ing" process, which consists chiefly in the completion of the outer envelope of the middle piece and the smooth-

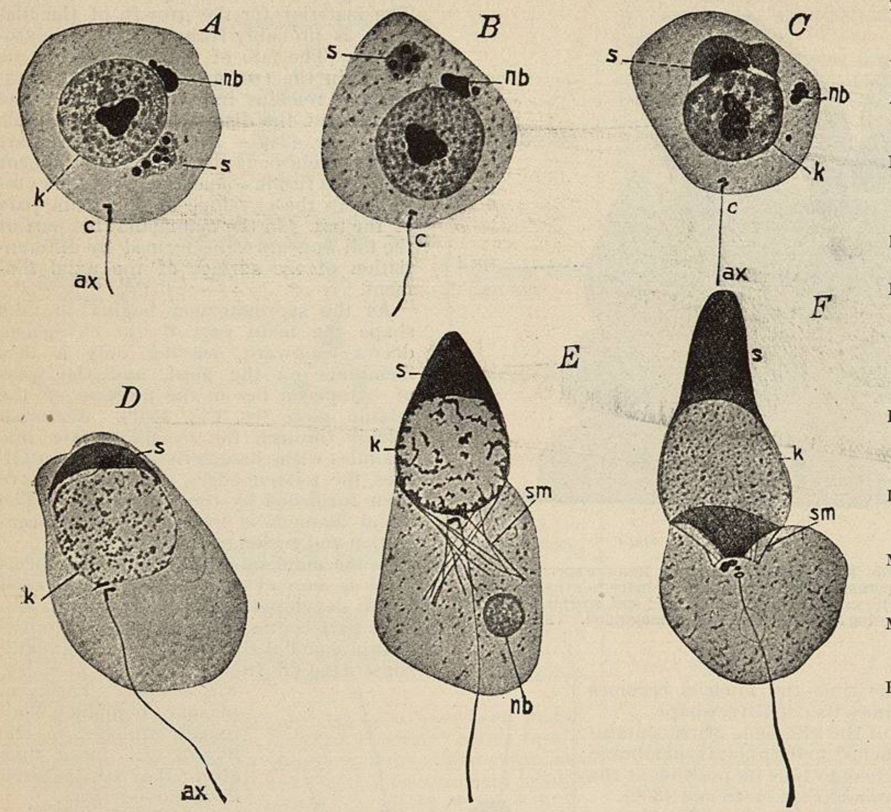

FIG. 4348.—Spermatids of the Guinea-pig, *Cavia cobaya*, in Various Stages of Metamorphosis. *k*, Nucleus; *s*, sphere; *c*, centrosome; *ax*, axial filament. Highly magnified. (After Meves, from Korschelt and Heider.)

ing off of any projections or irregularities that may have remained after separation from the Sertoli cells.

It will be seen from this brief review of the development of spermatozoa that there can be no further question as to the character of these bodies. Each one contains all the essential elements of a cell.

Robert Payne Bigelow.

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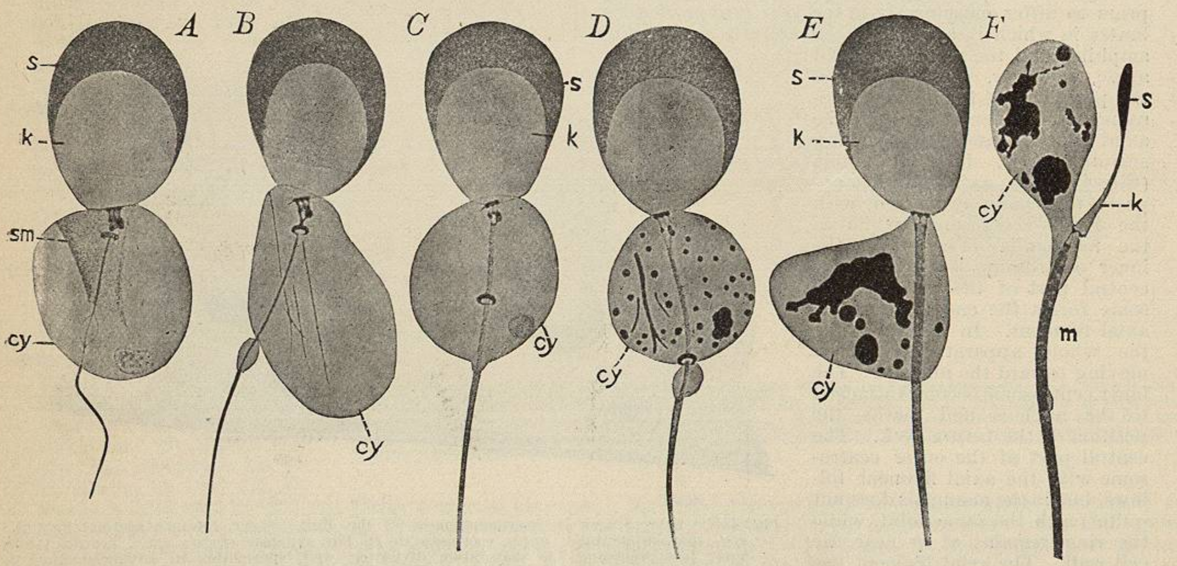

