. *Anatomy:* Tunica vaginalis, T. albuginea, corpus Highmori, trabeculæ, tunica vasculosa, tubuli seminiferi, tubuli recti, rete vasculosum, vasa efferentia, epididymis, vas deferend, seminal vesicles, seminal or ejaculatory ducts.[1]

Secretion of the Testicles (Seminal Fluid, Semen).— A thick, viscid fluid, containing spermatozoa, squamous and columnar epithelium, seminal granules. *Chemistry of semen:* Reaction neutral or alkaline; 82 per cent.

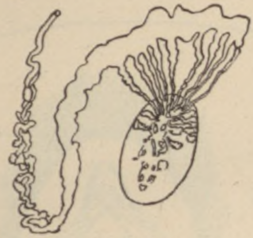

FIG. 7.

water; serum-albumin, alkali albuminate, nuclein, lecithin, cholesterin, fats, phosphorized fats; salt, 2 per cent., especially phosphates of the alkalies and earths; together with sulphates, carbonates, chlorides, and spermatin.[2]

[1] Quain's Anatomy, 9th ed., p. 685.
[2] Landois's Human Physiology, p. 859.

SECTION II.

ANATOMY OF THE FEMALE ORGANS OF GENERATION.

The Vulva.—This comprises all that part of the genitals visible to the eye when the subject is in the dorso-recumbent position with thighs flexed and knees widely separated. The vulva (valve to vagina, *V. connivens*, *V. hians*) includes the following parts: *Mons Veneris*, *Labia Majora and Minora*, *Clitoris*, *Perineum*, *Fourchette*, and *Vestibule*.

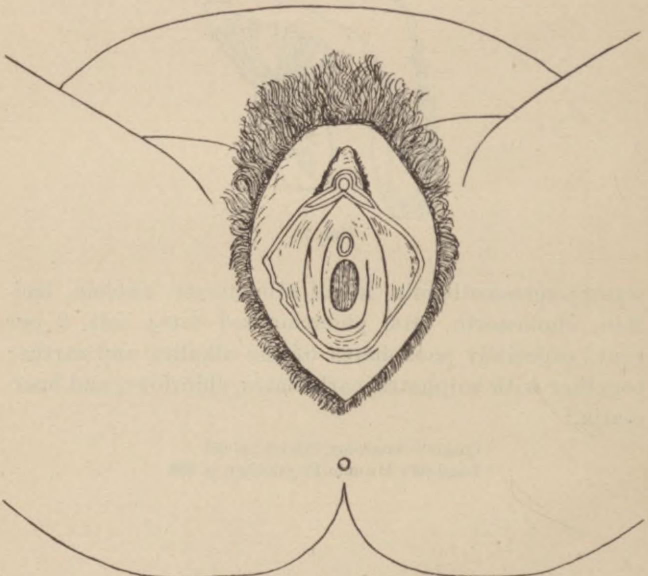

FIG. 8.

Mons Veneris.—This is a triangular space lying in front of the pubic symphysis, and forming the superior boundary of the labia majora. It consists of a pad of fat with areolar tissue and integument, and is covered, after puberty, with coarse hair, which has a tendency to curl. Its apex is toward the labia majora and its base is bounded by the hypogastric fold. The skin contains sweat-glands and numerous sebaceous follicles, which give rise to an oily feel of the parts. Function unknown; acts, perhaps, as a buffer to the male pubis during coitus.

Labia Majora (*Greater Lips*).—Lateral cutaneous folds extending from mons veneris to perineum, where they are united by the anterior and posterior commissures, forming the lateral boundary of the vulva-cleft. Homologue of male scrotum. The lips are thicker anteriorly than posteriorly, and receive the terminal fibres of the round ligaments. The external surface of the labia consists of integument of a darker color than that of the body, and is covered by hair after puberty. On the internal surface the integument is rosy and covered by downy hair. The lips are approximated in virgins, but are separated in old women.

Structure.—On section the great lips have a triangular shape, and internally consist of elastic fibres arranged in the form of a sac (dartos), fat, and large blood-vessels. The skin contains large hair-bulbs and sebaceous follicles. The labia are in relation, during early life, with the inguinal canal, which closes from the twentieth to the thirtieth day after birth.[1] An open canal (canal of Nuck) may give rise to hernia of intestines, ovary, uterus; hydrocele.[2]

[1] J. H. Warren, Practical Treatise on Hernia. Marcy, Anatomy and Surgical Treatment of Hernia, p. 29.

[2] Barber, Transactions of the Michigan State Medical Society, 1891, p. 324. Thomas and Mundé, Diseases of Women, vol. ii, p. 141. Pozzi, Medical and Surgical Gynæcology, p. 188.

Arteries, superficial perineal branch of Internal Pudic.

Veins, rich plexus communicating with Bulb of Vagina.

Lymphatics enter superficial Inguinal glands.

Nerves, superficial perineal branch of Internal Pudic, inferior branch of small Sciatic.

Labia Minora (*Nymphæ, Smaller Lips*).—"Muco-cutaneous folds" hidden under greater lips in the virgin. Above, meet and bifurcate to form *frenulum* and *prepuce* of the *Clitoris;* below, appear to blend with labia majora at about their middle, but re-appear farther down, and are united by the *Fourchette* behind.

Color, red in virgins, darker in adults and aged; may resemble, in form and color, a cock's comb.

Structure—arteries, veins, etc.—derived as in labia majora. Numerous sebaceous follicles.

Nerves have "end bulbs."

Function, supposed to bring penis and clitoris in close apposition and to direct the stream of urine (nymphæ,—so called from mythological nymphs which presided over fountains). Hottentot apron (Cuvier), six to eight inches long.[1]

Vestibule (Latin, *Vestibulum*).—Triangular space: apex, below clitoris; base, anterior margin of vaginal mouth; sides, formed by nymphæ. *Covering*, corrugated mucous membrane. Pierced in the middle line, about one inch below the clitoris, by the urethra (*Meatus urinarius*). Contains *Glandulæ vestibulares minores*,—minute, five or six,—which may attain to one-third the size of meatus.

Arteries, from Pudic.

Veins, from Pudic, Pars intermedia, Isthmus, above

[1] Hyrtl, Anatomie des Menschen, p. 792.

and below meatus, uniting in Bulb of Vagina (*Corpus cavernosum urethræ*,—Savage).

Nerves, from Pudic.

Bulb of Vagina.—An oblong body, net-work of veins, "erecto-turgescent tissue," situated on either side of vestibule. Extends from root of clitoris to lower third of vaginal orifice. About one and one-half inches long by half an inch at lowest end (Savage). Free communication of veins with opposite side,—veins of clitoris, labia, perineum, vagina, obturator plexus, epigastric.

Arteries, from Internal Pudic.

Nerves, from Sympathetic.

Vulvo-Vaginal Gland (*Glands of Bartholin, Tiedeman, Duvernay, Cowper*).—Reddish-yellow body, size of bean, about one-half inch long; one on either side of vagina at lower end of bulb. Duct one-half to three-fourths of an inch long; opens on inner surface of nymphæ, in front of base of hymen. Secretion thin, penetrating odor.

Use, to lubricate vaginal orifice during coitus; fluid sometimes ejaculated in jets; thought by the ancients to be similar to semen.

Perineum (Greek, *περι*, around; *ναιον*, a temple).—An irregularly quadrilateral body forming part of sacral segment of pelvic floor.[1] Extends from divergence of rectum and vagina to vulvo-anal space. Measures about one and one-fourth inches vertically, one and one-fourth inches transversely, three-fourths inch antero-posteriorly. Formed of muscles and fascia.

[1] Hart, Structural Anatomy of the Female Pelvic Floor, 1880. Marcy, The Perineum, 1889. Agnew, Laceration of the Female Perineum, 1879. Bantock, Treatment of Ruptured Perineum, 1878. Olshausen, "Ueber, Dammverletzunge und Dammschutz," Volkmann's Klinische Vortrage, No. 44. Garrigues, American Journal of Obstetrics, April, 1880.

Muscles. — Bulbo-cavernosus, Transversus perinæi (superficial and deep), Sphincter ani, Levatores ani.

Median raphé (central tendon) may become almost cartilaginous in old persons. "If a straight line be made to join the tip of the coccyx and the subpubic ligament, it will just clear the apex of this structure."[1]

Importance of perineal body greatly overestimated; *not* a key-stone supporting parts above. The Levator ani is the great supporting muscle and constrictor of the vagina. Tears of this and the neighboring fascia during childbirth destroy the integrity of the pelvic

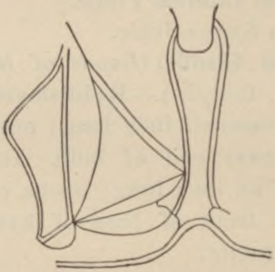

FIG. 9. (See Fig. 10.)

floor and give rise to a train of genesic ills. Repair of this muscle most important; stitching of perineal skin least important.[2]

Arteries.—Inferior Hæmorrhoidal, Transversus perinæi, Superficial Perineal, from Internal Pudic.

Veins terminate in Pudic veins.

Nerves, from Pudic, small Sciatic, fourth Sacral.

Lymphatics unite with those of external genitals and enter Inguinal glands.[3]

Urethra.—A narrow musculo-membranous canal

[1] Hart and Barbour.
[2] Emmett, Principles and Practice of Gynæcology.
[3] Ranney, "The Female Perineum," New York Medical Journal, 1882.

buried in anterior vaginal wall, extending from bladder to meatus, slightly curved, concavity upward, held in position by pubo-vesical ligament. About one and one-half inches long, diameter one-fourth to one-third inch, funnel-shaped, posterior wall dilated above meatus. Two coats,—mucous, muscular. Mucous follicles and glands. Very dilatable (coitus; urethrocele).

Meatus, external orifice of urethra, puckered, prominent mucous margin. Mucous glands. Skene's glands.[1] Jet of urine larger than in male. Tears may occur during parturition or passing the catheter.

Arteries.—Vaginal, Internal Pudic, and the uterine branches; from Internal Iliac.

Veins, urethral plexus,—the "true erectile plexus" (Savage); from Internal Iliac.

Nerves, from hypogastric plexus of Sympathetic, fourth Sacral, Pudic of Spinal.

Lining, mucous membrane,—pavement variety of epithelium below, "transitional" above.

Fourchette.—A delicate fold of skin uniting the posterior extremities of the nymphæ, situated above posterior commissure 2.5 to 2.7 centimetres. With labia in apposition the fourchette bags downward; when the former are stretched apart its free border appears as a tense, whitish band. A space exists between the fourchette and the posterior commissure,—Fossa Navicularis,—an artificial depression. Frequent seat of condylomata.

Arteries, *veins*, and *nerves* as in labia.

Anterior and Posterior Commissures.—The junction of large lips with mons veneris anteriorly and with each other posteriorly. Not transverse connecting bands (Luschka).

[1] Skene, Diseases of the Bladder and Urethra in Women.

INTERNAL ORGANS.

The female internal sexual organs comprise the *Hymen*, *Vagina*, *Uterus*, *Fallopian tubes*, and *Ovaries*.

Hymen.—Formed by a folding in of entire vaginal wall. Double fold of mucous membrane containing vessels and nerves. Continuous with vaginal wall posteriorly, free margin anteriorly. Partially closes vaginal ring. Perforated, for escape of discharges, above centre. Normally, in erect position of body, the hymen lies loosely against posterior vaginal wall. It is usually

FIG. 10.

ruptured at first intercourse, but may be so tough as to prevent act. May persist even after birth of premature (seven months') child (Ranney). Opening generally crescentic (*H. semilunaris*) or round (*H. annularis*), sometimes several perforations (*H. cribriformis*) or with fringed borders (*H. fimbriatus*). Complete closure is pathological (*H. imperforatus*). Rudimentary or absent, not uncommon. The ancients considered the hymen a mark of virginity. Some of the ungulata, the ruminata, carnivora, and monkeys have an analogous membrane.

Carunculæ myrtiformes are not remains of the hymen.

Blood-vessels and *nerves*, from those supplying the vagina.

Vagina (Latin, *Vagina*).—A musculo-membranous tube lying between bladder and rectum, extending from external orifice to uterus. It is attached below to the ischio-pubic rami, continuous above with the neck of the uterus. Somewhat contracted at lower extremity. **H**-shaped on section.

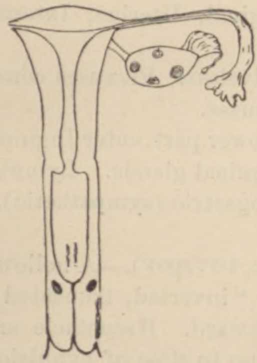

FIG. 11.

Direction slightly curved,—sixty degrees to plane of horizon. Two walls, anterior and posterior.

Length of anterior wall $2\frac{1}{2}$ inches, of posterior wall $3\frac{1}{2}$ inches.

Walls in apposition, not an open canal. Three layers,—mucous, muscular, and connective tissue. Thickness varying according to amount of muscular tissue present.

Columns of vagina most marked on anterior wall. May be divided.

Anterior Wall, firm connection with urethra, lower half (urethro-vaginal septum). Less firm connection above with bladder (vesico-vaginal septum). Contains vesico-vaginal plexus of veins. Anterior *cul-de-sac* shallow.

Posterior Wall joins anterior lip of cervix high up. Separated from rectum in upper fifth by *cul-de-sac* of Douglas. Loosely attached in space between *cul-de-sac* and perineal body (recto-vaginal septum).

Mucous membrane consists of connective tissue, elastic fibres, and pavement epithelium.

Arteries, Vaginal, Uterine, Internal Pudic, from Internal Iliac.

Veins rich, valveless. Plexuses communicating with neighboring plexuses.

Lymphatics, lower part, enter Inguinal glands; upper part, internal Inguinal glands. Lymph-follicles.[1]

Nerves, Hypogastric (sympathetic), Fourth Sacral, Pudic (spinal).

Uterus (Greek, υστερον).—A hollow, muscular, pear-shaped organ or "inverted, truncated cone," flattened from before backward. Receptacle and nidus of impregnated ovum up to time of expulsion (labor).

Length, 2½ to 3 inches; *cavity*, 2 to 2½ inches; *breadth*, widest, 2 inches; *isthmus*, 1 to 1½ inches; *thickness*, 1 inch; of walls, ½ inch; *weight*, 7 to 12 drachms (virgins).

Situation, middle of pelvic cavity, between bladder and rectum.

Position, slight anteflexion,[2] varying according to state of distension of bladder and rectum. Mobility considerable; motion during respiration.

[1] Lowenstein, Centralblatt f. Med. Wissensch., p. 546, 1871.

[2] Schultze, The Pathology and Treatment of Displacements of the Uterus, translated by Macan, 1888.

Parts, three,—cervix, body, and fundus.

Cervix (vaginal portion), in young virgins, about one-third inch long; longer and larger in nulliparous and those who have borne; nearly flush with vaginal vault in senile. Variable shape,—conical in virgins. Partly projects into vaginal canal. A central dimple or transverse slit is the *Os externum* (os tincæ, mouth of tench-fish). Feel, in virgins, similar to that conveyed to finger by pressing tip of nose. Anterior and posterior lips: consistency, hard in virgins, softer in

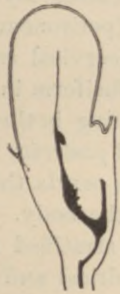

FIG. 12.

those who have borne children and in disease. Generally lacerated during childbirth. "The end of the cervix marks nearly the centre of the pelvic cavity, the centre of a radius of about two inches" (Savage). The cervix is separated from the body by the *Isthmus*,—a slight constriction at the *Os internum*.

Body extends from isthmus to fundus, tapering from above downward. It is softer in consistence than the cervix. Its length is nearly two inches, the anterior surface being flattened, while the posterior is more convex. At the upper angles are the openings of the *Fallopian tubes*.

Fundus, the free convex upper portion of the uterus above the openings of the Fallopian tubes. It lies slightly below the plane of the pelvic brim, and is covered with peritoneum. The uterus is suspended laterally by the *Broad Ligaments*, along the upper margin of which run the Fallopian tubes; the *Round Ligaments* and *Vesico-uterine Folds* anteriorly, the *Sacro-uterine Ligaments* posteriorly (*Musculus retractor uteri*,—Luschka), and the *Pelvic Fascia*.

Structure, three layers, from inward without,—a mucous, a muscular (three layers, chiefly unstriped muscle), and a serous (peritoneum).[1]

Cavity of Cervix (cervical canal) extends from os externum to isthmus, fusiform in virgins, more tubular in the parous. The lining is thrown into folds, giving rise to the *anterior* and *posterior ridges* (*Palmæ Plicatæ* or *Arbor vitæ*). In the cervix the mucosa is firmer and more fibrous than in the body. Columnar epithelium lines the upper part, stratified cells the lower. The mucosa contains cylindrical and goblet glands and the so-called *ovula Nabothi*.[2]

Cavity of the Body.—The cavum uteri extends from the isthmus to the fundus. Form triangular, with convex sides. Base above, with minute openings of the Fallopian tubes at the angles. Apex at isthmus. The mucosa of the body is smooth, devoid of ridges, spongy (muscularis mucosæ). It is lined with ciliated columnar epithelium, and contains the utricular glands.

The so-called *globus hystericus*, the peculiar feeling in the throat which often ushers in an attack of hysteria,

[1] Ercolini, The Reproductive Process, translated by Marcy, 1884.

[2] According to Hyrtl, Martin Naboth, professor in Leipzig, an otherwise unknown man, attempted to give to these vesicles, which the anatomists held to be hydatids, the same importance as the ovaries. (Lehrbuch der Anatomie des Menschen, 1881.)

was supposed by the ancients to be due to the womb rising into the throat. From this the name of this nervous condition was derived.

Arteries, four,—two Ovarian (spermatic in the male), from Abdominal Aorta; two Uterine, from anterior division of Internal Iliac. "Curling arteries." Circular artery.

Blood-vessels of the cervix distinguished by the great thickness of their walls.

Veins.—Venous plexuses, sinus-like in middle layer, communicate freely with Vaginal, Vesical, Pampiniform plexuses, and terminate in Internal Iliac and Ovarian veins.

Nerves arise chiefly from inferior Hypogastric plexus, Spermatic plexus, and third and fourth Sacral nerves.[1]

Lymphatics unite with those from the tube and the ovary to form an extensive net-work in the broad ligament and enter the lumbar glands. The lymphatics of the cervix and upper three-fourths of the vagina open into the Hypogastric glands, or Obturator glands.[2]

Fallopian Tube (*Oviduct*).—A sinuous tube, one on either side, extending from the angle of the uterus, inclosed in upper free margin of broad ligament, extending outward to the pelvic brim. Length, from 3 to 6 inches, the right usually slightly longer than the left. Course, outward, backward, inward (shepherd's crook). Three parts: *Isthmus*, narrowest portion, diameter 2 to 3 millimetres, cord-like, extends through uterine wall to ampulla. Lumen at uterine ostium minute, admits only a fine bristle. *Ampulla*, dilated portion of the tube, diameter 6 to 8 millimetres, extends to fimbriated portion

[1] Frankenhauser, Die Nerven der Gebarmutter und ihre endigung in den glatten Muskelfasern. Jena, 1867.

[2] Leopold, "Die Lymphgefasse des normalen, nicht Schwangeren uterus," Archiv f. Gynakologie, Bd. vi, p. 1, 1874.