FIG. 4349.—Later Stages in the Metamorphosis of the Spermatids of the Guinea-pig. *A—E*, views of broad side; *F*, narrow side. *cy*, Cytoplasm; *m*, middle piece. Other lettering same as in Fig. 4348. Highly magnified. (After Meves, from Korschelt and Heider.)

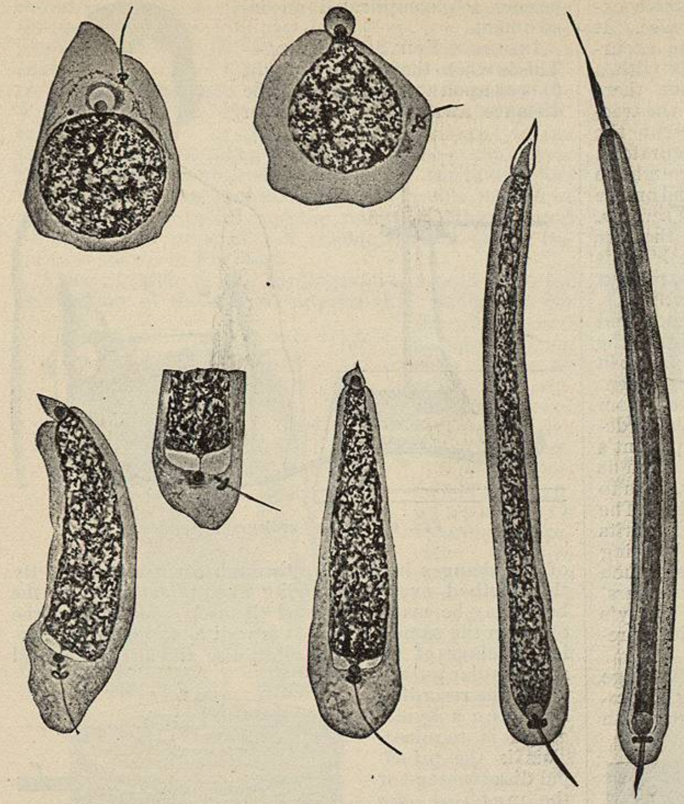

FIG. 4350.—Various Stages in the Metamorphosis of the Spermatids of Amphiuma. Highly magnified. (After McGregor.)

Spallanzani: Expériences pour servir à l'histoire de la génération des animaux et des plantes, Geneve, 1785.
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SPHACELUS. See *Gangrene.*

SPHYGMOGRAPHY.—Sphygmography (Gr., *σφυγμός*, the pulse; *γράφειν*, to write), strictly interpreted, is the art of taking pulse tracings. The present article will deal not only with the art of recording the arterial and the venous pulse, but also with the graphic method as

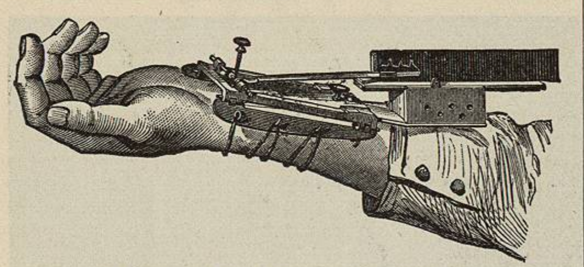

FIG. 4351.—Marey's Sphygmograph (new form).

applied to the heart (cardiography). The instruments employed for these purposes are of many types, but the principles involved can be made sufficiently clear by a few examples. Two essentials are common to all of them, a recording surface and a writing lever or pen. The recording surface is usually smoked paper set in motion by clock-work. The writing lever may be directly applied to the pulse or connected with it by a rigid or jointed support, in which case we speak of *direct sphygmography;* or the move-

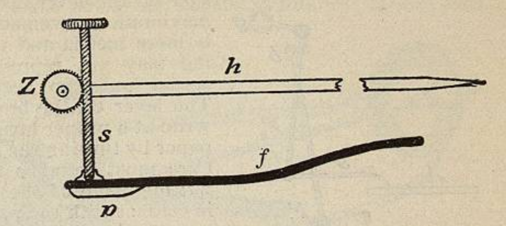

FIG. 4352.—Diagram of Connections in Marey's Sphygmograph.

ments to be recorded may be carried to the lever by air transmission, constituting *indirect sphygmography.*

DIRECT SPHYGMOGRAPHY.—Two examples of direct sphygmography will be given as represented in the instruments of Marey and of Dudgeon.

In *Marey's sphygmograph* (Figs. 4351 and 4352) the button *p* is pressed down upon the artery by the spring *f*. The screw *s* is connected with the button by a joint and rests against a cog-wheel *Z*, which is on the axis of the writing lever *h*. The thread of the screw catches in the teeth of the cog-wheel so that when the button is lifted by the pulse it raises the screw so as to turn the wheel and elevate the lever. At one end of the instrument there is a clock-work which moves a metal frame carrying a strip of smoked paper. The screw, which may be seen in Fig. 4351 under the centre of the writing lever, regulates the pressure of the button on the pulse.

In using the instrument, a strip of smooth paper is cut to fit the frame and smoked over a piece of burning camphor, a lamp burning without a chimney, or a tallow candle. The position of the

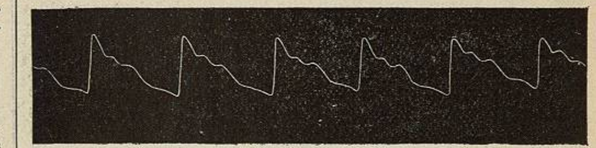

FIG. 4353.—Sphygmogram taken with Marey's Sphygmograph.

radial artery is determined and the point where the pulsation is best felt is noted. The instrument is then

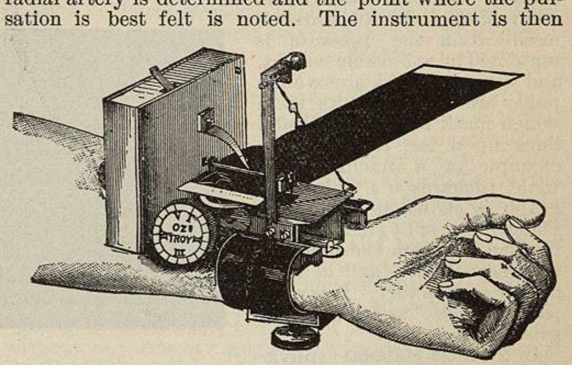

FIG. 4354.—Dudgeon's Sphygmograph.

bound to the arm, as shown in the figure, with the button on the point selected. The clock-work is wound up. The pressure of the button is regulated by the screw provided for the purpose, so that a suitable excursion of the lever is obtained with each pulse. It is usually wise to be satisfied with a moderate excursion of the lever, as with a maximum movement there is more inertia and the tracing may not represent the actual pulse so accurately. The lever can be brought to write at a proper level on the paper by turning the screw *s*. Care must be taken that the writing point of the lever is in contact with the paper but not pressing too heavily.

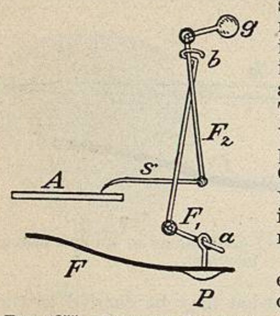

FIG. 4355.—Diagram of Connections in Dudgeon's Sphygmograph.