(also called infundibulum, pavilion). Abdominal mouth of the tube called the *ostium abdominale*, *morsus diaboli*.[1]

Infundibulum, trumpet-shaped. It has four or five fimbriæ, which have been compared to the tentacles of the sea-anemonæ. The serous membrane of the peritoneum and the mucous membrane of the tube join at this point, the only instance of the kind in the human

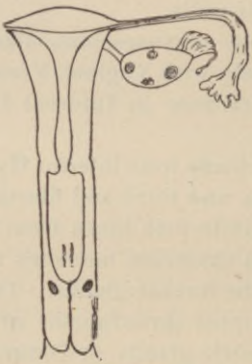

FIG. 13.

body. One of the long, finger-like processes of the infundibulum extends to the ovary (fimbria ovarica). A small cyst called the *Hydatid of Morgagni* is often seen hanging from one of the lower fimbriæ of the tube. This represents the blind extremity of Müller's duct.

[1] A plant which, on account of its astringent properties, was much used for healing wounds and sores was called *Scabiosa succisa.* Its raveled-out roots appeared as if gnawed off (*Radix præmorsa*), and it was supposed that the devil, annoyed at the good service which the plant had rendered man, had bitten them off in anger. The older anatomists in Germany, France, and Holland, down to the time of Haller, were also professors of botany (anatomists in winter, botanists in summer), and from them the abdominal end of the Fallopian tube came to be known as the morsus diaboli, from its fancied resemblance to the root of the plant. (Hyrtl, Anatomy, p. 786.)

Structure of Tube.—Three layers,—serous (peritoneal); muscular, consisting of circular and longitudinal fibres; and mucous. This membrane is thrown into longitudinal folds, most numerous in the ampulla (*Arborescent processes*). The lining is of columnar epithelium.

Use, to convey ovum from ovary to uterus. Possibly participating in the menstrual function (Lawson Tait).

The *vascular* and *nervous* supply is derived from the vessels and nerves supplying uterus and ovaries.

Ovaries (Latin, *Ovarii*).—The genital glands are flattened, ovoid bodies, one on either side of the uterus,

FIG. 14. (See also Fig. 13.)

attached to the posterior fold of the broad ligament by a straight side (*hilus*). The opposite border is free and convex (oöphoron), as are its sides. The end of the ovary toward the uterus is smaller and more pointed than that directed toward the pelvic wall.

Size.—This varies in different individuals and at different periods of life. It is largest during the first six weeks after parturition (Henning), and the two are usually unequal in size in the same individual. The average length is about $1\frac{1}{3}$ inches, by $\frac{3}{4}$ inch wide and $\frac{3}{8}$ inch thick (Farre). The weight is from 60 to 135 grains (Hart).

Situation.—The ovary is normally on a level with the inlet of the pelvis, behind the Fallopian tube and round ligament. It is slung between two ligaments, which are attached to either pole. At the uterine, internal end is the *Ovarian Ligament*, a fibro-muscular cord about an inch long, running from the side of the uterus below the origin of the Fallopian tube. The external or *Infundibulo-pelvic Ligament* is that part of the upper margin of the broad ligament unoccupied by the Fallopian tube. Above this is the elongated fimbria from the infundibulum.

Position.—This is variable, as the ovary is not a fixed organ; probably oblique to the axis of the pelvis. The ovary is in contact with the small intestine on the right side, with the rectum on the left.

Color of the ovary is a pinkish, pearly hue, varying to dark purple at menstruation (Tait).

Structure.—Three layers: (*a*) An external epithelial layer, consisting of a single layer of polyhedral cells (*germinal epithelium*).[1] Whether this layer is distinct from the peritoneum of the broad ligament, the point of transition being marked by an irregular or wave-like line, is still in dispute. Waldeyer, Leopold, Klein, and others claim that the surface of the ovary is covered by a layer of cells in "marked contrast to the transparent, flattened endothelial plates covering the ligamentum latum" (Klein); while Lawson Tait, on the other hand, affirms that the ovary is covered by peritoneum, and Bland Sutton states that "the external covering of the ovary is directly continuous with the posterior layer of the broad ligament." (*b*) A firm, fibrous layer (*tunica albuginea ovarii*). (*c*) Stroma, cortical layer, consisting of a fine connective tissue, in which

[1] Waldeyer, Eierstock und Ei. Leipzig, 1870.

are muscular fibres and many spindle-shaped cells. The superficial cortical substance (parenchymal zone) contains numerous groups of small *Graafian follicles* (ovisacs), and, deeper in the stroma (zona vasculosa), isolated and larger follicles occur. The portion of the ovary nearest the hilus (paroöphoron) never contains follicles (Sutton).

The blood-vessels, nerves, and lymphatics of the ovary find entrance and exit at the hilus.

Arteries, Ovarian from Abdominal Aorta and branch from Uterine.

Veins, Ovarian. Just below the ovary is a club-shaped, venous body, the *Bulb of the Ovary* (Savage). This anastomoses with the uterine and spermatic plexuses, and with them forms the

Pampiniform Plexus.—This plexus terminates in the ovarian vein. The vein of the right side has a valve.

Nerves are derived from the Ovarian plexus and the Uterine nerves.

Lymphatics unite with those from the tube and upper part of the uterus and enter the lumbar glands.

Graafian Follicles.—The smallest of these measure about $\frac{1}{100}$ inch and have no proper wall, a single layer of cells surrounding the ovum. The larger follicles ($\frac{1}{20}$ inch) present a basement membrane (*membrana propria*) and an internal lining of columnar epithelial cells (*membrana granulosa*). The ovum is usually situated at a point in the follicle farthest from the surface of the ovary, and is surrounded by the *discus proligerus.* The rest of the follicle is filled with fluid (*liquor folliculi*), which contains paralbumin. The most prominent point of the follicle, at which rupture will occur, is called the *Stigma.* From 36,000 to 70,000 follicles are said to exist in the ovary at birth, but no authority is given for the statement.

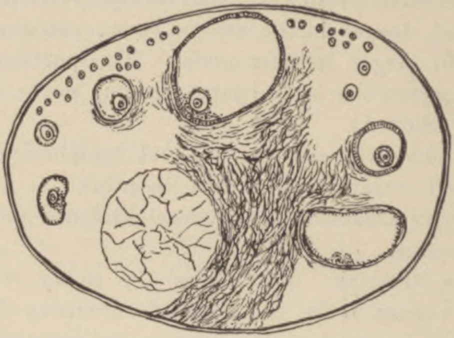

FIG. 15.

Parovarium, also called the *Organ of Rosenmüller* and *Epi-oöphoron.* Analogous to the epididymis in the male. This is a series of tubules situated in the broad ligament near the external end of the ovary. Their course is parallel and somewhat zigzag as they spread

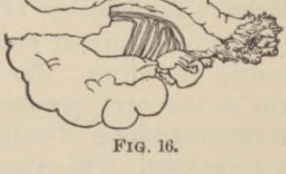

FIG. 16.

out, fan-like, toward the upper portion of the ligament. The apex of the parovarium is at the hilus of the ovary, the base a transverse canal, the remains of the duct of Gärtner, in which the tubules terminate. This canal ends in a fine, thread-like structure running toward the uterine wall. The number of the tubules varies from

5 or 6 to 24 (Doran).[1] They are the remains of the Wolffian bodies.

Structure.—The walls of the tubules consist of two layers of fibrous tissue,—an external circular and an internal longitudinal. The lining is ciliated epithelium and the contents a clear, coagulable fluid.

Rectum comprises the lower eight inches of the large intestine, extending from the sigmoid flexure to the anus. In its entire length it is contained within the true pelvis. The rectum begins opposite the left sacro-iliac articulation, runs obliquely downward from left to right to the middle of the sacrum, then curves forward behind the cervix uteri and vagina, and again turns downward and backward to the anus. The course is therefore somewhat **S**-shaped. The upper end of the rectum is smaller than the lower, which is dilated into an ampulla.

Structure.—Three coats,—serous (peritoneal above), muscular, and mucous.

Connections.—The rectum is attached above to the uterus, the middle portion anteriorly to the posterior wall of the vagina, and below to the perineal body. Posteriorly it is attached to the sacrum by folds of the peritoneum (*mesorectum*).

Arteries.—Superior Hæmorrhoidal from Inferior Mesenteric, Middle Hæmorrhoidal from Internal Iliac, Inferior Hæmorrhoidal from Pudic.

Veins are numerous, forming hæmorrhoidal plexus. They terminate in the Internal Iliac and Mesenteric.

Lymphatics enter the Sacral and Lumbar glands.

Nerves numerous, from Sacral plexus of Cerebro-spinal, and from Inferior Mesenteric and Hypogastric Plexuses of the Sympathetic.

[1] Tumors of the Ovary, Fallopian Tube, and Broad Ligament. London, 1884.

Bladder (Latin, *Vesica urinaria*).—A hollow, muscular organ, balloon-shaped when distended, triangular or **Y**-shaped when collapsed; situated between the pubic symphysis and the vagina and uterus. The normal capacity of the bladder is about a pint, but it is capable of great distension.[1] There are three openings into the viscus,—two for the ureters and one for the urethra. The organ is divided, for description, into three portions,—a body, a base or fundus, and a neck. The former is that portion lying above the level of the ureters and the centre of the symphysis; the base is all the portion below and includes the trigone; the neck is the narrowest portion and surrounds the opening of the urethra.

Structure.—Three layers,—muscular, mucous, and peritoneal. The muscular layer varies from one-sixth to one-half inch in thickness, according to the amount of distension.

Ligaments.—Two sets,—true and false. The true ligaments are derived from the vesico-rectal fascia,—two anterior and two lateral. The false ligaments, five in number, consist of peritoneal folds,—two posterior or recto-vesical; two lateral, from sides of bladder to iliac fossæ; one superior, urachus (*ligamentum suspensorium*), extends from top of bladder to umbilicus.

Arteries.—Superior Vesical from Hypogastric, Inferior Vesical from Internal Iliac, branches from Uterine, and from Vaginal to neck.

Veins.—Large plexuses cover the organ and empty into the Internal Iliac.

Lymphatics enter the glands near the Internal Iliac.

Nerves, from Hypogastric plexus of Sympathetic and Sacral Plexus of Cerebro-spinal system.

[1] Manton, Sudden Emptying of the Bladder as a Cause of Cystorrhagia.

SECTION III.

The Spermatozoön; Spermatogenesis—The Ovum, Oögenesis, Menstruation.

The Spermatozoön.—The spermatozoön is the smallest element of the human body, measuring rather more than 0.05 millimetre, and consists of three parts,—a head, a middle piece, and a tail. It differs in appearance in different animals.

The Head.—In man the head of the spermatozoön is a flattened ovoid when viewed from above, being $\frac{1}{8000}$ inch in length and $\frac{1}{10000}$ inch in breadth (Quain). If viewed from the side the head appears somewhat pointed or pear-shaped, the larger, thicker end being joined to the middle piece. A slight concavity on each surface of the anterior portion gives a lighter, thinner appearance to that part.

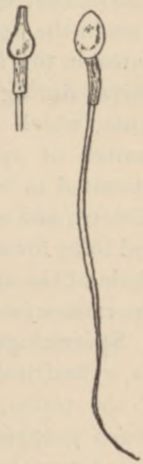

Fig. 17.

The Middle Piece is about as long as the head, and is cylindrical. It is wound by a spiral thread, and is often rough or granular in appearance.

The Tail resembles a fine hair or *flagellum*, and gradually tapers to its end.

Motion.—The spermatozoön is propelled by a circular or rotary movement of the tail, the energy being propagated from the middle piece. The distance traversed by the spermatozoön is estimated to be from 1.2

to 3.6 millimetres per minute (Bonnet), the movements being particularly active in normal vaginal secretion.

Water, alcohol, and various other fluids have a paralyzing effect on the movement, but cold only temporarily suspends action; spermatozoa may be frozen and thawed several times without apparent injury. The average life of the spermatozoa after ejaculation was supposed to be only a few days, but it has been recently shown that they may retain their vitality in the vagina for a period of at least seventeen days, and even through a menstrual epoch.[1] The same period of vitality obtains in the domestic fowl; while in the bat, which copulates in the fall of the year, the spermatozoa remain active during the entire winter and fecundate the ovum, which is discharged only in the spring. The number of spermatozoa in one ejaculation has been estimated to be upward of two hundred and twenty-five millions, and eight hundred and forty-eight millions are said to be formed for one Graafian follicle (Lode). "The whole of the spermatozoa derived from a spermatophore (spermatocyst) are together equal to one ovum."[2]

Spermatogenesis.—The walls of the *tubuli seminiferi*, cylindrical tubes forming the glandular substance of the testes, consist of two layers,—an external, or *tunica propria*, and an internal, or lining epithelium. The lumen is relatively large and the walls strong. The diameter of the tube is from $\frac{1}{100}$ to $\frac{1}{150}$ inch (Quain). The length of each tube is about two feet, and between eight hundred and nine hundred tubes have been found in a single testis. The epithelial lining of the duct (seminal cells) consists of an outer layer near the *tunica propria* and an inner layer of

[1] Bossi, Nouvelles archives d'obstetrique et gynecologie, April, 1891.
[2] Balfour, Comparative Embryology, vol. i, p. 54.

small granular cells. Between these is a layer of so-called supporting tissue,—Sertoli's columns (Minot). From the small cells are developed the spermatozoa. A large cell nearest to the tunica, the *parent-cell*, divides into two or three *mother-cells*, and these again divide into *daughter-cells*, which lie nearest to the seminiferous duct. The cells of this column are called *spermatocysts*. From the daughter-cells are formed the *spermatoblasts*, the last stage in the development of the spermatozoa. The head of the spermatozoa is largely formed from the chromatin of the nucleus, the middle piece within the nuclear membrane; while the

FIG. 18.

tail, or contractile thread, arises from the protoplasm at a later period. The cell-membrane finally disappears, and a column of material filled with nuclei, its lower end resting on a single large cell (parent-cell), is left.[1] The spermatozoa attached to the upper (inner) end of the column are ultimately set free into the seminiferous canal, the column subsequently disappearing, —according to some, by a process of fatty degeneration.

The Ovum.—The fully-developed human ovum is a clear, spherical body, measuring, with its envelopes, about $\frac{1}{120}$ inch in diameter. It consists of five por-

[1] The latest and most satisfactory account of spermatogenesis is to be found in Minot's treatise, p. 42.

tions,—an *external membrane*, an *internal membrane*, a *yelk*, a *nucleus*, and a *nucleolus*.

The **Zona pellucida,** external membrane, so called from its transparent appearance, is developed from the primary Graafian follicle. It is a rather thick and

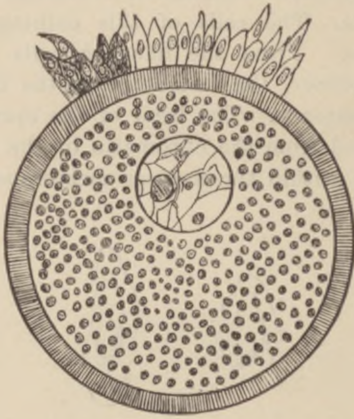

FIG. 19.

tough membrane, and appears striated from the presence of minute pore-canals, the purpose of which is not distinctly understood. In man the Zona pellucida has a diameter of about 20 μ (Minot).

The **Vitelline membrane,** internal membrane, a very thin and delicate covering, is developed from the egg itself, and lies in close contact with the yelk. Between the two envelopes a slight space, the *peri-vitelline space*, exists, so that the egg moves freely within the Zona pellucida.

The **Yelk,** or **Vitellus,** is somewhat granular in appearance, and is composed chiefly of yelk-grains—the nature of which is not determined—and protoplasm.

The amount of yelk in the human ovum is small, there being no necessity for a reserve supply after the ovum has escaped into the Fallopian tube, where, during its migration, it is nourished by the transudation of the secretion from the tube.

The **Nucleus, Germinal vesicle,** *vesicle of Purkinje*, occupies an eccentric position in the ovum, and is surrounded by a nuclear membrane. Its interior is traversed by a net-work of threads (chromatin), which radiate from the nucleolus; the interstices are filled with an albuminoid material called **deutoplasm** (*achromatin*).

The **Nucleolus, Germinal spot,** *spot of Wagner*, consists mainly of chromatin,[1] and is placed somewhat eccentrically in the nucleus.

Maturation of the Ovum.—The process by which the ovum becomes fully ripe and ready for impregnation is known as maturation. The first stage consists in the

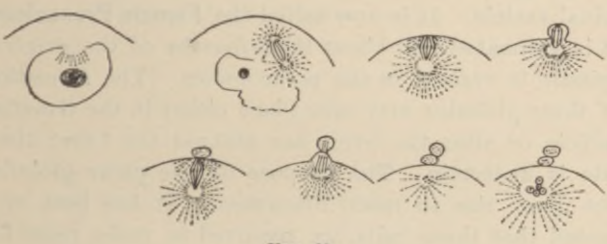

FIG. 20.

approach of the nucleus to one pole of the ovum (animal pole) and a shrinking of the yelk, so that a space filled with clear fluid exists between the Vitelline membrane and the Zona pellucida. The nucleus then becomes pale and its membrane disappears, the nuclear

[1] So called from its strong affinity for staining fluids. Achromatin exhibits just the opposite condition.

substance lying free in the yelk. Fine, thread-like, parallel strands then appear and unite at their top and bottom to form a spindle-shaped body. At either end of this the clear protoplasm of the surrounding material becomes arranged in rays, producing a sun-like appearance,—*archiamphiaster*. The chromatin of the nucleus occupies a central position in this spindle body, and shows like a darkish band across the latter. The spindle then advances toward the surface of the egg, pushing before it some of the yelk-substance until a rounded mass containing a portion of the former is projected between the egg and the Zona pellucida. This body becomes constricted off and forms the **First Polar Globule.** A second nuclear spindle is then formed from the remnants of the first still in the egg, and a **Second Polar Globule** is extruded as described. The remaining portion of the spindle subsequently re-appears as a nucleus in the egg, but is much smaller than the original germinal vesicle. It is now called the **Female Pronucleus.** It is estimated that about three-fourths of the original spindle is cast off in the polar bodies. The formation of these globules may take place either in the Graafian follicle or after the ovum has entered the tube; their fate is uncertain. The purpose of the polar globules has given rise to much discussion. It has been suggested that these cells are removed to make room for the male element necessary to fecundation; that by this process *parthenogenesis* is prevented,[1] etc. It has been shown that in the self-fertilized summer eggs of the maple-leaf louse, and other insects, but one polar globule is formed; while in the winter eggs, which require the addition of the male element, two globules are thrown off.[2]

[1] Balfour, Comp. Embryology, vol. i, pp. 62 and 63. [2] Blochmann.

Ovulation consists in the rupture of a Graafian follicle and escape of the ovum. The causes which act to produce this are not known; by some ovulation is considered synonymous with menstruation. While the ovum is developing, changes also take place in the Graafian follicle; it becomes more and more distended with fluid, and its walls are thinned, especially at one point,—the *Stigma*, the point of rupture,—so that it finally projects as a clear vesicle on the surface of the ovary. Rupture having taken place, the ovum, surrounded by the *discus proligerus*, either enters the Fallopian tube and begins its journey to the uterus, or falls into the peritoneal cavity and perishes. It is altogether probable that ovulation may occur prior to puberty and continue after the establishment of the menopause, and it is well established that it does take place during the intermenstrual period.