If the hand is steady and everything seems right, the clock-work may now be set in motion and the tracing taken. The tracing is removed from the frame and anything desired, such as the patient's name, the date, and the pulse rate, scratched upon it with a pin or other sharp instrument. Finally, it is to be fixed by dipping it in a suitable varnish. The writer uses a solution of shellac in methylated spirits with a little glycerin added to prevent the tracing being too brittle. Others use negative varnish, such as is employed by photographers, and yet others friars' balsam. A sample of the result obtained with Marey's sphygmograph is shown in Fig. 4353. For the interpretation, see the article on *Pulse*.

Dudgeon's sphygmograph (Fig. 4354) has the advantage over Marey's of being more compact and having a simpler arrangement for connecting the smoked paper with

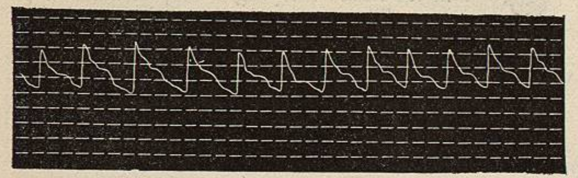

FIG. 4356.—Sphygmogram taken with Richardson's Sphygmograph.

the clock-work. The arrangement of the levers is shown in Fig. 4355. This instrument is applied to the wrist in much the same way as Marey's. The pressure of the button on the pulse is regulated partly by the tightness of the band around the wrist, and partly by turning the wheel marked *oz troy*, which regulates the pressure of the spring.

Richardson's sphygmograph is a modification of Dudgeon's, which is preferred to it by some. In Richardson's modification the pressure is regulated by a movable weight, and the rollers which move the paper are supplied with teeth which mark broken horizontal lines upon the tracing. An example of a tracing taken with Richardson's sphygmograph is shown in Fig. 4356. Dudgeon's sphygmograph is the one to which the writer is most accustomed, and he finds it very satisfactory. It is compact, simple, and moderate-priced.

In the more elaborate sphygmographs of von Jacquet and of Frey there are arrangements for recording the time, and von Jacquet's permits of varying the rate at which the paper moves. There are often more disadvantages than advantages, however, in having too complicated an instrument.

INDIRECT SPHYGMOGRAPHY.—This is where the pulse is brought to bear upon a writing lever some distance away by transmission

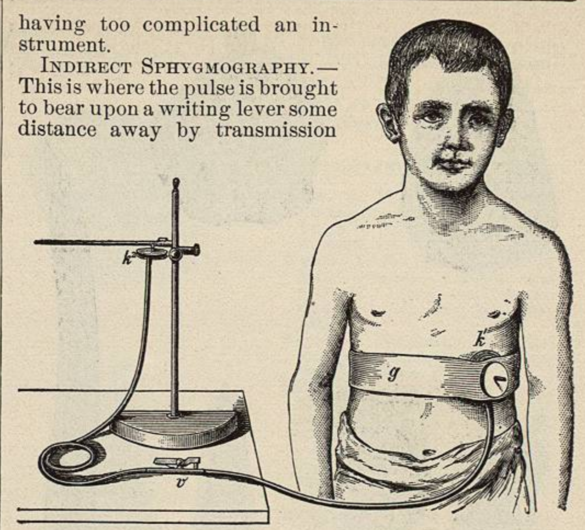

FIG. 4357.—The Cardiograph Applied.

of the changes in pressure through a rubber tube. By this method events occurring at different parts of the body may be made to record themselves one under the other on the same paper. It is well adapted for obtaining tracings of the cardiac impulse and of the carotid and jugular pulses.

For the recording surface a kymograph is required. This is the principal disadvantage of the method, for kymographs are usually large and not very portable. The arrangement of the apparatus for receiving and transmitting the cardiac impulse is shown in Fig. 4357. The essential parts of the apparatus are a receiving tambour, a connecting tube, and a recording tambour. A receiving tambour for the cardiac impulse is known as a *cardiograph*, and an example is shown in Fig. 4358. *k* is a shallow metal box or tambour covered with rubber membrane and bearing a button, *p*, to press upon the point where the impulse is felt; *r* is a tube opening into the tambour and of a suitable size for the attachment of the connecting rubber tubing. The surrounding outer box, spring, and screw are for regulating the pressure exerted by the button on the skin. The recording tambour (k^2, Fig. 4357) is a similar metal box covered with rubber membrane. Resting upon the centre of the membrane is a support which raises the writing lever when air is driven over from the receiving tambour, k^1. In applying the cardiograph to the heart care must be taken to adjust the button exactly on the apex beat, as an inch or two nearer the middle line the chest wall may recede during the systole instead of being pressed outward, and the tracing obtained would be difficult to interpret. A tracing of the cardiac impulse is shown in Fig. 4359.