Changes in the Graafian Follicle After Rupture.—These depend somewhat on the time of month at which ovulation occurs. The discharge of the ovum and the emptying of the fluid contents of the follicle are followed by the formation of the **Corpus luteum.**

Corpus Luteum of Menstruation (*False Corpus Luteum*).—The bursting of the distended vesicle relieves the pressure on the surrounding blood-vessels, which at this period are greatly engorged, and gives rise to hæmorrhage into the collapsed follicle. This blood soon coagulates, forming a firm clot within the cavity, but not attached to its walls,—the **Corpus hæmorrhagicus.** Hypertrophy of the follicle-wall then takes place, as the result of which the wall is thrown into irregular folds, which encroach more and more upon the central clot. Contraction and diminution of the clot follow, while capillary loops, surrounded by newly-formed cells from the follicle-wall, penetrate its substance. In an external layer of cells around the clot pigment-granules of *lutein* are formed, and give rise to the yellow margin from which the corpus derives its name. The point of rupture in the follicle is marked by a fine stellate line. After the third week changes of a retrograde nature begin in the corpus luteum, and "at the end of eight or nine weeks the whole mass is reduced to the condition of an insignificant, yellowish, cicatrix-like spot."[1] A period of seven or eight months, however, may elapse before this spot has entirely disappeared. When the Graafian follicle ruptures during the intermenstrual period, little or no hæmorrhage may result, the vesicle-cavity being filled by a whitish coagulum, the origin of which is unknown.[2]

Corpus Luteum of Pregnancy (*True Corpus Luteum*).—The intervention of pregnancy produces a very remarkable change in the behavior of the corpus luteum. Instead of diminishing in size, it continues to enlarge up to the fourth month, the walls becoming thicker and the convolutions more numerous. From the fourth to the seventh month of pregnancy it remains stationary and then gradually declines, so that at term it is much smaller than at the fourth month. The retrograde changes following labor are rapid; by the eighth or ninth week post-partum the remains have become almost unrecognizable.

Migration of the Ovum.—The assumed function of the infundibulum, in grasping the ovary just preceding the rupture of a Graafian follicle, must be considered as entirely chimerical. In all probability a large number of ova fall into the peritoneal cavity and become ab-

[1] Dalton, Human Physiology, 1875, p. 713.

[2] Coste. See also Leopold, Archiv für Gynäkologie, Bd. xxi, p. 347.

sorbed. Others are carried into the abdominal opening of the tube by a current produced by the ciliated epithelium of the latter, and from thence onward by the action of the cilia and the muscular contractions of the tube itself (peristalsis). That the cilia have much to do with the movement of the ovum is evident from the fact that women whose tubes have been deprived of their normal mucous covering by disease are usually sterile. In batrachians, in which the tubes are fixed, pathways of ciliated epithelium converging toward the openings of the tubes are formed on the peritoneum.[1] In cases of pregnancy where the corpus luteum is found on the side of a completely-occluded tube, it must be assumed that the ovum passed entirely around the uterus and entered the tube of the opposite side. Various explanations have been ventured for this phenomenon. It is supposed that a period of from six to eight days is consumed in the migration of the ovum from ovary to uterus.

Impregnation.—Two varieties are considered, viz.: *external*, as in the osseous fishes, etc., in which the sperm is cast on to the ovum after it has left the body; *internal*, as in mammals, in which the seminal fluid is deposited in the vagina or uterus during coitus. Impregnation of the ovum takes place in the outer third of the tube; an ovum which has reached the uterus without coming in contact with spermatozoa is no longer capable of fecundation (Bonnet).

The manner in which spermatozoa obtain entrance into the uterus, traverse its cavity, and enter the tube is not known. It is possible that, under the stimulus of copulation, an adspiratory process is set up in the

[1] Thiry, quoted by Lusk, Science and Art of Midwifery, 1884, p. 40. Heil, Archiv für Gynäkologie, Bd. xliii, p. 503.

uterus, or that the retentive power of the abdomen contributes to the ascent of the spermatozoa.[1]

A condition of attraction seems to exist between the egg and the spermatozoa; the latter swarm about the ovum, attempting to penetrate its envelopes. Several may gain entrance through the Zona pellucida to the peri-vitelline space. As soon as the first spermatozoön approaches the yelk, a small protoplasmic swelling is thrown out toward the approaching organism. This may be penetrated by the spermatozoön, or, before this occurs, the projection may be withdrawn, leaving a slight

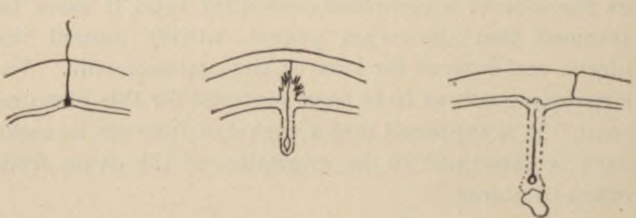

FIG. 21.

hollow or depression at its apex, through which the spermatozoön enters. One spermatozoön only penetrates into the yelk, the resulting changes in some manner preventing ingress to the others. It has been suggested that the attractive power of the ovum is diminished or stopped by the entrance of the single individual (Minot). The spermatozoön, after entering the yelk, speedily loses its tail and middle piece, and the head enlarges by absorption from the surrounding material. The head has now become the **Male Pronucleus.** Around each pronucleus a clear spot is formed, and from this the protoplasm soon radiates in fine lines, forming an *aster*.

[1] Duncan, Researches in Obstetrics, p. 431.

Each nucleus now approaches the other and also travels toward the centre of the egg. Meeting, they remain in contact for a time, and then fuse,—probably by a solution of their wall-membranes,—and together form the **First Segmentation Nucleus.** The whole ovum is now called the **Oösperm.**[1] The process of impregnation has been chiefly studied in the lower animals, those having a transparent ovum being selected for this purpose. According to Bonnet, in the sea-urchin the entire process occupies but ten minutes.

Menstruation.—Every healthy, normally-developed woman, between the age of puberty and the menopause, has a discharge of blood from the uterus, lasting on the average about five days, and recurring periodically, except during pregnancy, once every twenty-eight or thirty days. The menstrual discharge is acid, non-coagulable, of a peculiar penetrating odor, purplish-red (prune-juice) color, and consists of blood, uterine and vaginal secretions, white blood-corpuscles, and epithelial scales.[2] The amount lost during a period is variously estimated from 100 to 200 grammes (Lantois). The flow from the genitals is usually associated with more or less local and often general disturbance, especially of a secondary or reflex nature. The process primarily concerns the uterus, but it is possible that the tubes may also participate in the condition (Tait). Menstruation is the sign of perfected womanhood. The changes which take place in the uterus during the period consist in the destruction of its superficial mucosa, the exposure and rupture of the capillaries, followed by a development of new cells and restoration of the lining membrane.

[1] Balfour, Comparative Embryology, p. 66.
[2] Krieger, Die Menstruation, Berlin, 1869.

SECTION IV.

THE GENERAL DEVELOPMENT OF THE EMBRYO.

Segmentation.—Following the formation of the first segmentation nucleus, a short resting stage occurs, and then begins the active division of the yelk,—segmentation. The pronucleus undergoes karyokinesis, or indirect cell-division, and then a groove appears around the oösperm, at right angles to the position assumed by the dividing nucleus. This primary groove passes through the axis of the oösperm, its position being marked by the two polar globules. The groove, deepening, divides

FIG. 22.

the oösperm into two parts. A second groove at right angles to the first then appears, and four cells result. The third groove, at right angles to the first and second, divides the four cells into eight, and segmentation continues in a somewhat irregular manner until the oösperm assumes a form which has been compared to a mulberry, and is called the **Morula,** each cell of which contains a nucleus.

In those eggs (*e.g.*, fowl) in which the process of development goes on outside the body, the segmentation is only partial, and is known as **meroblastic segmentation,** the greater portion of the yelk being reserved for the nourishment of the embryo. When the embryo is nourished inside the maternal organism (*e.g.*, mammals), the segmentation is total, or **holoblastic.** The oösperm has by this time reached the uterine cavity. Here it gradually enlarges, a cleft filled with clear fluid makes its appearance in the interior of the solid mulberry mass, and a cavity is formed,—the **Segmentation Cavity.** The oösperm has now dilated into a vesicle, and is known as the **Blastodermic Vesicle,** or **Blastula,** the walls of

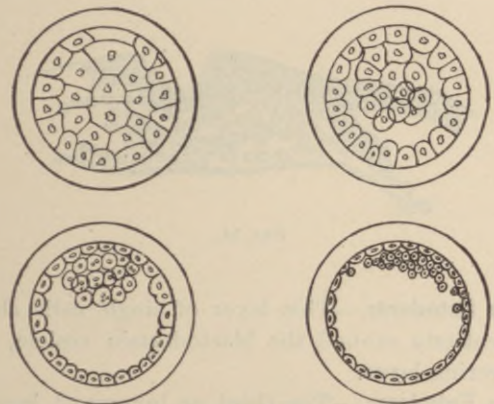

FIG. 23.

which, formed of a double layer of cells, is the **Blastodermic Membrane.** The cells of the interior of the mulberry mass are crowded together at one point in the blastodermic vesicle, forming a *lens-like body.* The former minute egg has now increased in size by the absorption of fluids from the uterus so as to be visible to the naked eye.

Development of the Three Primary Layers.—*Covering Layer.*—A section through the segmented oösperm at this period shows that part at which the lens-like mass is attached to be composed of three layers, the rest of the blastodermic wall having but two. The first of these three layers, the covering layer, extends completely around the blastodermic vesicle, and is composed of a single layer of thin cells. It lies immediately under the Zona pellucida, which by this time has become reduced to a thin membrane. The covering layer is a temporary structure, and either entirely disappears or unites with the layer immediately beneath.

FIG. 24.

The Ectoderm.—This layer of single cells also extends entirely around the blastodermic vesicle, lining the covering layer.

The Entoderm.—The third or innermost layer, the *entoderm*, consists at first of the cells which form the lenticular body, but which at a later period grow by peripheral extension so as to line the ectoderm.

The Mesoderm.—After a time a third layer of cells is developed between the two primary layers, and extends from the axial line outward. This layer does not grow entirely around the blastodermic vesicle, like the others, but remains confined to that portion in which the developing embryo is situated. The origin of the mesoderm is still in dispute, but it is known that, when once started, it becomes independent of the other two layers, and grows by the proliferation of its own cells.

The mesoderm at first extends from just outside the

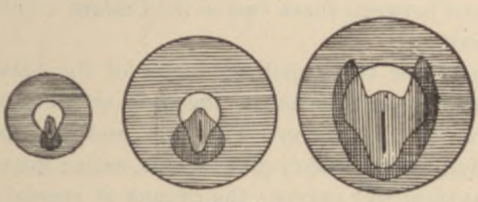

FIG. 25.

germinal area posteriorly to a short distance beyond the primitive streak anteriorly. It grows in all directions, but as it extends cephalward it sends out two projections, which, leaving an interval between them, unite and again spread out. A space is thus left just in front of the head in which two layers only exist,—the ectoderm and the entoderm. This space is the **Proamnion,** the importance of which will be noticed farther on.

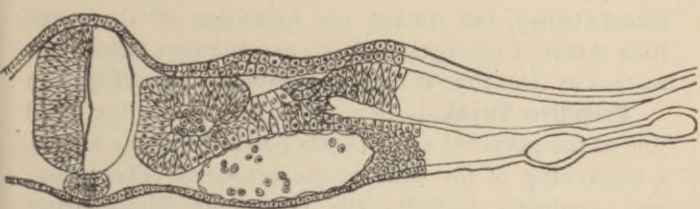

FIG. 26.

Two cavities of considerable size soon form in the mesoderm, one on either side of the mesian axial line, and these, gradually extending, split the middle layer into two leaves. The upper leaf goes with the ectoderm to form the **Somatopleure,** or beginning body-wall, while the lower leaf, together with the entoderm, forms the **Splanchnopleure,** or wall of the primitive digestive tract. The space between these two is the **Cœlum,** or primitive body-cavity.

From these three primary layers of the blastoderm all the organs and tissues of the body are developed :—

From the *Ectoderm:* The skin and its glandular structures, the mammary glands, hair, nails; the cerebro-spinal system and nerves; the organs of special sense.

From the *Mesoderm:* The chorium, muscles, bones, connective tissue, digestive tract, blood-glands, vessels, blood, lymphatics, spleen, urogenital apparatus.

From the *Entoderm:* The epithelium of the digestive tract.

Embryonic Area (*Germinal Area*).—As the result of the thickening of the blastodermic wall at the point where the three layers exist, a distinct patch is seen when the oösperm is viewed from above. This is the embryonic area, in the central long axis of which the embryo is developed. At first the area is oval or shield-shaped, but during the formation of the primitive streak it enlarges, and one end becomes drawn out so that at that time it resembles a pear. (See Fig. 25.)

Primitive Streak.—At a point in the median axial line of the germinal area, a little posterior to the centre, a thickening of the cells of the ectoderm takes place, and gradually includes the other two blastodermic layers, so as to form a distinct spot. This is the *Knot of Hensen,*—the anterior boundary of the primitive streak,—the latter being a continuation of the thickened wall, extending backward toward the margin of the germinal area. (See Fig. 25.)

Medullary Plate and Groove.—The Ectoderm in front of the primitive streak, on either side of the median line, increases in thickness by a proliferation of its cells, so that a band of cells several rows deep results. This forms the *Medullary Plate.* The edges of the plate on either side and at the cephalic end of the shield then grow upward from the surface of the shield,—**Medullary Folds,**—thus forming a deepening groove between their sides,—the **Medullary Groove.** The lower portion of this groove is shallower than the upper end, and appears to embrace the beginning of the primitive groove. The sides of the groove continue to rise higher and higher,

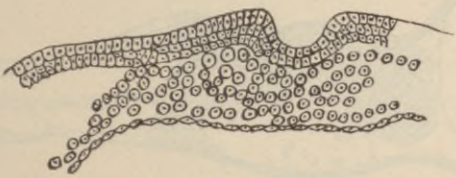

FIG. 27.

at the same time arching inward so that after a time they meet in the central line, their edges fuse, and a tube is formed,—the **Medullary** or **Neural Canal.** This canal first closes in the future cervical region and afterward at the head end, the posterior portion remaining open for a time as the *Sinus Rhomboidalis.* The medullary canal is the primitive central nervous system. It is now easily understood how the external layer of the blastoderm comes to form the brain and spinal cord.

The Notochord.—Just below the medullary groove a rod of cells, beginning at the future *Pituitary Body* and running to the primitive streak, is developed from the entoderm. This is the *Notochord*, the first indication of the future skeleton. After a time the notochord becomes separated off from the entoderm, which grows under its lower surface. (See Fig. 28.) Above, as the medullary groove deepens, the notochord comes to lie directly below the canal, but it does not unite with it. The notochord is a temporary structure, and commences to disappear during the second month of embryonal life (Minot).

Protovertebræ.—At the time that the notochord is forming a longitudinal thickening of the dorsal mesoderm takes place on either side of the chord. Two

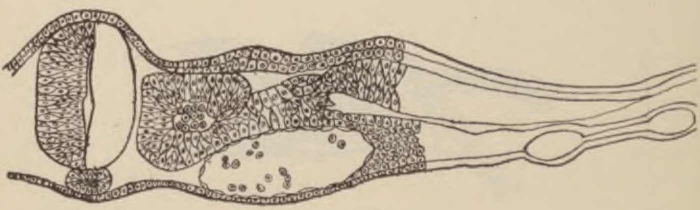

FIG. 28.

lateral plates result. (See Fig. 29.) That portion nearest the chord is thickest, the plate gradually thinning out toward the blastodermic wall. The thicker portion is divided from the thinner, and is called the *Segmental Zone*, while the thinner portion is the *Parietal Zone*. By a process of transverse cleavage of the segmental zone a series of squarish bodies, or *somites* (Balfour), is formed. These bodies are afterward converted into cavities. They bear a certain relation to the future vertebræ, as well as to the muscular and dermal development.

Folding off of the Embryo.—The germinal area alone has to do with the development of the embryo, the rest of the blastodermic vesicle merely furnishing nutriment while the various processes are going on, the wall acting

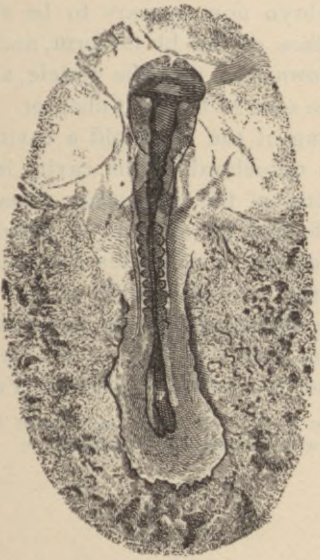

FIG. 29.

as a support. Up to this time the embryo lies flat upon the surface of the vesicle. Now a constricting fold

FIG 30.

appears around the embryo, slightly raising it above the rest of the blastoderm. This fold is more marked anteriorly, where it is called the *Head-fold*, and posteriorly, where it is known as the *Tail-fold.* At the sides it is at first not quite so deep.[1] The anterior or cephalic end of the embryo now appears to be slightly raised above the surface of the blastoderm, and at the same time to sink downward into the vesicle, an explanation of which will be seen in the next chapter. As the result of the deepening of the head-fold a cavity is shut off just below the notochord. This cavity is the **Foregut,** or the beginning of the alimentary canal. A similar cavity is also formed behind, and is called the **Hindgut.**

At the sides, where the folds are not so deep, the opening into the vesicle is still wide. The yelk-sac, now called the **Umbilical Vesicle,** has already begun to diminish in size, and is connected to the embryo by a wide duct,—the *Omphalo-mesenteric* or *Vitelline Duct.*

[1] These are not folds in the actual meaning of the word, as they result from the growth (enlargement) of the embryo.

SECTION V.

THE UTERINE AND FŒTAL MEMBRANES; THE PLACENTA AND UTERO-PLACENTAL CIRCULATION.

The Deciduæ.—Coincident with the impregnation of the ovum, active changes are inaugurated in the

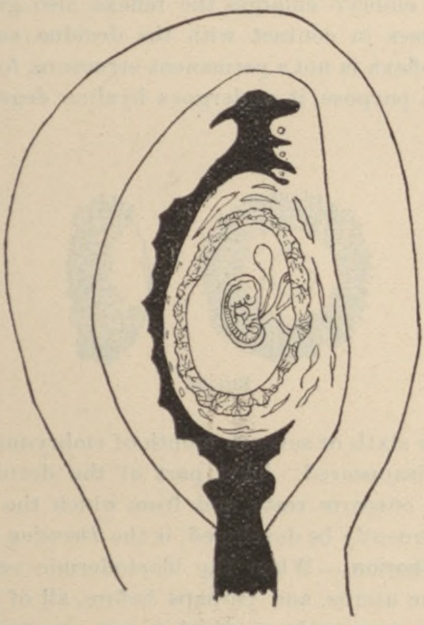

FIG. 31.

uterus; the organ becomes more vascular, increases in size, and its mucosa undergoes marked alterations. The mucous membrane of the body-cavity becomes greatly thickened, except at the openings of the os internum and the Fallopian tubes, where it remains thin and is thrown into folds. This lining is the *Decidua Vera.* When the oösperm has completed its journey through the tube and enters the uterus, it lodges in a depression between two of the folds of the vera, and these, growing over it, soon shut it off from the general uterine cavity. The oösperm appears as if in a sac. These encapsuling folds form the *Decidua Reflexa.*

As the embryo enlarges the reflexa also grows, and finally comes in contact with the decidua vera. The decidua reflexa is not a permanent structure, for, having served its purpose, it undergoes hyaline degeneration,

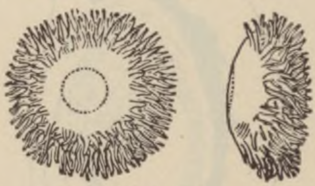

FIG. 32.

and by the sixth or seventh month of embryonal life has entirely disappeared. That part of the decidua upon which the oösperm rests, and from which the placenta will subsequently be developed, is the *Decidua Serotina.*

The Chorion.—When the blastodermic vesicle has reached the uterus, and perhaps before, all of that portion of the somatopleure which is not concerned in the formation of the embryo, and which at this time constitutes the external envelope of the oösperm, develops numerous villi on its surface, which give it a shaggy appearance. This is the *Chorion*, and the whole egg is sometimes spoken of as the *Chorionic Vesicle.* That part of the embryonic shield which is free from chorion subsequently becomes covered as the result of the formation of the amnion. In the uterus the tips of the chorionic villi touch and slightly penetrate the deciduæ. As development proceeds that portion of the chorion covered by the reflexa loses its villi and is called the *Chorion Læve*, while that portion in contact with the serotina persists, enters into the formation of the placenta, and is called the *Chorion Frondosum.*

The Amnion.—The description of the formation of the amnion usually given is that which takes place in the avarian and some mammalian embryos. In man

FIG. 33.

the process has been little studied, and appears to differ somewhat from that of other animals.

Development of the Amnion in Hen-Embryos.—At the same time that the so-called head and tail folds are forming, the upper leaf of the vesicle-membrane (somatopleure), consisting of ectoderm and a part of the mesoderm, which was split off by the formation of the cœlom, rises as a hollow ridge around the embryo, and, by a continuous growth upward and arching over the back of the latter, its edges finally meet and unite. Two layers are thus formed ; an *internal*, with the ectoderm turned toward the embryo, and an *external*, with the ectoderm turned toward the chorion. The upper and lower portions, respectively, of each layer consist of mesoderm. The internal layer has been called the *true* amnion, the external layer the *false* amnion. At first the amniotic membrane lies in contact with the dorsum of the embryo, but soon a clear fluid makes its appearance (the *Amniotic fluid*, Liquor amnii) and a cavity is formed (*Amniotic cavity*), which increases in size as the embryo develops. The space between the false and true amnions is in direct communication with the body-cavity. Some time during the third month the amnion comes in contact with the chorion and a loose connection between the mesodermic layers is established. This union never becomes firm, and the amnion can easily be stripped from the external membrane after delivery.

Development of the Amnion in Human Embryos.—After the sinking of the embryo (see p. 44) a semicircular fold of the vesicle-wall arises in front of the head and gradually grows upward and dorsalward over the head and trunk of the embryo to the stalk of the allantois. The side portions of the fold unite over the embryonal anlage and grow in a longitudinal direction. The embryo thus becomes inclosed in the amniotic sac,[1] and is shut off from the chorion except at its posterior end, which forms the *Bauchstiel*.

The Liquor Amnii.—This is a clear, watery fluid, having a specific gravity of 1007 to 1028, alkaline in reaction, and contains ½ to 2 per cent. of fixed solids (Landois). Among these are albumin, urea, grape-sugar, chloride of sodium, and other salts. The liquor also contains epithelial scales from the skin, bladder, and kidneys of the embryo, and *lanugo*,—wool-hair with which the embryo is covered. At term the amount of liquor is about a pound (15 to 18 ounces), but it is consider-

[1] His, Anatomie Menschlicher Embryonen, i, p. 172.

ably more than this near the middle of pregnancy. The liquor is derived from both the maternal and embryonal structures. During the later months of pregnancy the fœtus adds to the liquor a considerable quantity of urine evacuated from the bladder.[1] The liquor amnii insures an equal distension of the uterus, protects the embryo from injury and the cord from pressure, facilitates the dilatation of the maternal passages by "the bag of waters" during the first stage of labor, and lubricates the parturient canal during delivery.

The Allantois.—In young embryos the allantois appears as the continuation of the hind end of the body,

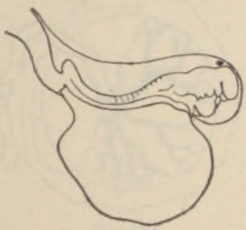

FIG. 34.

attaching the latter to the chorion in connection with the *Bauchstiel*.[2] It arises as a hollow bud or diverticulum from the lower ventral surface of the hindgut, and joins itself to the chorion to assist in the formation of the placenta. The allantois has a narrow canal in connection with the intestinal lumen. The lining is derived from the entoderm, while the outer wall is of mesoderm, derived from the intestine. The allan-

[1] Nagel, Archiv für Gynakologie, Bd. xxxv, p. 131.

[2] The description of the Allantois, as given in most books, is that of the avarian or mammalian ovum. An allantoic vesicle is not found in the human embryo. See Hertwig, Kolliker, or Minot.

tois carries with it from embryo to chorion two arteries and two veins.

The Placenta.—This is the organ of respiration (sometimes called the fœtal lung) and nutrition of the fœtus. At term the placenta is a softish, spongy mass, usually covered more or less with blood, and varying in color from light to dark red. It is round, oval, or reniform in shape, and presents two surfaces for examination. The upper surface is irregular, rough, and traversed by numerous furrows, which give it a somewhat checkered appearance. These patches are the *cotyledons*, between which the decidua (serotina) dips down,

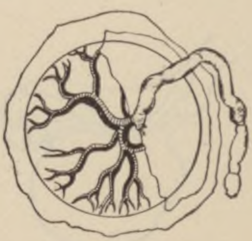

FIG. 35.

forming partitions or septa. This upper surface of the placenta is that portion of the decidua which has split off from the uterine wall during the casting of the cake. The under, fœtal surface of the afterbirth is smooth, concave, and glistening, and is covered by the amnion. Immediately under the latter membrane it is traversed by a net-work of blood-vessels, which appear distended and cord-like. The *arteries* lie external to the *veins*, which are the larger. At term the placenta is from six to eight inches in diameter, and one-third to over an inch in thickness at its thickest part, gradually thinning toward the edge. Its weight is about sixteen ounces, but varies somewhat with the size of the child. The insertion of the umbilical cord in the placenta is always eccentric (Minot).

The Umbilical Cord.—The sides of the *Bauchstiel* grow downward and inward and finally unite along its ventral surface, forming a tube, which includes the stalk of the allantois. The cavity of the tube is directly continuous with the cœlomic cavity. While these changes are in progress, the amnion, which at first arises from the *Bauchstiel*, becomes separated from the latter up to the insertion of the chorion; so that the umbilical cord at term is never covered by the membrane, as generally stated (His).

The cord carries one artery and two veins, which soon establish a circulation between the embryo and the chorion, later with the placenta. In the further development of the cord the cavity becomes obliterated and the allantois and yelk-stalk shrivel and nearly or quite disappear. At term the cord appears as a "long, twisted rope of tissue" (Minot) covered by epithelium, which is continuous with that of the amnion, and contains a jelly-like matrix,—**Wharton's Jelly,**—which surrounds the vessels. Wharton's jelly contains *mucin*, branched corpuscles, lymphoid cells, and connective-tissue fibrils (Landois). The vessels run in a spiral course, usually from left to right. The usual length of the cord at term is from eighteen to twenty inches, but it may be much longer or shorter.

The Utero-Placental Circulation.—This is a subject of much controversy, but may be briefly outlined as follows: Prolongations arise from the decidua serotina, and between these the chorionic villi penetrate. The vessels of the decidual prolongations (arteries), running in a somewhat irregular manner with many corkscrewlike turns, become tuft-like as they approach the surface of the prolongations, and by a solution of continuity lose their coats, so that they open freely into the intervillous spaces. The veins, on the other hand, open at the base of the prolongations and along the decidua of the intervillous spaces. The chorionic villi thus hang more or less free in a sinus, and are bathed in maternal blood. Each decidual prolongation has its own current region, the blood being poured out from the sides of the

FIG. 36.

former, and is carried off by the veins which lie below. The greater the distance from the decidual prominences, the slower the blood-stream, until at the greatest distance a stasis occurs, with resulting fibrin deposit. The circular sinus at the edge of the placenta receives the blood from the lowest prolongations, but, as it appears often interrupted, it can have but limited importance in carrying off the blood. The chorionic villi rarely, if ever, penetrate into the mouths of the arteries, but they do enter the veins, and often for a considerable distance.[1]

[1] Bumm, Archiv für Gynakologie, Bd. xliii, p. 181.

SECTION VI.

THE DEVELOPMENT OF SPECIAL ORGANS AND PARTS—THE HEART, BLOOD-VESSELS, AND BLOOD.

The Heart.—When the cœlom, or body-cavity, is formed by the splitting of the mesoderm into two parts, the lower portion, with the entoderm, forms the intestinal plate (splanchnopleure). Before the infolding and approach toward each other of the two intestinal plates begin, a small cavity in the mesodermal portion of each plate is formed in the midst of a number of isolated cells situated at some distance from the middle line of the embryo, and in the region of the future throat.

FIG. 37.

The mesodermal cells which bound this cavity undergo a change and become endothelial in character. These two cavities are the two halves of the *primitive heart-cavity*. As the infolding of the intestinal plate progresses, the two halves of the heart are brought nearer and nearer together, and, following coalescence of the plates, unite in the median line, the thin partition-wall disappearing and a single cavity remaining. As the heart-cavity enlarges it pushes the surrounding tissues into the pleuro-peritoneal space, forming a noticeable projection on either side. The heart lies on the ventral side of the future throat, and at first is attached above and below by a dorsal and a ventral *mesocardium.* The ventral mesocardium finally disappears, as does also the middle portion of the dorsal mesocardium, and the heart is left projecting freely into the body-cavity.

At this period the heart consists of a short tube

FIG. 38.

having an external (mesodermal) muscular coat and an internal endothelial lining, the two coats being at first separated by a considerable interval. As the head-fold deepens it crowds the heart backward so that it comes to lie under the midbrain ; at a later period the growth

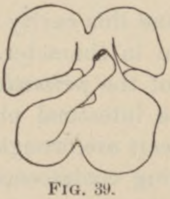

FIG. 39.

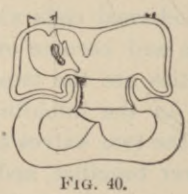

FIG. 40.

of the neck carries the heart still farther backward. In the rabbit traces of the heart are visible when five proto-vertebræ have developed. A slight dilatation of the upper end of the heart-tube now takes place, marking the future *aortic bulb.*

The lengthening of the cardiac tube in a confined space causes it to assume an **S**-shaped bend to the right,—that portion of the **S** to the right and in front representing the future auricles; that toward the left and behind, the ventricles. A constriction, the Auricular Canal, then appears, separating auricle from ventricle. Septa subsequently develop, which divide the single ventricle into two parts, and later other septa divide the auricle, each auricle being in communication, through the *Foramen ovale*, with its fellow, and with the ventricle of the same side.

Blood-vessels.—The primitive blood-vessels develop as a cord-like net-work in the mesoderm (splanchnopleure) of the embryonic area. This net-work does not include the whole of the area, but that portion represented by the *Areas Opaca* and *Pellucida*. It is bounded by a limiting vessel, the *Sinus terminalis*, which in man subsequently disappears. Yellowish-red masses are seen at intervals in the net-work, the cells of which develop hæmoglobin. A "liquid vacuolation" then takes place in the cord-like net-work, and the cells from the islands subsequently become detached and circulate as free blood-corpuscles (Minot). The newly-formed blood-vessels send out prolongations which meet with others, and, uniting, form a series of branches and ramifications. A growth of the blood-vessels toward the embryo also takes place, the vessels penetrating to the heart, and thus the circulation is established.

THE PRIMARY EMBRYONIC CIRCULATION.

While the changes described are taking place in the heart, blood-vessels are also developing in various parts of the embryo, as described, and a primitive circulation is soon established. The tubular heart is continued anteriorly as a single vessel, the **Truncus arteriosus.** This divides in the region of the first branchial arch, each branch running right and left around the body-cavity to the posterior surface of the embryo, where they turn caudalward and extend in the long axis of the embryo to its hind end. These two vessels are the **Primitive Aortæ.** Lateral branches are given off from the aortæ, the largest of which are the **Omphalo-mesenteric Arteries.**

The blood is returned to the heart by large veins in the *area vasculosa.* From the anterior portion of the **Sinus terminalis** it flows through the two **Anterior Vitelline Veins,** which receive branches along their course; from the posterior portion of the sinus it returns through the **Posterior Vitelline Veins.** All of the veins unite near the middle of the embryo, in the **Omphalo-mesenteric Vein,** which enters the posterior end of the heart-tube.

SECONDARY EMBRYONIC CIRCULATION; AORTIC ARCHES.

At a later period than described above, a right and left arterial branch is given off from the *Truncus arteriosus* at the first visceral arch. These run along the arches to the back of the embryo and unite on either side of the vertebral column with the *Primitive Aortæ.* Four other pairs of these *aortic arches* follow in succession and terminate in the same manner.

From the internal portion of the first arch on either side are developed the **External Carotid Arteries**; the third arch and the external (dorsal) parts of the second and first arches enter into the formation of the **Internal Carotid Arteries.** From the dorsal (external) portion of the fourth arch is given off the **Vertebral Artery,** and from this arises the **Subclavian Artery**; from the last arch are given off the **Pulmonary Arteries,** which at first are connected with the **Dorsal Aorta** by the **Ductus Botalli.**

The **Iliac Arteries** arise from the *umbilical arteries* as soon as the leg-buds appear. The venous blood is collected in the head by the two **Jugular Veins,** in the body by the two **Cardinal Veins.** These trunks unite in the cardiac region and form the **Ductus Cuvieri,** where they are joined by other veins, and enter the lower end of the heart as the **Sinus venosus.**

Blood.—The primitive red blood-corpuscles arise from the cells of the cord-like net-work during the process of lumen-formation, and multiply by indirect division. At first they are pale, granular, contain a large nucleus, and are surrounded by a layer of protoplasm. The earliest form is probably spherical or spheroidal, the characteristic mature shape being assumed later (Minot). The origin of the leucocytes, before the development of the lymphatic glands, is not definitely known.

The Central Nervous System.

The Spinal Cord.—Following the formation of the Medullary, or Neural canal, a transverse section of that portion which is to become the spinal cord appears of an oval shape, and presents a small, central lumen bounded by thick sides and thinner ends. In the further development of the cord the sides increase in thickness, by a proliferation of their cells, but the end pieces do not participate in this growth, the result being two thickened lateral halves, united above and below, at the bottom of more or less deep anterior and posterior grooves, by thin commissures. The sides at a later period give rise to the **spinal nerves,** and in time are converted into the *Anterior*, *Lateral*, and *Posterior Columns* of the cord.

Up to the fourth month the growth of the cord conforms to that of the vertebral column, and extends from the first cervical to the last coccygeal vertebra. From

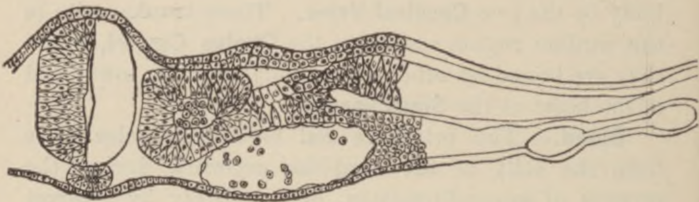

FIG. 41.

that time on the bony structures outgrow the nervous, so that the cord appears to be shortened and no longer fills the canal. The lower end of the cord does not enter into the ganglia and nerve-cell formation going on in the upper portion, but remains tube-like, the point of demarkation from the rest of the cord being indicated by a small, conical enlargement,—the *Conus medullaris.*

FIG. 42.

As the result of the superior growth of the vertebral column and consequent apparent shortening of the cord, the terminal tube, which is attached to the coccyx, becomes drawn out into a long, fine filament, which persists in adult life as the *Filum internum* and *externum.*

At the beginning of the sixth month the conus is at the sacral canal, at birth it has reached the region of the third lumbar vertebra, and a year later it is at the lower border of the first lumbar vertebra, where it remains (O. Hertwig).

Another result of the lengthening of the vertebral column is seen in the changed direction of the nerve-processes. At first the nerves spring from the cord at right angles, and so remain in the cervical region, passing direct to the intervertebral foramina; but lower down their course becomes more and more oblique, until at the lower end of the cord they run in a vertical direction and remain for some distance in the spinal canal before making their exit. This lower mass of nerves surrounds

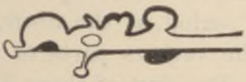

FIG. 43.

the Filum terminale, and forms the so-called *Cauda equina.*

Between the third and fourth months an enlargement of the cord takes place at the point where the nerves are given off to the upper and lower extremities. These thickenings persist, and are known as the *cervical* and *lumbar enlargements.*

The *gray matter* of the cord is first developed apparently from without inward, and is followed by the formation of the *white matter*, which proceeds from a differentiation of the outermost layer of cells of the cord.

The Brain.—The anterior portion of the neural canal is at first a simple tube, but it soon dilates, and, two lateral constrictions appearing, it becomes divided into three parts,—the **Primary Cerebral Vesicles** (Fig. 43).

These communicate through their central canal. The first of these vesicles is known as the **Forebrain,** the second as the **Midbrain,** and the third as the **Hindbrain.** These vesicles occupy about one-half of the dorsal portion of the entire length of the embryo.

Cerebral Flexures.—The cerebral end of the neural

FIG. 44.

tube is at first straight,—that is, parallel to the surface, —but at an early period, as the result of the unequal development of the various parts of the brain, three bends take place. The first of these flexures occurs in the region of the midbrain, the forebrain being thus thrown forward and downward so that it lies at a right

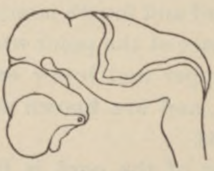

FIG. 45.

angle and later at an acute angle to the hindbrain. The midbrain is also carried upward to the top of the head. This is the *Primary head-bend.*

The second bend occurs at the junction of the hind-brain and the cord. This throws the whole head still farther ventralward, so that the floors of the fore- and hind- brains come to lie parallel. This is the *Neck-bend.*

The third bend consists of the forward growth of the ventral side of the hindbrain, and is called the *Varolian bend* (Minot).

The Forebrain.—At the same time that the cerebral vesicles are being marked out, the walls of the first vesicle grow outward, forming lateral pouches,—the **Optic Vesicles.** The forebrain continuing to grow forward and upward, the optic vesicles become constricted off from the former until they are connected only by a narrow stalk,—the anlage of the **Optic Nerve.** A forward and upward growth of the dorsal wall of the forebrain soon takes place, and, becoming constricted off, forms a fourth vesicle,—the *Secondary* or **Permanent Forebrain.** This is the anlage of the *cerebral hemispheres;* the opening between it and the primary vesicle is the *Foramen of Monro.*

From this permanent forebrain are developed the *Cerebral Lobes, Corpus Callosum,* and the *Fornix.*

From the primary forebrain arise the Optic Thalamus, the structures of the floor of the *Third Ventricle* (Tractus Opticus, Chiasma, Tuber Cinereum, Infundibulum, Corpora Mammillaria), the **Pineal Gland,** the **Posterior Commissure,** and the epithelium of the **Tela-choroidea Superior.**

The Midbrain.—The midbrain takes the least active part in the development of the cerebrum of the three original vesicles. The posterior wall thickens, and the opening into the forebrain remains large. As the result of the development of the other parts, which grow over it, the midbrain is crowded downward and backward, ultimately forming the **Aqueduct of Sylvius.** From its roof are developed the **Corpora Quadrigemina.**

The Hindbrain.—At the time of the development of the head-bend the length of the hindbrain more than equals that of the rest of the brain (Minot). The third vesicle is soon differentiated into two portions,—a dorsal part with thick walls, the anlage of the **Cerebellum**, and a ventral portion, the Varolian bend, the apex of which is the anlage of the **Pons Varolii.**

That part of the thickened wall between the pons and the cord becomes the **Medulla Oblongata.**

The ventricle of the third vesicle becomes the *fourth ventricle* of the adult brain.