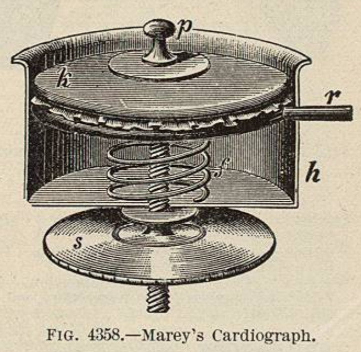

FIG. 4358.—Marey's Cardiograph.

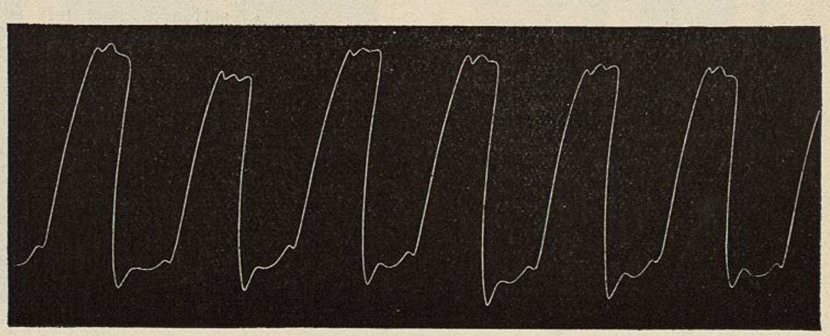

FIG. 4359.—Apex-beat Tracing from Man.

A modification of the cardiograph has been made for application to the carotid arteries (Fig. 4360), but for this purpose and also for the venous pulse an ordinary or cup-shaped funnel of suitable size usually suffices.

FIG. 4360.—Receiving Tambour for Carotid Pulse. (Hürthle.)

A small portable kymograph with recording apparatus for two simultaneous tracings is shown in Fig. 4361. The peculiarly shaped receiver *D* is for applying over the edge of the liver to obtain a tracing of the liver pulse.

COMBINED DIRECT AND INDIRECT SPHYGMOGRAPHY.—James Mackenzie has devised an arrangement which he calls "*the clinical polygraph*" (Fig. 4362). In this a recording tambour is attached to a Dudgeon's sphygmograph in such a way that while the radial pulse is being recorded in the ordinary way by direct sphygmography, a tracing of the carotid or jugular pulse or of the apex beat can be recorded over it on the same strip of paper by air transmission. This is a very portable apparatus and is quite delicate enough for obtaining venous pulse tracings. The writer uses an instrument improvised by

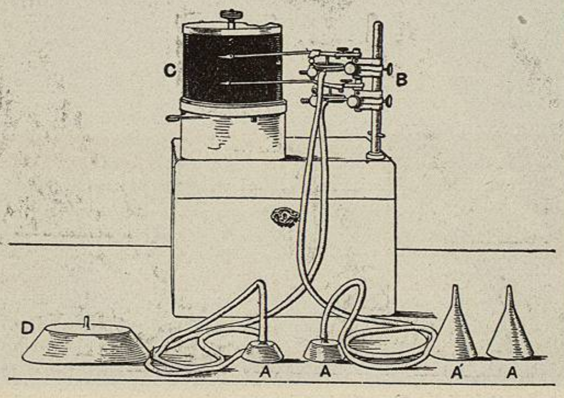

FIG. 4361.—Knoll's Polygraph with Receivers. (Mackenzie.)

himself and his laboratory assistant, but based on Mackenzie's model; with it he took most of the simultaneous tracings figured in the article on *Pulse*. Fig. 4363 shows an example of the radial and external jugular pulses taken simultaneously with this apparatus in a case of dilated heart without valvular lesion. In two of the curves simultaneous points are marked by vertical lines. These points are marked as follows: Before starting the paper the two writing levers are allowed to mark vertical lines (× ×, Fig. 4363), to show the relative position of the writing levers. Points on the two tracings equidistant from these vertical lines correspond in time and may be measured off to any desired number. In taking venous tracings the writer usually selects the external jugular, but Mackenzie prefers the internal. The receiving funnel is held over the vein by hand, the amount of pressure required being learned by practice.

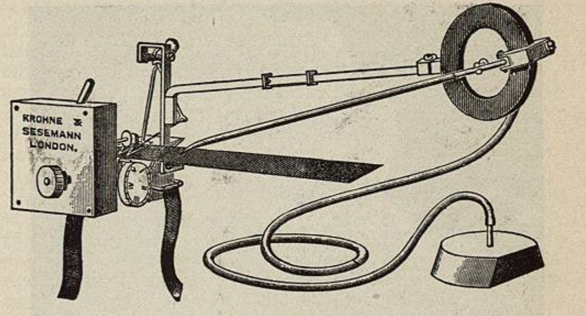

FIG. 4362.—The Clinical Polygraph. (Mackenzie.)

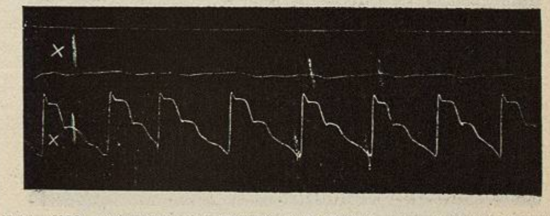

FIG. 4363.—Simultaneous Tracing of Radial and Jugular Pulses taken by the Combined Method. Jugular above, radial below.

A figure illustrating the method of taking the volume pulse (plethsymography) is given in the article on *Circulation*. For further examples of pulse tracings and their interpretation, see article on *Pulse*.

References.—In preparing this article use has been made of the following books: O. Langendorff's "Physiologische Graphik," F. Shenk's "Physiologisches Practicum," James Mackenzie's "Study of the Pulse," T. G. Brodie's "Experimental Physiology," Hutchinson and Rainy's "Clinical Methods," and the catalogues of Baird and Tatlock, London, and Eugen Albrecht, Tübingen.

William S. Morrow.

SPINA BIFIDA.—PATHOLOGY.—Two congenital malformations of the spine, rachischisis and spina bifida, are so closely related that they should be considered together. While both are characterized by a deficient formation of the arches of the vertebræ, they differ in the degree of development attained by the spinal cord. In rachischisis it is so rudimentary that even the central canal of the cord has not formed and the endothelium which should line it is exposed as a transparent membrane on the back, through which is seen a flat red area consisting of vascular nerve and connective tissues representing nature's abortive attempt to grow a spinal cord without any axis or "anlage." When the whole cord is involved it is spoken of as rachischisis totalis, amyelia, or absence of the cord; when only a part, partial rachischisis. In spina bifida the cord more nearly approaches its proper development. A hernia-like sac of fluid protrudes through the cleft laminæ of the vertebræ; it may or may not contain the cord, spinal roots, and nerves.

Rachischisis and spina bifida have their counterpart in the skull and brain; total rachischisis, or amyelia, in cranioschisis or anencephalus, partial rachischisis in derencephalus; the three varieties of spina bifida, me-

Fig. 4364.—Anencephalus with Total Rachischisis. Showing the short neck, upturned face, and dark area medullo-vasculosa in the centre of back; also the area epitheloidea on each side and the mane-like growth of fine hairs.

ningomyelocele, myelocystocele, and spinal meningocele in hydrencephalocele, encephalocele, and meningocele. Furthermore, they are frequently associated and are to be classed as defects of the central nervous system due to arrest of development or persistence of early embryonic conditions, combined with distention of certain cavities with cerebro-spinal fluid.