The **Olfactory Lobes** arise as a longitudinal ridge from the under surface of the primitive hemispheres during the fourth week.

The Urinary Organs.

The Kidneys.—The development of the kidneys takes place in three stages :—

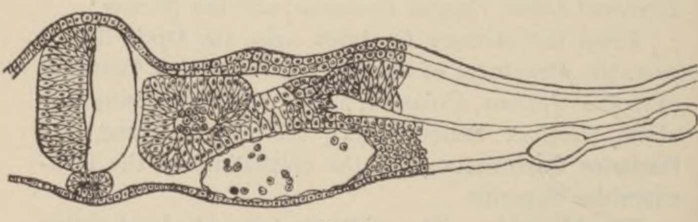

Fig. 46.

1. A solid rod of cells, probably derived from the ectoderm, makes its appearance in the "intermediate cell-mass" lying between the protovertebræ and the point of junction of the body and intestinal plates (somatopleure and splanchnopleure). In the rabbit this rod appears between the eighth and ninth day, in the

region of the fourth or fifth protovertebra, and develops rapidly caudalward to the posterior end of the primitive gut. The rod soon acquires a lumen which opens into the dorsal side of the lower portion of the allantois, where that structure is given off from the hindgut. The cells around the canal now develop, and a longitudinal column is formed, which projects somewhat into the cœlom. This projection is called the **Wolffian Ridge,** while the canal is the **Segmental** or **Wolffian Duct.** This duct functionates as a ureter until the development of the permanent kidney.

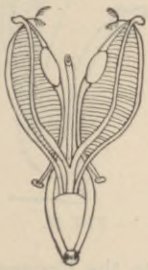

FIG. 47.

2. Within the column a simple comb-like gland appears. A series of lateral (transverse) tubules are developed, which open into the duct (externally), a few of them also opening into the body-cavity (internally). The parts about the tubules and duct become more compact and vascular, and *convoluted canals* and *glomeruli* are developed. This gland is the **Wolffian Body.** All except the upper end of this body ultimately disappears (eighth week).

3. Just above its opening into the Cloaca a tubular bud is developed from the dorsal side of the Wolffian duct. The upper part of this bud grows quite rapidly,

extending forward to the cephalic end of the Wolffian body, where it dilates and covers the latter dorsally. This is the anlage of the *permanent kidney.* The glandular parts of the kidney are subsequently developed from the surrounding cells.

The forward growth of the blind end of the renal bud causes its lower portion to become more and more stretched out until a long, narrow tube is formed,—the **Ureter.** At first the ureter opens into the Wolffian duct, but as the result of subsequent changes it acquires

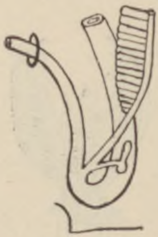

FIG. 48.

a separate opening into the **Urogenital Sinus,** in front of that of the Wolffian duct.

The Supra-renal Capsules.—These capsules consist of two parts, which originate independently. The *cortical* portion of the capsule is derived from the mesoderm, while the *medullary* portion develops from an offshoot from the sympathetic nervous system, lying in the abdomen below the aorta. The two parts unite at an early age, forming a body which at first is greatly in excess of the kidney in size.

The Bladder.—During the second month of embryonal life that portion of the allantois which lies within the abdominal cavity, and which is still in open communication with the lower end of the intestine (Cloaca), becomes dilated into a spindle-shaped vesicle, the middle portion of which represents the future urinary bladder. The distal portion of the spindle is still pervious up to the umbilical opening, but its lumen gradually narrows, and in time the whole dwindles to a solid connective-tissue cord, the **Urachus,** extending from the summit of the bladder to the umbilicus, and forming the *Ligamentum vesicæ medium.* The spindle-shape of the bladder

FIG. 49.

persists for a considerable time. The organ is lined by entoderm; the connective tissue and muscle of the walls are derived from the mesoderm.

The Urethra.—See under "External Genitals."

THE ALIMENTARY TRACT.

The primitive gut is formed by the infolding and fusion of the splanchnopleural plates, and at first extends as a simple tube nearly the whole length of the embryo.

It soon becomes differentiated into three parts,—the *Foregut*, that part lying within the head-fold, and from which are developed the *pharynx*, *œsophagus*, *stomach*, and *duodenum;* the *Hindgut*, that portion included within the tail-fold; and the *Midgut*, lying between these two and opening on its ventral surface into the yelk-

FIG. 50.

sac. From the latter the large and small intestines are developed.

The Mouth.—By the formation of the head-fold the ectoderm and entoderm of the primitive gut are brought together at a point between the forebrain and the heart. The mesoderm is pushed caudalward so that

FIG. 51.

the outer and inner layers of the blastoderm are in apposition. This point is called the *Oral Plate.* As the result of the head-bend the oral plate is carried downward and to the ventral side of the head. Heart and forebrain now growing forward, a pit is formed between the two, at the bottom of which lies the oral plate, the sides being covered by the somatopleure, extending from heart to head. This pit appears about the twelfth day (His). Rupture of the oral plate now taking place, a communication is established with the anterior end of the foregut, the opening representing the *Primitive Mouth*. The mouth at this time appears bounded by five sides, each side being raised in a small prominence. The upper tubercle, which is unpaired, forms the superior border of the mouth and is developed from the forebrain. The superior paired tubercles, **Maxillary Processes,** have to do with the development of the **Superior Maxilla,** while the lower two tubercles become

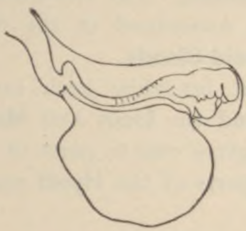

FIG. 52.

the **Mandibular Processes,** and are a part of the first **Branchial Arch** which forms the **Inferior Maxilla.**

The Pharynx.—The upper part of the foregut, into which the mouth opens, and which is to become the pharynx, is much wider than the succeeding part of the gut, and at first is of uniform diameter. Very soon the upper portion of this cavity dilates, while the lower part contracts, a triangular or funnel-shaped space resulting. At the beginning of the third week, four paired pouches, the first beginning at about the level of the mouth, extend outward from the entoderm of the sides of the pharynx until they meet the ectoderm, with which they unite. These pouches are called the **Branchial, Visceral,** or **Gill Clefts.** In the lower vertebrates a rupture of the membrane of the clefts takes place, forming slit-like openings into the pharynx; but in man no opening is formed, the membrane persisting. The tissue between the clefts, composed of the three primary layers, appears as tongue-like ridges, which project on the external (ectodermal) and internal (entodermal) surfaces of the pharynx. These ridges are the **Branchial Arches,** five in number, and in them run the vessels forming the **Aortic Arches.** From the first visceral cleft are developed the **Auditory Canals,** and from the second the **Tonsils.** The entoderm of the remaining two clefts is concerned in the formation of the **Thymus** and **Thyroid Glands.**

From the first branchial arch are developed the **Inferior Maxilla** and the **Incus** and **Malleus** of the ear. The second arch gives rise to parts of the **Hyoid Bone,** and the third to parts of the **Hyoid** and the **Thyrohyoid Bones.**

The fourth and fifth arches have no particular significance.

The **Tongue** and **Epiglottis** are developed from the floor of the pharynx.

The Œsophagus.—The folding in of the splanchnopleural plates gives rise to the formation of a straight tube running along a portion of the lower aspect of the embryo. This is the primitive intestine, or *Archenteron.* The anterior portion of the tube is called the *Foregut.* Immediately behind (caudalward) the pharynx the foregut narrows into a short tubular portion,—the Œsophagus. During the fourth and fifth weeks, as the embryo body and neck elongate, the gullet becomes larger and longer, but still remains a comparatively straight tube.

The Stomach.—The stomach is indicated early as a slight, spindle-shaped widening of the foregut between the œsophagus and the liver. By the fifth or sixth week a decided bulging of the posterior wall of the gut has taken place, while the anterior wall becomes somewhat depressed. The *greater* and *lesser curvatures* of the stomach are thus marked out. The stomach still lies in the axis of the body, but it soon descends into the abdominal cavity, and at the same time rotates so that it comes to lie across the body-cavity, the larger

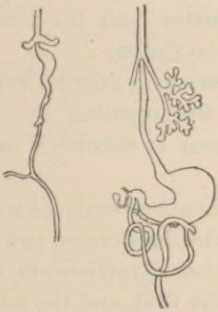

FIG. 53.

end being carried to the left, while the lesser or pyloric end is turned to the right. While the direction of the stomach is longitudinal it is attached along its whole posterior length by mesodermic tissue to the body-wall, but as soon as the change in position takes place this attachment becomes drawn out into a thin membrane,—the **Mesentery.** Following rotation, that portion of the mesentery which connected the posterior wall of the greater curvature to the body becomes stretched out and folded, and forms the anlage of the future **Omentum.**

The Intestine.—This includes all of the primitive gut between the stomach and anus. While like the rest of the tube it is at first straight, it increases rapidly in length and diameter, and as a result of this growth is thrown into numerous coils, which lie toward the ventral side of the body.

The **Duodenum** is formed by a loop immediately below the stomach. Lower down another loop is developed, the **Vitelline Loop,** which at a later period extrudes some from the body, and is in connection with the yelk-sac. As soon as the cloacal space becomes divided into urogenital sinus and rectum, the latter increases in thickness and diameter, and the lower portion of the gut develops into the **Colon.**

The **Cæcum** arises as a pouch from the vitelline loop in the region of the opening of the yelk-sac. The formation of the **Anus** is described under "The Sexual Organs."

The Liver.—This arises early as a diverticulum from the ventral side of the duodenum, and is situated behind the heart. A second diverticulum is almost immediately formed from the first, and the walls of both become greatly thickened. These are soon permeated by blood-vessels; the cells between are converted into solid cords, which form a net-work, and later, acquiring a lumen, represent the *lobular tissue* and *ducts* of the liver.

The duct connecting the liver with the intestine becomes the **Common Bile-duct,** and from this during the second month the **Gall-bladder** appears as a diverticulum. At birth the liver is very large, its weight to that of the whole fœtus being as 1 to 18, while in the adult it is as 1 to 36 (Marshall).

The Pancreas.—During the fourth week this develops as a bud from the dorsal portion of the foregut nearly opposite the liver, and grows dorsalward into the mesentery. Its duct is the remains of the original evagination.

The Spleen.—This appears toward the end of the second month as an epithelial (mesenchymal) thickening in the mesogastrium, in the vicinity of the pancreas, and close to the large blood-vessels. The collection of cells forming the spleen anlage become stratified, blood-vessels penetrate its substance, and the organ becomes gradually separated from the surrounding tissues, but still retains its connection with the mesogastrium.

FIG. 54.

The Lungs.—These begin about the fifteenth day as a vertical diverticulum (pulmonary anlage) of the ventral wall of the œsophagus, which extends from the fourth gill-cleft to the stomach. On transverse section at this time the œsophagus appears as an oval aperture, which lower down becomes pear-shaped. At the lower end the pulmonary groove divides into right and left pouches, which are surrounded by mesodermal tissue. A transverse section at this time shows the lumen of three tubes. These diverticula project into the body-cavity; the peritoneum, which is pushed before them, forming the pleural covering and later the **Pleural Sacs.** By the growth and repeated branching of the lateral pouches the *bronchi*, *bronchioles*, and *alveoli* are formed, while the original tube, having separated off from the œsophagus, becomes the **Trachea.** The upper, slit-like opening into the pharynx represents the **Glottis.**

The **Larynx** is developed during the fifth week as a dilatation of the anterior part of the trachea.

The Sexual Organs.

The External Genitals.—By the fourth week (Kölliker) an invagination of the ectoderm at a point on the posterior end of the embryo has taken place, so that this layer is brought in contact with the entoderm of the cloaca, and, rupture of the two layers following, an external opening is formed into the posterior end of the gut,—the *Cloacal Opening*, or **Primitive Anus.**

A thickening of the anterior portion of the anal plate now takes place, giving rise to a slight protuberance, the **Genital Eminence,** which is the anlage of the *Clitoris* and *Penis.* On the under surface of the eminence a slight groove appears, the **Genital Groove,** and runs backward into the cloacal opening. The sides of this groove increase in size and project somewhat as the **Genital Labia** (Minot). About the middle of the third month a partition wall divides the cloacal space into two cavities, the anterior of which receives the urinary and Müllerian ducts, and is called the **Urogenital Sinus,** while the posterior opening persists as the **Anus.** The dilated portion of the archenteron immediately above the anus, into which at first the allantois and intestine both open, is the **Cloaca.**

By the further growth of this partition the two openings are carried farther and farther apart, the tissue

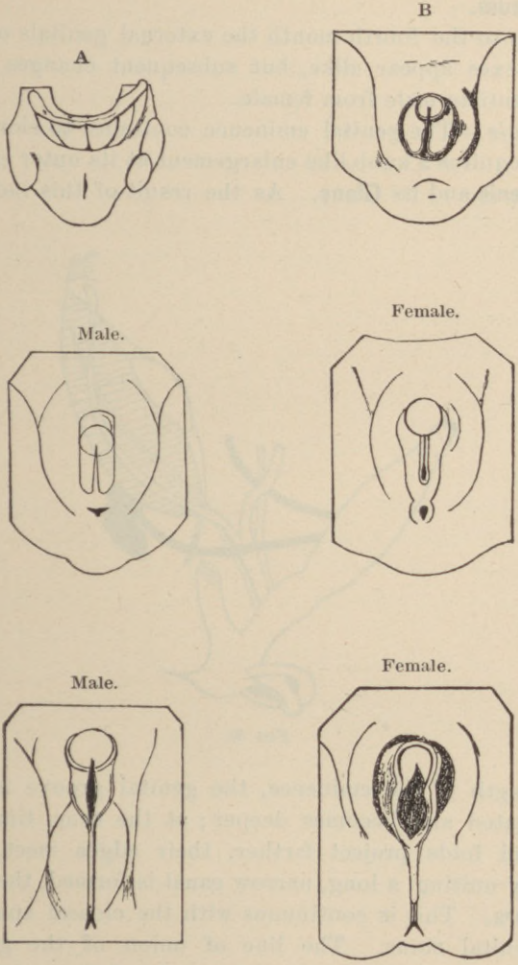

FIG. 55.

developing between them ultimately becoming the **Perineum.**

Up to the fourth month the external genitals of the two sexes appear alike, but subsequent changes soon differentiate male from female.

Male.—The genital eminence continues to elongate, and acquires a knob-like enlargement at its outer end,—the **Penis** and its **Glans.** As the result of this increase

FIG. 56.

in length of the eminence, the genital groove is also elongated and becomes deeper; at the same time the genital folds project farther, their edges meet, and, finally uniting, a long, narrow canal is formed, the male **Urethra.** This is continuous with the cloacal space, or urogenital sinus. The line of union of the genital folds is seen in the adult as the *raphé* of the penis.

The **Prostate Gland** is formed by a circular thickening in the walls of the upper end of the urogenital sinus. The glandular portion results from the ingrowth of the epithelium lining the canal. By the fusion of the lower portion of the ducts of Müller the so-called **Uterus masculinus,** or *prostatic vesicle*, is formed. About the middle of the third month a slight prominence called the **Genital Ridge** develops on either side of the genital eminence. These ridges grow outward as folds, their edges meet and unite, and give rise to the future **Scrotum,**—the point of fusion of the folds persisting as the *scrotal raphé.*

At a later period, preceded by the *Processus vaginalis*, the testicles descend and find lodgment in the scrotal sac.

Female.—In the female the changes which take place in the formation of the external genitals are less pronounced. The genital eminence increases slowly in size and becomes the **Clitoris,** the genital folds enlarge and form the **Labia Minora,** and the sinus urogenitalis persists as the **Vestibulum vaginæ.** Into this opens the **Urethra**—the elongated and narrowed portion of the allantois—and the vagina.

The genital ridges enlarge by acquiring fat-tissue, project, but do not unite, and become the **Labia Majora.** The *Prepuce* of the clitoris is formed by the folds of skin which pass over the glans.

INTERNAL ORGANS OF REPRODUCTION.

Müller's Duct.—At a period subsequent to the appearance of the Wolffian duct, a second canal, the duct of Müller, is developed external—that is, lateral—to the former. This begins as a thickening of the mesothelium of the Wolffian body, and extends backward as a solid cord to the allantoic portion of the cloaca. The anterior end of the cord becomes funnel shaped as the result of the invagination of the peritoneal epithelium, and the cord gradually acquires a lumen dorsalward. The duct of Müller, therefore, has two openings,—one above into the body-cavity, and one below into the allantois. In the female this duct is the anlage of the **Fallopian Tube,** the anterior opening representing the *Morsus diaboli* of the *Ostium abdominale*, while the lower portion develops into the *Utero-vaginal Canal.*

The Genital Fold.—At about the same time that the

FIG. 57.

development of the ducts of Müller takes place, a small ridge, the *Genital Fold*, is formed on either side, between the Wolffian body and the mesentery, and projects slightly into the body-cavity. This ridge extends nearly the whole length of the abdominal space, and is mainly formed by a thickening of the peritoneal epithelium, the **Germinal Epithelium.** The middle portion of this ridge is the anlage of the **Sexual Gland.** By further growth the genital fold becomes so intimately connected with the Wolffian body as to appear to have arisen from it. Further changes consist of the approach of the caudal ends of the urogenital ridges toward the middle line, where they unite to form the **Genital Cord.**

The differentiation of sex in the internal organs becomes apparent about the fifth or sixth week.

The Testis.—In that portion of the genital fold, the *Sexual Gland*, which is to become the testis, a series of cellular cords, *Sexual Cords*, are developed from the germinal epithelium. These are separated from one another by a loose, embryonal connective tissue. They contain a number of large nucleated cells,—the primitive **Sperm Cells.** The cords acquire a lumen and become the **Seminal Canals.** The anterior tubules of the Wolffian body extend into the sexual gland, unite with the seminiferous tubules, and, anastomosing in various directions, form the **Rete testis**; the outer portion of the tubules remaining as connecting channels—**Vasa efferentia**—between the latter and the Wolffian duct. The anterior portion of the Wolffian duct becomes the **Epididymis,** the posterior part the **Vas deferens.**

In the male the middle portion of the ducts of Müller entirely disappears, the anterior part remaining as the *Hydatids of Morgagni*, while the posterior, the genital cord, becomes the *Uterus masculinus.*

The Ovary.—In the development of the ovary the sexual cords, later called the *Cords of Pflüger*, are larger than in the male, and the cells which they contain are much more numerous. The connection with the Wolffian duct is established in the same manner as in the male, the cords acquiring a lumen and becoming the *tubuliferous tissue* of the ovary. The large cells, which develop into **ova,** are derived from the germinal epithelium together with the cords.

The upper portion of the ducts of Müller become the **Fallopian Tubes.**

The genital folds thin out into the **Broad Ligaments.**

The tubules of the upper portion of the Wolffian duct persist as the **Parovarium,** with its longitudinal duct.

The lower portion of the Wolffian duct persists, or not, in the genital cord as the *Ducts of Gaertner.*

The Uterus and Vagina.—By the formation of the genital cord the two ducts of Müller are brought into apposition; their walls fuse, become thinner, and finally disappear, leaving a single tube, or *Genital Canal.* A differentiation of this simple tube into uterus and vagina begins about the sixth month. (See Fig. 57.)

The upper portion of the tube into which the Fallopian ducts open develops thick, muscular walls, representing the *Body* and *Fundus* of the *Womb*, and a lower, knob-like prominence the *Vaginal portion*, or *Cervix.*

In the lower portion of the tube the lumen remains wide and the walls thin,—the **Vagina.**

The Skeleton.

With exception of the notochord (vertebræ), which is derived from the entoderm, all the bones of the body are developed from the mesoderm. In point of time the skeleton is relatively late in appearing, the anlage of most of the important structures of the embryo-body being already present before the future bony structure is indicated. The development of the skeleton may be placed in three stages: (1) the membranous stage; (2) the cartilaginous stage; (3) the bony stage.

With certain exceptions, the bones of the body are first "laid in" in cartilage, which is later replaced by true bone,—the so-called *cartilaginous ossification.* A few bones originate in connective tissue, the process being known as *intra-ligamentous ossification.*

In both forms the process of ossification is essentially the same.

The Muscular System.

Following the division of the protovertebral plates of the mesoderm into the primitive segments, a differentiation of the cells of the latter bodies also takes place, two distinct portions being formed in each. The innermost of these parts, that which is nearest the medullary canal, is called the *Myotome*, while the outermost section is the *Nephrotome*. From the innermost portion of the myotome a body of cells is further differentiated, these cells being known as the *Muscle-plate*, and from which the muscular system of the body is developed. The muscle-plates grow rapidly, especially dorsalward, covering the medullary canal, and extending into the somatopleure. The muscles of the extremities are probably derived from offshoots from the muscle-plates.

Development of the Extremities.

The limbs appear in the thoracic and pelvic regions, as bud-like outgrowths of a lateral longitudinal ridge

Fig. 58.

which runs on the level of the lower end of the muscle-plates for nearly the whole length of the trunk (Balfour). These buds are at first flat and at right angles to the body. During the fifth week they have increased in size and divided into two parts, the distal and smaller segment being the future hand or foot. Notches also appear in the anterior margin of the hand, marking the future **Fingers.** During the sixth week a crease appears in the proximal portion of the limbs, which are thus divided into the **Arm** and **Forearm,** the **Thigh** and **Leg.** The **Toes** are also indicated at this time, and the limbs rotate so that the elbows point forward and the knees backward. By the seventh week the **Nails** appear as thickenings over the finger-tips; their subsequent shifting to the dorsum of the fingers is the result of the growth of the palmar surface of the latter (Kölliker). The development of the anterior extremities is in advance of that of the posterior.

The Face.

The development of the Mouth has already been described. (See page 66.)

The Nose.—This develops at a very early age by the

Fig. 59.

thickening of a patch of ectoderm, the **Olfactory Plates,** on the under surface of the forebrain, in front of the mouth. An upgrowth of the ectoderm and mesoderm along the median, lateral, and superior borders of the plates soon converts them into depressions,—the **Nasal**

Pits (Fig. 60). The lower sides of these pits remain open, and by further growth a groove, the **Nasal Groove,** is formed, which runs backward to the mouth-cavity. A tongue of tissue, the **Nasal Process,** growing downward from the anterior wall of the head to the mouth, now sends out a rounded process, the **Processus globularis,** on either side; the two constrict the nasal openings, and, growing sideways, unite with the maxillary processes. The nasal grooves are thus covered in and two tubes formed, the *posterior nasal passages,* leading from the nasal pits to the cavity of the mouth. The epithelium of the plates gives rise to the olfactory or **Schneiderian Membrane** of the nose, and this at a later period is brought in relation with the *Olfactory Lobes* by means of ganglia developing in its epithelium.

The middle portion of the nasal process, which appears depressed on account of the upgrowth of its sides, pushes forward, forming an angle at its lower middle end, and this becomes the *tip* of the future nose. The superior central portion of the process becomes the *Nasal Bridge.*

By the growth of the surrounding parts the olfactory pits gradually become converted into the slit-like apertures of the **Anterior Nares,** while the **Alæ nasi** are formed, toward the end of the second month, by the nasal ridges of the process.

By the uniting of the two globular processes the anlage of the upper **Lip** is formed. Behind these a second ridge, arising, forms the anlage of the **Gums.**

The Ear.—*Internal Ear.*—The first traces of the ear appear, about the fifteenth day, as a thickened plate of ectodermal cells, lying just back and above the first gill-cleft. An inpouching of the ectoderm here takes place, forming a pit, which is later covered over and separated from the tissues above as a vesicle,—the **Auditory Vesicle,** or **Otocyst.** The otocyst is at first round, but subsequently it sends out a dorsal prolongation, the *Recessus vestibuli*, which later comes in contact with the *Auditory Ganglion.*

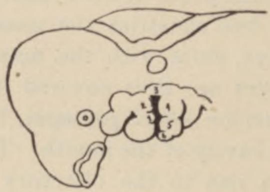

FIG. 60.

The **Semicircular Canals** and **Cochlea** are developed from the walls of the auditory vesicle.

The **Auditory Canal** and **Eustachian Tube** arise from the first visceral cleft.

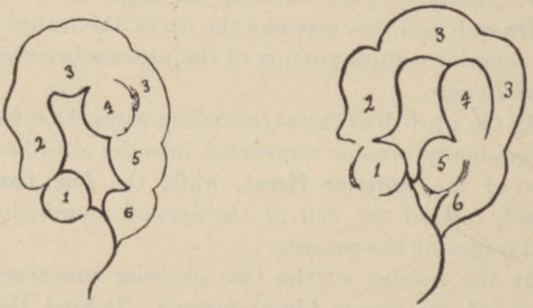

FIG. 61.

The **Tympanum** develops from the membrane covering the first cleft.

The External Ear.—During the first month six tubercles make their appearance around the end of the first branchial cleft,—two from the maxillary arch, three from the second arch, and one, intermediate, at the end of the cleft. A groove then appears below the tubercles on the second arch, raising the future Helix from the surrounding surface. The first tubercle of the maxillary arch becomes the **Tragicum**; the second and intermediate tubercles fuse to form, with the raised portion of the ear, the **Helix**; the first superior tubercle of the second arch becomes the **Antihelix,** the middle the **Antitragus,** and the last the **Lobe.**

The Eye.—The development of the primary optic vesicles has already been described (page 61).

The Lens.—By the fourth or fifth week a small pit, the *Primary Optic Cup*, is formed on the surface of the

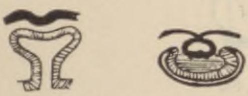

FIG. 62.

FIG. 63.

optic vesicle by the inpouching of the ectoderm. This cup increases in size, and is gradually constricted off to form a vesicle, the anterior portion of which is connected with the ectoderm for a time by a band of tissue. The vesicle is the future lens. As the constricting off of the lens progresses, the edges of the ectoderm approach each other and finally unite over the lens as an unbroken layer. At this point the ectoderm, together with the mesoderm, which grows in between the external layer and the lens, forms the anlage of the **Cornea.**

The Retina.—As the lens develops the optic vesicle becomes invaginated behind it and forms a *Secondary*

Optic Cup, which surrounds the lens on all sides except in front. The posterior wall of this cup ultimately unites with the posterior wall of the optic vesicle to form the retina, the original wall of the vesicle being the future *Pigmented Layer*.

Between the lens and the retina there is at first but little space, but as the eye enlarges this space is increased and furnishes the **Vitreous Body.**

The secondary optic cup never entirely covering over the anterior surface of the lens, a circular aperture is left, which forms the primitive **Pupil.**

The **Anterior Chamber** of the eye is formed by a split in the mesoderm, which grows in between the ectoderm

FIG. 64.

and the lens, the external layer assisting in the formation of the **Cornea,** the internal the **Iris.** The tissues about the eyeball become more compact and thicker, and form the anlage of the **Sclera** and the **Choroid.**

The Optic Nerve.—At the same time that the invagination of the optic cup takes place, a groove is formed along the lower border of the optic stalk. (See Fig. 64.) The lumen of the stalk is thus diminished, but an open communication still exists between the *Third Ventricle* of the brain and the *Post-lenticular Space.* The groove is called the *Choroidal Fissure.* An artery soon appears along this groove and runs through the vitreous body to supply the lens,—the *Arteria centralis retinæ.* The anterior part of the artery is subsequently obliterated.

The choroidal fissure suddenly closes up, from behind forward, and becomes a solid rod, which, acquiring nerve-fibres from the brain and retina, forms the optic nerve.

The Eyelids.—These originate as upper and lower folds of integument in front of the eye. The folds increase in size, meet in the middle line and fuse, but again become separated before birth.

SECTION VII.

General Consideration of the Child at Birth.

Owing to the arrangement of the circulation and the consequent better nourishment of the anterior portion of the body, the anterior part of the trunk and the head appear better developed at birth, but the increase in size thereafter goes on more rapidly in the lower extremities. The average weight of the child at birth is $7\frac{1}{3}$ to $7\frac{3}{10}$ pounds (Lusk), males being somewhat heavier than females.[1] The average length of the infant is 20 to 21 inches.

The Head is generally covered with hair about an inch long, and is usually misshapen as the result of pressure in the bony canal during labor, the so-called "molding" having effected a lapping of the bones along the line of the sutures. Furrows and depressions in one or more of the cranial bones may also be seen. A distinct swelling on that part of the head, face, or buttocks which presented at the uterine *Os* during labor may be present, and is called the *Caput succedaneum*. This is a serous infiltration of the skin due to absence of pressure at that point during labor, with pressure on the surrounding parts. *Cephalhæmatoma*, a circumscribed hæmorrhage situated between the pericranium and the bone, due to pressure or traumatism, is less frequently met with. Both swellings disappear,—the first in a few days, the latter in from ten to sixty days.

[1] In 1000 cases noted by Parvin but one child weighed 11 pounds. In 7000 cases LaChapelle found but 13 weighing 10 pounds, and none more. In 1156 cases Hirst records but one child of 12 pounds. Lusk saw one weighing 11 pounds in 200 cases.

The last mentioned may go on to suppuration. The average size of the head of the newborn child immediately after expulsion is as follows :—

Bitemporal (BT) diameter, . . .	8	centimetres.
Biparietal (BP) diameter, . . .	9¼	"
Occipito-frontal (OF) diameter, . .	11¾	"
Occipito-mental (OM) diameter, . .	13	"
Maximum (MM) diameter, . . .	13½	"
Suboccipito-bregmatic (SOB) diameter,	9½	"
Trachelo-bregmatic (TB) diameter, .	9½–10	"

Circumferences : OF, 34½ cm. ; SOB, 30 cm. ; OM, 37 cm.[1]

Circulation.—Marked changes take place in the circulation of the blood after birth. The fœtus, which up to the time of delivery has been dependent upon the mother for aëration of the blood, nourishment, and the discharge of its effete products, has now to carry on an independent existence.

In the fœtus the blood, returning from the placenta by the umbilical vein, divides into two currents,—one of which proceeds through the *Ductus venosus* to the *Inferior vena cava*, and thence to the *Right auricle* of the heart; the other to the *Liver* through the *Hepatic Veins* and *Arteries*, and on to the *Right auricle.* When the heart contracts, the blood in the *Right auricle* is forced through the *Foramen of Botal* into the *Left auricle.* The *Right ventricle* receives but a limited supply of blood, a small part of which it sends to the lung through the *Pulmonary artery*, but most of which goes to the *Aorta* through the *Ductus arteriosus.* The *Left ventricle* receives the blood from the *Left auricle* and *Pulmonary veins* and sends it into the *Aorta*, where it mixes with the blood coming from the *Right ventricle* through the *Ductus arteriosus.* The head and extremities are supplied by the *Aorta*, and the blood is returned

[1] Hirst, Am. System of Obstetrics, vol. i, p. 215.

to the placenta by the *Umbilical vein.* After birth cessation of the placental circulation and obliteration of the umbilical vessels take place. The *Ductus venosus* soon becomes transformed into a fibrous cord, the *Foramen ovale* between the auricles is closed (in about fifteen days), and the *Ductus arteriosus* becomes obliterated. The circulation now assumes the character found in the adult.

The Skin.—At birth this is of a rosy color, and is covered, on the back and flexor surfaces especially, by a whitish, sticky material,—the *Vernix caseosa.* This is composed of a greasy mixture of sebaceous matter and macerated cells and *Lanugo*, which by this time has nearly disappeared from the body. The vernix contains 47.5 per cent. of fat (Landois).

The Breasts are well formed, the lobes are distinct, and the ducts open at the nipple. In both male and female children an enlargement of the gland often takes place, and a thin, watery, finally a milky, fluid may be squeezed out.

Breathing.—As soon as the child is born the thorax expands, a few spasmodic inspirations take place, followed by more regular breathing and a more or less vigorous cry. The cause of the first inspiration has been variously stated, but it is probably due to the demand on the part of the system for oxygen. After the first inspiration the thorax never again assumes its previous form.

The Nails of the fingers and toes are well formed, and those of the former project beyond the finger-tips.

The Eyes are open and staring, but it is probable that no distinct perception of objects takes place before the fifth or sixth week.

The Testicles are usually down in male children ; the labia majora in apposition in females.

Excretions.—The urine of the newborn child is limpid, and after the first few hours abundant. It is sometimes stained with blood, bile, etc., and there may be at first a heavy deposit of sediment.

The Meconium, a thick, tarry material resembling poppy-juice,—whence its name,—is passed in abundance from the bowel after the first few hours, but ceases, after a few days, to be present in the evacuations. It consists of water, mucus, epithelium, fat, cholesterin, and 3 per cent. of bile-pigments, crystalline bilirubin, and biliverdin.

EMBRYO AND FŒTUS AT DIFFERENT PERIODS OF DEVELOPMENT.

First Month.—Indistinguishable from the ovum of other animals. Brachial plexus. Spinal canal closes. Buds of rudimentary extremities appear. Indication of eyes, anus, mouth. The heart is four-tenths inch long.

Second Month.—About one inch long. The eyes, nose, and ears are distinguishable. Suggestion of hands and feet. External genitals.

Third Month.—Ovum about the size of a goose-egg. Fingers and toes separated. Nails as fine membranes. Neck separates head from body. Sex distinguishable; uterus formed. Weighs 460 grains.

Fourth Month.—Six inches long. Weighs 850 grains. *Lanugo* present.

Fifth Month.—Ten inches long. Weighs 8 ounces. *Vernix caseosa* forming. Eyelids begin to separate. Heart-sounds perceptible. Quickening takes place.

Sixth Month.—Twelve inches long. Weighs 23½ ounces. Hair on head, eyebrows, and lashes. Testicles near rings.

Seventh Month.—Fourteen inches long. Weighs 41½ ounces. Pupillary membrane disappears.

Eighth Month.—Sixteen inches long. Weighs 3½ pounds. Left testicle descended. Nails do not protrude beyond finger-tips. Lanugo begins to disappear.

Ninth Month.—Eighteen inches long. Weighs 4½ pounds.

SECTION VIII.

Changes in the Maternal Organism Incident to Pregnancy.

The condition of pregnancy inaugurates a new era in the life of woman. Incident to this a great variety of changes take place in the maternal organism. Many of these are quite apparent, and are put down as the "signs and symptoms" of pregnancy, and serve to enable the physician to make a correct diagnosis of the gravid state; while others are more obscure, but not less important, a knowledge of which furnishes a key to many of the morbid processes which may arise during the pregnant state, at time of labor, or in puerpery.

General Considerations.—The general appearance of the woman is changed. During the first few months mental or nervous manifestations and reflex phenomena are usually presented, nutrition is altered, every function is augmented, "every drop of liquid, every cell, every fibre, every organ feels the new impulse."[1]

After the first few months, in the erect position the centre of gravity is shifted from an imaginary line running from the top of the head through the ileo-femoral articulation and knee- and ankle- joints to a vertical line falling in front of the pubes. This is due to the forward growth of the uterus, and explains the squaring of the shoulders and throwing backward of the trunk seen in nearly all pregnant women.[2]

The incurvation of the spine is increased and the

[1] Barnes's Obstetric Med. and Surg., vol. i, p. 246. London, 1884.
[2] Duncan, Researches in Obstetrics, p. 38. London, 1868.

pelvic inclination diminished. The nutrition is generally augmented, fat accumulations sometimes taking place, especially in the abdominal parietes, and there is often a general rounding out of the body. An increase in weight of from 1.5 to 2.0 kilogrammes takes place during the latter months of pregnancy.[1]

Owing to the changes in circulation, constitution of the blood, and consequent nutrition, softening of the pelvic joints takes place, and the osseous system as a whole is deprived to a greater or less extent of lime-salts, which are called off for the building up of the fœtus. Fractures of the bones of pregnant women often heal slowly for this reason.

Thin, bone-like masses, called *osteophytes*, consisting largely of lime-salts, are often deposited between the dura mater and the skull. They are supposed to represent an excess of material prepared for the fœtal bones, and may have some relation to the elaboration of milk. Owing to the intercalation of the placenta between the arteries and veins of the uterus, and perhaps partially as the result of the pressure of the enlarging organ upon the blood-vessels, a larger amount of work is thrown upon the heart, to meet which a compensatory hypertrophy of the left ventricle takes place. This gradually disappears after delivery, but following successive labors a slight subinvolution of the organ may persist.

The Blood, as a whole, is increased in amount, especially during the latter months of pregnancy, and is changed in the relative proportion of its constituents. The water, fibrin, and white corpuscles are increased, the red corpuscles diminished, and there is less iron. This may progress to such a degree as to give rise to a

[1] Gassner, Monatsschrift für Geburt. kunde, 1862.

physiological *leucocytosis* (Virchow), or even to a *pernicious anæmia.*

The excretions are generally increased, the glands of the skin and the kidneys becoming more active. The urine may contain normally a small amount of albumin, in from 3 to 5 per cent. of cases,[1] and traces of sugar are often present.

The Liver is sometimes enlarged as the result of a physiological fatty infiltration.

The Lung-capacity, especially toward the close of pregnancy, is considerably diminished, respiration being accommodated by the spreading out of the thorax, the antero-posterior diameter being diminished.

The Skin becomes more active, pigmented spots appearing at different points, notably on the face, abdomen, and breasts.

Special Considerations.—During gravidity the uterus enlarges from a small, hollow organ having a capacity of about 1 cubic inch,[2] measuring about 3 inches in length by 2 inches in width at its widest part, and weighing from 7 to 12 drachms, to an immense sac occupying the greater part of the abdominal cavity, with a capacity of 400 cubic inches and a weight of about 2 pounds. This increase in size is gradual and dependent upon the influence exerted by the developing ovum. The uterine wall is at first thickened, but afterward thinned, especially in its lower segment. The muscular fibres elongate and thicken until they ultimately become about eleven times as long and five times as thick as in the unimpregnated womb. At the same time there is an actual increase in the number of fibres (hyperplasia).

[1] Veit, Müller's Handbuch der Geburtshulfe, Bd. i, p. 224.

[2] Simpson's Works, 1871, p. 595.

The Cervix uteri, with the exception of a slight thickening, does not participate in these changes, but remains practically the same until within a few weeks before delivery, when it is gradually taken up—*i.e.*, shortened —and entirely disappears during the first stage of labor.