To better understand the condition spoken of as rachischisis, let us turn to the normal development of the central nervous system in the embryo. The earliest embryonic appearance of the central nervous system is a thickening of the ectoderm in front of the primitive furrow. This thickened area soon bears a longitudinal furrow of its own, which grows rapidly in length while the primitive furrow disappears, and the walls of the furrow grow together on the surface, forming a closed tube, which, however, retains for a long time a direct communication at its posterior end with the cavity of the intestine, while its anterior end expands to form the primitive cerebral vesicles of the rudimentary brain. This embryonic structure is not to be the future cord and brain, but represents the little central canal of the cord and the cerebral vesicles; the real elements of the spinal cord and brain grow around it as an axis. The walls of the neural furrow first coalesce to form a closed tube in what becomes the upper dorsal cord; hence that part is always a little in advance of the rest in its development, and malformations are rarer there than in any other part of the spine. The central canal forms very early. It exists as a closed tube in minute embryos less than one-eighth inch in total length, which, according to the tables of Mall, represent about the twelfth day. The beginnings of the vertebral bodies appear later and the arches of the vertebræ still later, so that they project only a short distance from the sides of the vertebral bodies at the end of eight weeks, and it is four weeks more before they unite to enclose the dorsal section of the cord, which is also the first part of the spinal canal to close in.

Fig. 4364 is a photograph of the back of a rachischisic and anencephalic child at term. The cranial vault is wanting, and both the base of the skull and the middle of the back expose an irregular band of dark red, glistening, moist tissue looking like mucous membrane, the area medullo-vasculosa. External to this on each side is a glistening smooth membranous space, the area epitheloidea, merging in turn into normal skin. Outside of this again are a series of small elevations caused by the ends of the cleft arches protruding under the skin, and along this line a band of long, fine, silky hairs grow like a divided mane, extending from the forehead half-way down the back. The back and neck together are very short, the face is turned upward like a frog's, the ears rest on the shoulders, the eyes protrude. A median longitudinal section (Fig. 4365) shows the absence of both spinous processes and spinal cord and an abnormal curve of the cervical spine, which explains the frog-like position of the head on the shoulders. That this position is due to the condition of the spine rather than to deformity of the skull is shown by Fig. 4366, the skeleton of a rachischisic with abnormal cervical curve and a well-developed cranium, whereas Fig. 4367, a median

Fig. 4365.—Longitudinal Section through Eight-months' Fœtus with Total Rachischisis. Showing abnormal curves of spine.

section through a fœtus with simple anencephalus, is without abnormal curves of the spine and the position of the head is normal. The study of twenty skeletons of rachischisics in the Warren Medical Museum, Boston, shows that both antero-posterior and lateral spinal curvatures are very common. The cleft in the spine is both

wide and long. It is symmetrical, due to absence of the spinous process and of both laminæ; sometimes the transverse processes are unformed. Occasionally the bodies are cleft as well as the arches, so that there is

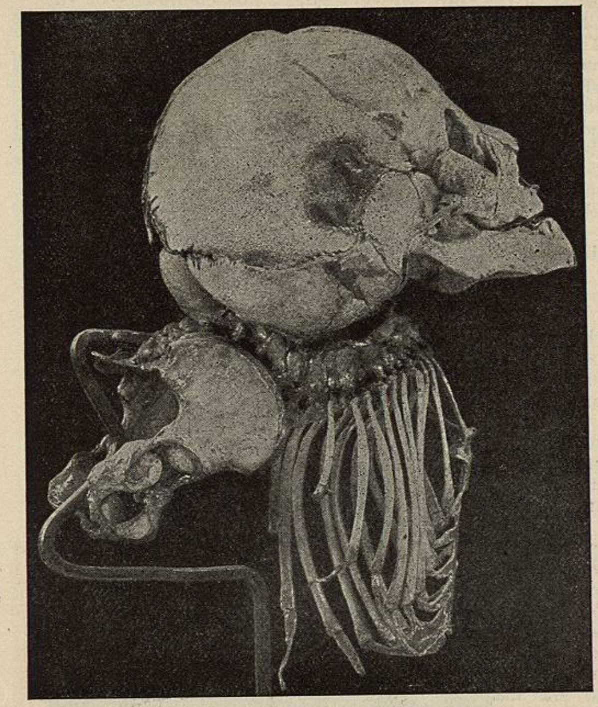

Fig. 4366.—Rachischisis with Great Shortening and Abnormal Antero-posterior Curvatures. Skull well developed. (Warren Museum.)

both an anterior and a posterior split in the spine. The halves of the divided spine separate from each other, to unite below the cleft (Fig. 4368). Absence of a vertebra is not uncommon; also segmentation of one or more vertebral bodies, or absence of ribs; deformities of the thorax are common.