The changes in the uterine mucosa have already been described in the discussion of the *Deciduæ*.

The other portions of the sexual organs are also more or less affected by the advent of pregnancy. The ligaments are stretched, but also increase in their tissue-elements. The ovaries are little or not at all affected.

The Vagina is relaxed and moistened by secretions, the latter often amounting to a considerable discharge (leucorrhœa). The introitus vaginæ presents a pale-violet or deep-purple tinge, the result of the retarded blood-flow.

The External Genitals are often somewhat enlarged, and may present a number of dilated veins, which rarely amount to a considerable tumor.

The Breasts enlarge, and may be painful, especially on pressure, and the superficial veins appear as fine, blue lines on their surface. The nipple becomes more prominent, the areolæ darker in color, and the glands scattered about their circle increase in size.

SECTION IX.

PRACTICAL WORK.[1]

1. WHILE the student of embryology can acquire a fair knowledge of the subject from text-books, it is desirable that some practical work should be done in order that he may familiarize himself with the microscopical appearances of the various changes which take place during the process of development.

The work itself is fascinating, and the apparatus required such as may be found in the armamentarium of the general microscopist.[2]

For the beginner the study of the embryology of the domestic fowl (*Gallus domesticus*) is best suited, on account of the abundance of material always at hand and the distinct microscopical pictures presented during the various periods of incubation. The hen-embryo has, therefore, been taken to illustrate the methods of practical work included in this section; but the directions given for hardening, staining, etc., apply equally to all embryos.

2. **Apparatus.**—A good **microscope** with one-fourth and two-thirds inch objectives. Higher powers are at times useful, but not essential for the beginner. Fine, sharp-pointed, straight, and curved scissors,—those used by the oculist are the best. Two pairs of fine-pointed forceps. A fine scalpel. A section lifter. A razor, section knife, or microtome. Several glass individual

[1] The directions given in this section have been taken from articles by the author, published in The Transactions of the American Society of Microscopists, 1885, and The Microscope, 1888.

[2] Manton, Beginnings with the Microscope. Lea & Shepard, Boston.

salt-cellars. Two or three small glass dishes having deep sides. A glass sauce-dish. One or two fruit-jars. Glass slides, square cover-glasses, and some fine threads of glass, made by drawing out a piece of glass tubing in the spirit-lamp or gas flame.

Reagents.—(*a*) A 1-per-cent. solution of common salt.

(*b*) A 3-per-cent. solution of Chromic acid.

(*c*) A solution of Osmic acid.

Osmic-acid solution (1 per cent.), . . .	1 c.c.
Water, ...	100 c.c.

This must be kept in a dark-glass bottle or a bottle covered with black paper or plush, as the solution soon deteriorates in the light.

(*d*) A solution of Picric acid.

Cold saturated solution of picric acid, . .	100 c.c.
Sulphuric acid (concentrated), ...	2 c.c.

Filter and add

Distilled water, ...	300 c.c.

—(Kleinenberg).

(*e*) A thin solution of shellac in absolute alcohol.

(*f*) Clove-oil collodion.

Gun-cotton (photographers'), ...	2 grms.
Sulphuric ether, ...	15 c.c.
Alcohol (95 per cent.), ...	10 c.c.
Clove-oil, ...	100 c.c.

Dissolve the gun-cotton in the ether and alcohol, add the clove-oil, and filter (Schallibaum-Gage).

(*g*) Alum carmine.

Aqueous solution of alum (5 per cent.), . .	100 c.c.
Carmine, ...	1 grm.

Boil and, when cool, filter; add a few drops of carbolic acid and cork tight (Grenacher).

(*h*) Hæmatoxylin.

Hæmatoxylin, saturated alcoholic solution, .	4 c.c.
Ammonia-alum, strong saturated solution, .	150 c.c.

Let stand eight days, filter, and add

Glycerin, ...	25 c.c.
Methyl-alcohol, ...	25 c.c.

This stain works best after standing for some weeks or months.

(*i*) Paraffin.

Several ounces of paraffin with melting-points at 45° and 55° C., or the hardest and softest to be had in the shops. These are to be mixed according to the temperature of the work-room, usually 2 parts of the hard to 1 of the soft.

(*j*) Clove-oil; turpentine-oil; xylol, or benzoline; spirits chloroform; Canada balsam; concentrated hydrochloric acid; bees-wax, hard and soft.

The latter is common yellow wax to which enough Venetian turpentine has been added to give it the consistency of putty.

(*k*) Celloidin.

(*l*) Alcohol, 75 per cent., 95 per cent., and absolute (Squibb's).

3. **Material.**—In order to develop the *germ* in the egg, an incubator of some kind is necessary. For this purpose a setting-hen may be utilized, or a simple incubator may be constructed by any tinsmith as follows: A strong tin box with copper bottom, having a deep indentation on one side, is made (Fig. 65). Into the indenture two wooden drawers, each with a bottom capacity for a dozen eggs, are fitted (*c*, *c*) and the whole can encased in wood. Between the tin and the wooden box there should be room enough to pack a considerable amount of cotton or sawdust, to keep the warmth generated in the can. The can must be supported on legs several inches above the bottom of the wooden box in order that a gas-lamp may be placed under it.

The box and can must be perforated above at one corner by a tin tube, which is stopped by a large cork (*D*), through which pass the thermometer and the thermo-regulator, the latter connected by rubber tubing (*F*, *G*) on one side with the gas-jet, and on the other with the small lamp below (*I*).

Probably the best and simplest thermo-regulator is that known as "Reichert's." This consists of a ther-

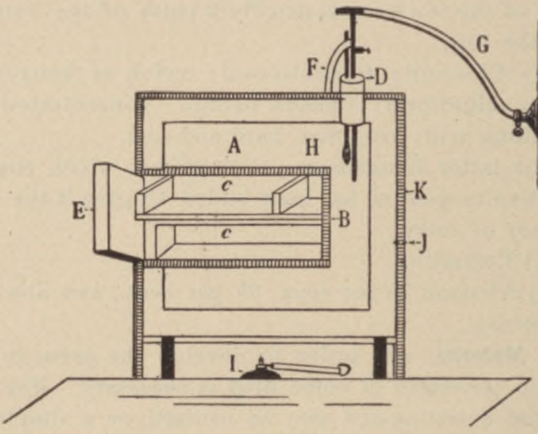

Fig. 65.

mometer-tube filled with mercury, the upper end of which is dilated to receive a glass T-shaped piece, into which the gas streams and is conveyed through the rubber tube (*F*) to the lamp below,—the amount of gas being regulated by a graduated screw at the back. As the temperature increases the mercury in the tube rises and stops the aperture in the end of the T-piece, thus lowering the gas-flame and maintaining an even temperature. The gas is, however, not extinguished, as a small hole in the side of the T admits just enough to keep the flame lighted. A thermometer is placed by the side of the regulator, so that the temperature of the water with which the can is filled may be determined, and the size of the gas-flame regulated accordingly.

The drawers in the can should be partly filled with cotton, in which the eggs are placed and lightly covered.

The water should be kept at 37° to 40° C. Hens' eggs thus incubated hatch in about three weeks.

Whether the hen or an incubator is employed, the eggs used must be newly-laid, in order that the stages of development may be accurately studied. Before commencing incubation the date and hour at which this is to begin must be plainly written on the shell with ink, and, as the eggs are placed in the incubator, the writing should lie uppermost, so that the date may be readily seen without disturbing the eggs.

The first eggs should be removed after about *eighteen hours'* incubation, when the first two layers of the blastoderm are well defined. After *thirty-six hours* the three layers, ecto-, meso-, and ento-derm, may be seen.

The embryos of forty-eight hours, three, four, and five days should also be preserved. Older embryos, up to the seventh or eighth day, should be obtained for the study of individual organs.

As soon as one egg is removed from the nest or incubator, another may be put in its place, and thus in the course of a week or ten days a sufficient number of embryos may be obtained to furnish work for the odd hours of many months.

During incubation the drawers of the incubator should be frequently opened and the covering cotton removed, in order that the eggs may get plenty of air.

The embryos of reptiles, amphibians, mammals, and fish may be obtained as follows :—

Turtles deposit their eggs in holes, which they dig in the sand along the margin of streams and ponds. The time for laying is about sun-down ; the period of the year, from the second week in June, varying with the locality. The eggs are hatched some time in September or October. As soon as a turtle is seen to deposit its eggs, these should be carefully removed and planted in a box of earth or sand, and covered by wire gauze or mosquito-netting. The eggs must be kept moist. As incubation is very slow, an interval of several days should elapse before the first eggs are removed for

FIG. 66.

examination. Turtles lay a large number of eggs; so that if a nest is found, material will be plenty.

Frog- and toad- eggs may be found about the 1st of June, in streams and ponds. The former occur in glairy, gelatinous masses; the latter in glairy, transparent strings. They should be placed in shallow dishes of water, and portions removed and hardened from day to day as the embryo develops. These latter appear as dark spots in the centre of the transparent globules. The eggs hatch into tadpoles in about six or eight days.

Fish-eggs and the embryos can best be obtained at a hatchery, but, when this is inaccessible, a spawning adult fish may be utilized.

"When a female fish is in fit spawning condition," says Francis, "the vent becomes slightly enlarged and of a reddish tinge. The ova, previously attached together by a membrane, become disconnected. Take up the fish and hold it, first, head downward, then reverse it, and if the great bulk of spawn be seen to shift and drop as if from one end of the fish's belly to the other, the eggs are loose and the fish is ready to part with its ova." The method usually advised for holding the fish and expressing the ova is seen in Fig. 66.

A still better method, introduced by Mr. Glover, is to hold the head of the fish with the left hand, seizing the tail in the right hand just behind the vent, so as to

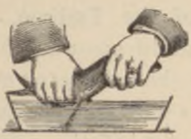

FIG. 67.

compress the back between the fingers and the palm of the hand. The fish is then slightly bent, and the side of the thumb rubs against its belly, just above the vent, which will cause the extrusion of the eggs. This should be done with the fish partly submerged in water. The *sperm* of the male is obtained in the same manner and in the same dish, and the eggs and sperm are then gently mixed together by means of a feather. The eggs should now remain for about two hours undisturbed, and are then transferred to the hatching box by means of a horn spoon and feather.

The hatching box, according to Exner, must have the floor covered with pebbles, while 1.5 cubic centimetres above this is arranged a layer of glass rods, about 2 to 4 millimetres from each other, upon which the eggs are laid. The box must then be provided with running water, the flow being drop by drop, or slightly swifter.

Dead eggs may be recognized by their opacity, and should be removed each day. The eggs should be examined every twelve hours.

Mammalian embryos, as of the sheep, etc., may be obtained at slaughter-houses: for those of smaller animals—rabbits, mice,[1] etc.—the females must be killed at varying periods after fecundation has taken place. The abdomen is laid open, the uterus and oviducts dissected and spread out, and careful search made with a lens for the ova, which must be removed and hardened.

4. **Preparation of the Embryo.**—The egg, having undergone the required amount of incubation, is carefully removed from the incubator or nest, with the side on which the date is written uppermost (for the embryo always lies on the top of the yelk), and rested on a glass individual salt-cellar. The shell is then broken by a sharp rap at the larger end, to let in air. The egg and cellar are then transferred to a dish of the salt solution, which has been warmed to blood-heat. The depth of the salt water should be sufficient to quite cover the entire egg. The upper part of the shell must now be broken by a few taps of the scissors or scalpel-handle, and the pieces removed with fine forceps over the space the size of a quarter-dollar, or larger, according to the period of incubation. This requires some little care, as the sharp-pointed bits of shell are apt to turn inward and cut the embryo, or open the yelk. When the shell has been removed, the embryo will be seen lying within

[1] For this purpose white mice may be utilized, and the exact time of copulation noted.

two rings (the *area opaca* and *area pellucida*), or in the midst of a vascular spot (*area vasculosa*) varying in size according to the time that incubation has progressed. A circling cut must now be made around (outside) these rings with a pair of fine-pointed, curved scissors, and the disc containing the embryo floated off and washed free of any adherent yelk by gently agitating it with the forceps in the salt solution.

5. **Hardening.**—Previous to opening the egg the glass sauce-dish should be prepared with a layer of wax, about a quarter of an inch deep, at the bottom. This is quickly done by pouring melted bees-wax into the dish and allowing it to spread out evenly. The dish is then partly filled with the Kleinenberg or chromic-acid solution,[1] the embryo transferred to it on a section lifter, and the edges of the filmy membrane drawn out and pinned down to the wax, so that the embryonic disc may harden without wrinkles or distortion. Any kind of pins may be used for this purpose, but the long German insect pins are the easiest to handle, and are not so readily affected by the acid.

The embryo should be left to harden undisturbed for from five to twenty-four hours, according to size. When this is accomplished, prepare a glass jar,—a half-pint fruit-jar or a tumbler will answer,—with 70-per-cent. alcohol, in which a piece of cotton floats just below the surface. Upon this cotton lay the embryo, and allow it to remain until the alcohol has withdrawn the picric acid and the specimen has become whitened. It is frequently necessary to change the alcohol several times before this is accomplished. When the embryo is quite bleached it may be placed in 95-per-cent. alcohol for indefinite keeping.

[1] This renders the embryo more brittle than the picric-acid solution.

When the chromic-acid solution is employed for hardening, the subsequent method of procedure is the same as that just given, except that the hardened specimen is transferred to a jar of water instead of alcohol. When washed free from the acid, which requires some little time, the embryo is first placed in 70-per-cent. alcohol and then stained, or in 95-per-cent. alcohol for keeping.

6. **Staining.**—Embryos may be stained *in toto* or after the sections have been placed on the slide. The former method will be found the simplest and most convenient for general practice.

If it is desired to stain the embryo at once after hardening and placing in 70-per-cent. alcohol, it must first be washed in water (if it is a picric-acid specimen, but not if chromic acid has been used), and then placed in the stain, where it should remain for several hours, according to the size of the embryo. Practice alone will teach the avoidance of either over- or under- staining. The specimen is then washed again in 70-per-cent. alcohol made slightly sour by the addition of a drop or two of concentrated hydrochloric acid. Thus stained, the embryo may be preserved in 95-per-cent. alcohol ready for imbedding at some future time.

Staining on the Slide.—After the imbedding material has been removed by the proper solvents, which may require from 15 to 20 minutes (see 13 and 14, pages 109 and 110), the slide is rinsed in 95-per-cent. alcohol and placed immediately in the stain, if this is an alcoholic solution, but if an aqueous solution it is first washed in water. On removing from the stain, wash in alcohol or water, as the case may be; if the latter, a second washing in alcohol must be given the slide. The sections are then cleared and mounted as given under 13, page 109.

7. **Infiltrating.**—Before sections of the delicate embryo

can be made it must first be infiltrated and imbedded in some material which will hold it firmly without injuring its tissues. For this purpose paraffin and celloidin are best suited.

8. **Paraffin Method.**—The specimen is first placed in absolute alcohol for several hours until it is thorougly dehydrated, and then in a vial of chloroform, where it may soak for some time longer. It is then transferred to a watch-glass containing chloroform and fine shavings of hard and soft paraffin (1 to 5). The watch-glass must now be carefully heated, either in what chemists call a double drying-jacket (which is similar to the tin can

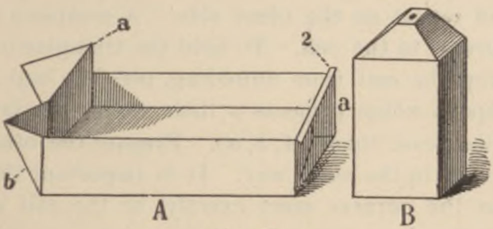

FIG. 68.

of the incubator already described, wire shelves replacing the drawers), kept at about 113° F., or over a water-bath, until the paraffin is melted and the chloroform evaporated. This properly takes from twelve to twenty-four hours, and is done in order that all traces of alcohol and chloroform may be driven off and the embryo become thoroughly permeated with the paraffin. The embryo is then arranged at one end of a paper cell, which has previously been partly filled with melted paraffin and the latter allowed to cool, and covered with warm paraffin.

9. **The Paper Cell and Imbedding.**—The cell may be

made of stiff glazed paper, cardboard, or like material. A convenient shape for small embryos is one and a half inches long by three-fourths wide and half an inch deep. Having cut the paper the required size, begin by folding down each side of a width to give the cell the necessary depth, and over them the ends a little wider than the sides. On opening the paper a small square will be seen at each corner marked out by the folds (*a*, *b*, *A*, Fig. 68). Now bring the end fold of one of these squares exactly against the side fold of the same square, and draw the intermediate paper (*A*, *b*) between the thumb and finger, which divides each square into two triangles. Turn the triangle over the end of the cell and repeat on the other side. A complete end is thus formed to the cell. To hold the triangles in place and keep the end from unfolding, turn the top of the end paper—which projects a little above the level of the sides—over them (*A*, *2*, *a*). Prepare the other end of the cell in the same way. It is important that the folds at the corners meet exactly, or the cell will be irregular in shape.

This cell is then about half-filled with melted paraffin, which is allowed to cool, and the embryo placed in it in the direction in which it is desired to make the sections.

When the embryo has been arranged in the cell, a little warm paraffin should be poured over it and left until it sets a little to fix the specimen, and then the cell must be filled with the liquid paraffin.

Should the embryo float out of place during the imbedding process it may be returned to any position desired, while the paraffin is still fluid, by the point of a hot needle. Air-bubbles, which frequently collect about the object, should be displaced by the hot needle before the upper layer of the paraffin has become hardened.

Specimens imbedded in this way may be kept almost indefinitely if not subjected to heat.

If it is desired to cut ribbon sections, the paraffin used should be that having the lowest melting-point. When cold it must be carefully cut away around the embryo, a sixteenth of an inch being left on each side, and the embryo re-imbedded in paraffin having a higher melting-point. The reason for this will be explained under "Section-Cutting," page 109.

10. **Celloidin Method.**—After hardening, and staining if desired, embryos may be placed for a few days in a thin solution of celloidin, and then transferred to a thicker solution, where they may be left for a week or even longer without injury. A cork is then wrapped with stiff paper, the latter projecting an inch or more beyond the former, and the top of the cork moistened with celloidin. When this has partially hardened it is slightly wet with ether, the embryo placed upon it in the desired position, and the cell then filled up with the celloidin. After exposing this to the air until a film has formed on top, the cork is carefully lowered into a jar of 75-per-cent. alcohol and left to harden. In order to keep the cork in the upright position it will be necessary to impale it on a weighted pin,—that is, a pin fastened to a little solder, which must be of sufficient weight to hold the cork in place.

After a few days the paper may be removed, and the embryo will be found firmly imbedded in the transparent celloidin.

11. **Preparation of the Slide.**—As the sections must be serial and laid upon the slide in regular order so that the parts may be studied with exactness, it is necessary that a number of glass slides be in readiness. The latter must be perfectly clean and clear. Each slide in turn

should be warmed over the spirit-lamp flame; and when the moisture that collects on the application of the heat disappears, a glass rod dipped in the shellac solution is pushed over the slide in such a way as to leave behind it a thin film of the lac. This may easiest be accomplished by running the rod across the glass, and then quickly drawing it over the length of the slide. It is not necessary, however, that over an inch of surface should be covered by the shellac. If the film left should turn opaque, it indicates that the glass was not hot enough, and in that condition the slide is unfit for use. The film should be perfectly smooth, free from waves, and so thin as to be perceptible only by the iridescent hue which it imparts to the glass.

When ready to make sections, a slide should be selected and a thin coating of clove-oil given it, with a fine camel-hair brush, over that portion covered by the film. Care must be taken not to go over the same spot twice, as the oil dissolves the varnish. Instead of the method just described, the slide may be painted with a thin layer of the Schallibaum clove-oil collodion just before using.

12. **Section-Cutting.**—Sections are made in three directions: (1) at right angles to the long axis of the body,—*transections;* (2) parallel with the long axis of the body, and passing from left to right,—*dextro-sinistral longisections;* (3) parallel to the long axis of the body, and passing from dorsal to ventral aspects of the body,—*dorso-ventral longisections.*

For sectioning embryos a microtome is almost indispensable, but fair sections may be made with the razor or knife by one used to free-hand cutting. The labor is much greater, however, and the sections vary greatly in thickness. Before sectioning, the paraffin cast in which the embryo is imbedded should be trimmed down to within a few lines of the object (Fig. 68, *B*), straight behind and triangular in front (Fig. 69, *A*). Each consecutive section, as removed, must be laid on the prepared slide, beginning at the upper right-hand corner and continuing in rows from right to left. Care must be taken that a little less space is occupied than the size of the cover-glass to be used.

If the microtome is used the sections have a tendency to roll up as they are cut, but this may be prevented by holding the point of a teasing-needle or a camel-hair brush just over the edge of the knife as it passes through

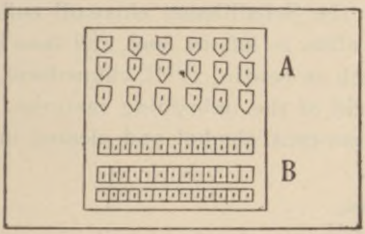

FIG. 69.

the paraffin; or, one of the numerous planishers, to be had of dealers in microscopical supplies, may be used.

In making ribbon sections the embryo must be imbedded as directed on page 107 (section 9). If the paraffin surrounding the embryo is of the proper consistency, each section as cut will adhere to the edge of the one in front of it, and a strip of any desired length may be had (*B*, Fig. 69). For ribbon sections a microtome is indispensable.

13. **Mounting—Paraffin Method.**—When a sufficient number of sections have been placed, the slide should be carefully warmed over the spirit-lamp flame, taking care

not to heat it too hot. This melts the paraffin, dispels the clove-oil, and permanently fixes the section. By allowing the slide to rest on its edge for a few minutes the paraffin will run down and collect at one point. When the slide is cool a few drops of oil of turpentine should be poured over the sections to dissolve the remaining paraffin and clear the sections. The length of time during which the turpentine should cover the object depends upon the size of the latter and the amount of paraffin left in the tissues. The oil must then be run off and the slide carefully wiped clean up to the sections. A drop of Canada balsam [1] and the adjusting of the cover-glass complete the procedure.

14. With the Schallibaum clove-oil collodion, after heating, the slide is left to cool, and then immersed in a solvent, such as benzin, xylol, chloroform, turpentine, etc., to get rid of the imbedding material. It is then rinsed in 95-per-cent. alcohol and cleared in the following agent:—

Turpentine, ...	3 parts.
Carbolic acid, ...	2 parts.

The sections are then protected by a cover-glass which has received a thin coating of the following:—

Pure Canada balsam, ...	25 grms.
Chloroform, ...	2 c.c.
Clove-oil, ...	2 c.c.

The clove-oil dispels all cloudiness (Gage).[2]

15. Celloidin sections may be treated thus: After fixing on the slide as in section 14, pour over the sections 95-per-cent. alcohol, and then dissolve out the celloidin with a few drops of ether and absolute alcohol.

[1] Dr. Minot recommends the use of very thin balsam,—pure balsam diluted with a large quantity of pure benzol.—The Microscope, May, 1888, p. 137.

[2] Proceedings of the American Society of Microscopists, 1884, p. 202.

Let these nearly evaporate, wash again in 95-per-cent. alcohol, clear, and mount as in section 14.

16. **Embryos as Transparent Objects.**—From the salt solution the embryo is pinned out in a little of the osmic-acid solution, in which it is kept until it acquires a light-brown color. It is then washed for some time in water to remove the acid; after which it is placed in 70-per-cent. alcohol, then in absolute alcohol, which latter must be changed once, and finally in clove-oil to clear up. This completed, the embryo is ready for mounting.

Having a clean slide ready, place a drop of Canada balsam on its centre and lay the embryo on this. All the clove-oil is then run off, by gently tipping the slide, wiped away, and another drop of balsam allowed to fall upon the object. The corners of the cover-glass are now tipped with wax to slightly raise them from the specimen, and the cover adjusted.

On either side a hair of spun glass must be run beneath the cover-glass to keep this permanently from resting upon the embryo. When the balsam becomes dry, the wax on the cover-glass may be removed. Embryos may be treated in this manner up to the forty-eighth hour, but after that they are rather too large for transparent objects.

17. **Labeling.**—A label having the name of the preparer neatly printed on it should be gummed to each end of the finished slide. On one label the place of mounting and the date are filled in with ink. At the upper left-hand corner the *series* to which the slide belongs is noted in Roman numerals, while just below it, in Arabic numerals, is written the *number* of the slide in the series, thus:—

Series X.
No. 5.

On the label at the other end of the slide is written the kind of section (transection, longisection, etc.), the variety and age of the embryo, and the hardening, staining, and mounting agents which have been employed.

18. **Slide-Cabinet.**—Any kind of a cabinet may be used in which to preserve the slides from injury and dust. A very convenient receptacle is a strong pasteboard box, with hinged front, holding ten or more pasteboard trays. Each tray should be divided into two or three compartments, which will hold from six to nine slides each, on the flat.

A GLOSSARY

OF SOME OF THE

Words and Terms used in Embryology.

Allantois (Gr. ἀλλᾶς, a sausage ; εἶδος, like)—A tubular diverticulum from the archenteron, extending to the chorion and conveying blood-vessels. Concerned in the formation of the bladder and urachus.

Amnion (Gr. ἀμνίς, a young lamb ; first observed in embryo of this animal)—A double membrane, the innermost layer of which envelops the embryo.

Anal plate—A bridge of tissue which temporarily closes the anal canal.

Anlage (Ger.)—Rudiment.

Archenteron (Gr. ἀρχή, beginning ; ἔντερον, intestine)—The primitive gastro-intestinal canal.

Archiamphiaster (Gr. ἀρχή, beginning ; ἀμφί, on both sides ; ἀστήρ, a star)—The star-like arrangement of the protoplasm at the ends of the nuclear spindle.

Blastocele (Gr. βλαστός, germ ; κοῖλωμα, hollow)—The segmentation cavity.

Blastoderm (Gr. βλαστός, germ ; δέρμα, skin)—The external layer of the segmented ovum. Later the blastoderm consists of three layers.

Blastodermic vesicle—The vesicle formed by the collection of fluid within the blastula.

Blastophore (Gr. βλαστός, germ ; πόρος, pore)—A small opening at the anterior end of the primitive streak, leading at first into the notochordal canal, and later into the archenteron.

Blastula—The stage following completed segmentation, in which the ovum is a hollow sphere filled with fluid and bounded by the blastoderm.

Brain (*Fore, Mid, Hind*)—The anterior, middle, and posterior divisions of the neural canal. The cerebral vesicles.

Branchial clefts (Gr. *βράγχια*, gills of fishes)—Visceral clefts.

Caduca (Lat. *cadere*, to fall)—Decidua.

Cerebral vesicles—Brain.

Chorion (Gr. *χόριον*, fœtal membranes)—*Primitive*, the shaggy, villous covering of the unattached ovum developed from the blastoderm. *C. læve*, the outermost envelope of the ovum in contact with the decidua reflexa. The *C. frondosum* is in contact with the decidua serotina.

Chromatin—The fine reticulated net-work of the cell-nucleus, so called from its strong affinity for staining fluids. *Achromatin* does not readily take colors.

Cicatricula (Lat. diminutive of *cicatrix*)—Germinal disc. A small white disc situated at the animal pole of the hen's egg.

Cloaca (Lat. *cloaca*, sewer)—The terminal (caudal) portion of the intestine.

Cœlom (Gr. *κοίλωμα*, cavity)—The body-cavity, or space between the somatopleural and splanchnopleural walls.

Conus medullaris—The lower end of the spinal cord between the lumbar enlargement and the filum terminale.

Corpus albicans (Lat. *albus*, white)—The decolorized clot found in a degenerating corpus luteum of pregnancy.

Corpus hæmorrhagicus—The clot which forms in the empty Graafian follicle immediately after its rupture.

Corpus luteum (Lat. *corpus*, body; *luteus*, yellow)—The yellow body formed in the Graafian follicle following rupture. *C. l. verum*, or true, forms in pregnancy. *C. l. spurium*, or false, in menstruation.

Cotyledon (Gr. *κοτυληδών*, socket or cup)—The small, squarish lobes of the maternal surface of the placenta.

Covering layer—The primitive external layer of the blastoderm.

Daughter-cells—The cells resulting from the division of the mother-cells in spermatogenesis.

Decidua—The thickened, spongy lining of the uterine cavity in pregnancy. *D. vera*, all the lining of the cavity except the *D. reflexa*, that portion which is reflected over and incloses the ovum, and *D. serotina*, that portion upon which the ovum rests.

Deutoplasm (Gr. δεύτερος, second; πλάσμα, formed matter)—The food-yelk.

Discus proligerus—A mass of cells surrounding the ovum within the Graafian follicle.

Ectoderm (Gr. ἐκτός, external; δέρμα, skin)—The external layer of cells of the blastoderm.

Embryo (Gr. ἔμβρυον, the young in the womb)—The products of conception up to the fourth month of gestation.

Embryonic area—The area within which the embryo is developed.

Entoderm (Gr. ἔνδον, within; δέρμα, skin)—The innermost layer of cells of the blastoderm.

Epitrichium (Gr. ἐπί, upon; θρίξ, hair)—The delicate, most external layer of cells of the epidermis found in young embryos.

Fœtus (Lat. *fœtus*, offspring)—The young animal from the fourth month to the end of gestation.

Filum terminale—The thin, drawn-out portion of the lower end of the spinal cord.

Folds (*Head, Tail, Side*)—Grooves by which the embryo is constricted off from the remainder of the blastodermic vesicle.

Foregut—The cavity shut off just below the notochord by the deepening of the head-fold.

Gaertner's duct—The persisting lower portion of the Wolffian duct.

Gastrula (Gr. γαστήρ, belly)—An embryonic stage supposed to be common to all animals. Gastrulation consists in a process of invagination of the blastula.

Genital cord—The posterior united portions of the urogenital ridges.

Genital eminence—A thickening of the anterior portion of the anal plate; the anlage of the penis and the clitoris.

Genital ridge—A paired ridge developed from the posterior wall of the cœlom median to the Wolffian body, and from which arise the sexual glands.

Genoblast (Gr. γένος, race; βλαστός, germ)—A sexual element, either male or female.

Germinal area—See "Embryonic area."

Germinal spot—Nucleolus of the ovum.

Germinal vesicle—Nucleus of the ovum.

Germinating cells—Cells developed from the epithelium of the medullary tube, which give rise to the neuroblasts.

Gill-clefts—Visceral clefts.

Graafian follicle—The ovarian vesicle containing the ovum. First described by Reinier de Graaf in 1672.

Impregnation—The fertilization of the female element by that of the male.

Karyokinesis (Gr. κάρυον, a nut; κίνησις, motion)—Indirect cell-division.

Knot, Hensen's—The point at which the two blastodermic layers are first included in the primitive streak.

Lanugo (Lat. *lana*, wool)—The downy hairs which cover the fœtus from the fifth month of utero-gestation.

Lateral plates—A longitudinal thickening of the dorsal mesoderm on either side of the notochord.

Lenticular body—The mass of cells crowded to one point in the blastula.

Liquor amnii—The fluid in which the embryo floats in the amniotic sac.

Lutein (Lat. *luteus*, yellow)—A peculiar, crystallizable substance which gives rise to the yellow color of the corpus luteum and coagulated blood.

Maturation—The ripening of the ovum preparatory to impregnation.

Medullary folds—The upgrowing sides of the medullary plates.

Medullary groove—A groove formed by the upgrowth of the medullary folds.

Medullary plates—A thickened portion of the ectoderm on either side of the median axillary line of the embryo.

Menstruation (Lat. *menstruus*, monthly)—The phenomena associated with the periodical discharge of blood from the female genitals.

Mesencephalon (Gr. μέσος, middle; ἐγκέφαλον, brain)—The midbrain.

Mesenchyma (Gr. μέσος, middle; ἔγχυμα, infusion)—Embryonic connective tissue.

Mesoblastic somites—Protovertebræ.

Mesocolon (Gr. κόλον, colon)—The embryonic mesentery connected with the large intestine.

Mesoderm—The second cell-layer of the blastoderm; derived from both (?) the ecto- and ento- dermal layers.

Mesogastrium (Gr. γαστήρ, stomach)—The greater omentum.

Mesonephros (Gr. νεφρός, kidney)—The Wolffian body.

Mesorchium (Gr. ὄρχις, testicle)—The suspensory ligament of the testicle.

Mesorectum—A fold of peritoneum between the upper part of the rectum and the sacrum.

Mesothelium (Gr. θηλή, nipple)—The epithelium lining the cœlomic cavities (Minot).

Mesovarium (Lat. *ovarium*, ovary)—The suspensory ligament of the ovary.

Micropyle (Gr. μικρός, small; πύλη, entrance)—A passage in the envelopes of the ovum through which the spermatozoön penetrates.

Morula (Lat. *morus*, mulberry)—The mulberry-like mass of spheres resulting from segmentation of the yelk.

Mother-cells—The three cells resulting from the division of the parent-cell.

Müller's duct—A paired tubular duct developed from the Wolffian body and running parallel with the Wolffian duct. The anlage of the Fallopian tubes, uterus, and vagina in the female.

Myotomes (Gr. μῦς, muscle; τέμνειν, to cut)—The proximal portion of the protovertebræ from which develop most of the voluntary muscles of the trunk and the vertebral column.

Nephridia (Gr. νεφρός, kidney; εἶδος, shape)—See "Segmental tubules."

Nephrotome (Gr. νεφρός, kidney; τομή, section)—The intermediate cell-mass; the distal portion of the protovertebræ, in which are developed the segmental tubules and nephridia.

Neuroblasts (Gr. νεῦρον, nerve; βλαστός, germ)—Young nerve-cells.

Notochord (Gr. νῶτον, the back; χορδή, chord)—A longitudinal rod of cells separated off from the entoderm, just below the medullary groove. The anlage of the spinal column.

Oösperm—The ovum after the fusion of the two pronuclei.

Oral plate—A point between the forebrain and the heart, where the mesoderm is absent and ecto- and ento- derm unite; rupture of which gives rise to the mouth.

Ovulation—The rupture of the Graafian follicle and escape of the ovum.

Ovum—The female generative cell or egg.

Parent-cell—A large cell lying near the tunica propria of the testis, which divides into the mother-cells in the process of spermatogenesis.

Parthenogenesis (Gr. πορθένος, virgin ; γένεσις, to beget)—Self-fertilization.

Perivitelline space (Lat. *peri*, around ; *vitellus*, egg)—The space between the vitelline membrane and zona pellucida.

Plastids—Non-nucleated adult red blood-corpuscles (Minot).

Pflüger's cords—Cord-like epithelial ingrowths of the ovary which include the primitive ova.

Polar globules—The rounded masses of nuclear material extruded between the yelk and zona pellucida during maturation of the ovum.

Primitive streak—A median axial thickening of the cells of the ectoderm extending from near the centre of the embryonic area caudalward.

Proamnion—A part of the germinal area in front of the head in which for a time the mesoderm is absent.

Proctodæum (Gr. πρωκτός, anus ; ὁδαῖος, on the way)—A pit-like depression at the caudal end of the embryo which gives rise to the cloacal opening.

Pronephros (Gr. πρό, before ; νεφρός, kidney)—The anterior portion of the Wolffian ridge, situated immediately behind the heart. The head-kidney.

Pronucleus—*Female :* The nucleus remaining in the ovum after extrusion of the polar globules. *Male :* The head of the spermatozoön after its entrance into the ovum.

Prosencephalon—The forebrain.

Protovertebral somites—Squarish-shaped bodies formed by the cleavage of the lateral plates.

Purkinje's vesicle—The nucleus of the ovum.

Segmental duct—See "Wolffian duct."

Segmental tubules—The tubules of the pronephros.

Segmentation—The division of the impregnated ovum into numerous spheres. *Holoblastic*, when the entire ovum participates in the segmentation (mammals) ; *Meroblastic*, when the division is limited to a part (birds) ; *Discoidal*, when a circular patch (hen's egg).

Segmentation cavity—The cavity of the blastula stage; the space within the segmented ovum.

Sertoli's cells—Large cells found in the second layer of the seminiferous tubules.

Smegma—See "Vernix caseosa."

Somatopleure—Body-wall.

Sperm-cell—See "Spermatozoön."

Spermatoblasts—The transformed daughter-cells from which the spermatozoa are developed.

Spermatocysts—Daughter-cells.

Spermatogenesis (Gr. *σπέρμα*, seed; *γέννεω*, to beget)—The formation of the spermatic cells.

Spermatozoön (Gr. *ζῶον*, animal)—The essential male element in the process of fertilization.

Spindle-shaped body—Fine thread-like bands appearing in the nuclear substance preparatory to the extrusion of the polar globules.

Splanchnopleure—Walls of the digestive tract.

Spongioblasts—Young neuroglia-cells.

Stigma (Gr. *στίγμα*, point)—Point of rupture of the Graafian follicle.

Stomodæum (Gr. *στόμα*, mouth; *δαίω*, to divide)—A pit-like depression at the cephalic end of the embryo from which the orifice of the mouth is developed.

Thalmencephalon—The 'tween brain.

Umbilical vesicle—The yelk-sac after the folding off of the embryo.

Urachus (Gr. *οὖρον*, urine; *ἔχω*, to hold)—The remains of the allantois extending from the bladder to the umbilicus.

Urogenital ridges—The ridges formed by the uniting of the Wolffian and genital ridges.

Vernix caseosa—A whitish, greasy substance formed of the secretions of the sebaceous glands mixed with epithelium, and found on the surface of the fœtus after the fifth month.

Visceral arches—The tissue between the visceral clefts, concerned in the development of the lower jaw, bones of ear, hyoid and thyrohyoid bones.

Visceral clefts—Pouches arising in the entoderm of the pharynx, and concerned in the development of the ear, tonsils, thymus and thyrohyoid glands.

Vitelline membrane—The covering developed from and lying in contact with the yelk.

Vitellus—The yelk.

Wagner's spot—The nucleolus of the ovum.

Wolffian body—A series of tubules developed from the Wolffian ridge and opening into the duct. The anlage of the kidney.

Wolffian duct (*Segmental duct*)—A paired, longitudinal, tubular duct, formed probably from the ectoderm and running caudalward between the protovertebræ and the point of junction of the somatopleure and splanchnopleure, and opening into the cloaca. The first indication of the genito-urinary apparatus. The upper portion persists in the female as the *parovarium;* in the male as the *epididymis.*

Wolffian ridge—A paired ridge on the dorsal surface of the body-cavity, containing the Wolffian and Müllerian ducts.

Zona pellucida—The external envelope of the ovum.

Zona radiata—See "Zona pellucida."

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