Partial or incomplete rachischisis may involve any number of vertebræ, from five up, in any part of the spine. Von Recklinghausen (in *Virchow's Archiv für Pathologie*, vol. cv.) describes the appearance of the back. There is absence of skin in a circular area in the median line of the back containing a central dark red area medullo-vasculosa, surrounded by thin glistening membrane which merges into true skin; two dimples, one at the upper and one at the lower part of the area medullo-vasculosa, called cephalic and caudal poles, mark the points where the central canal of the cord commences to be a tube above and below, and a bristle may often be passed into its lumen. Not infrequently a collection of fluid in the meshes of the pia raises this area on the top of a slightly projecting cyst. The appearance is then much like that of a spina bifida.

No surgical procedure has been performed for rachischisis. Most are still-born or die at birth, the rest a few hours after, although a recent case at the Infant's Hospital, Boston, lived eight days, and it is possible that some remain alive longer.

Spina bifida was first correctly described by Nicolai Tulpius, of Amsterdam, in 1685—a congenital malformation consisting of a cleft of the arches of the vertebræ and a sac containing fluid protruding on the back; very rarely there may be a cleft in the bodies of the vertebræ as well as in the arches. The Clinical Society of London in 1885 appointed a special committee to tabulate all the cases recorded in literature, all London hospital records and museum specimens, and incidentally to report on the best method of treatment. Their classification of the different forms of spina bifida is based upon the gross pathological appearances of museum specimens. It divides them into three varieties, according to the position of the fluid: first variety, fluid external to pia mater of cord; second variety, fluid contained in dilated cavities of pia-arachnoid; third variety, fluid within the cord itself in the dilated central canal. The first condition is named spinal meningocele, the second meningomyelocele, and the third myelocystocele. Then there are mixed forms in which a cyst of the cord is associated with one of the other varieties of spina bifida, called by Recklinghausen myelocystomeningocele. They constitute a fourth variety.

Spinal meningoceles represent a fairly large proportion of all cases of spina bifida, but different writers vary in their estimates. This is due to the scarcity of museum specimens, for unlike the other forms the death rate from operation is very low in this variety. The sac is usually large and always globular, either entirely covered with skin or with a relatively small membranous portion on top, while the pedicle is constricted and slender. Such sacs most frequently come in the lumbo-sacral or sacral region, are uncommon in the cervical and lumbar spine, and are rare in the dorsal region. The cleft is always small, involving only one or two vertebræ, is situated a little to one side of the median line, and the pedicle of the sac may even escape through a deficiency of the ligaments between well-formed arches of adjacent vertebræ. On opening it, a loop of cord or nerves may be found

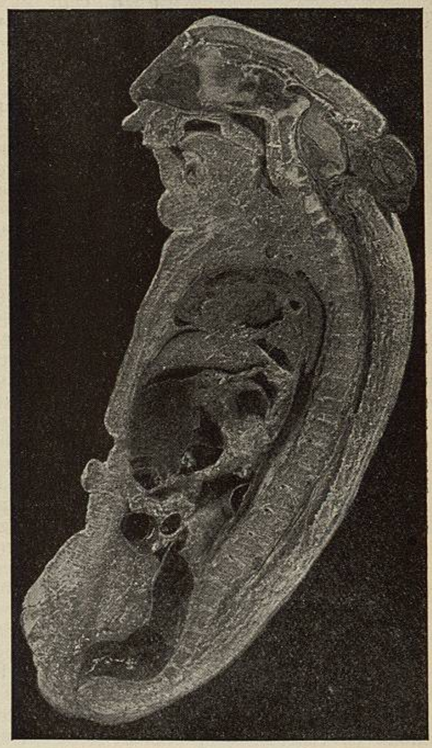

Fig. 4367.—Longitudinal Section through Anencephalic Fœtus. Showing almost normal spinal curves.

lying in the neck of the sac. Clinically the absence of subdivisions and of large nerves may be demonstrated by applying the hydroscope to the sac in the same manner as one would apply it in a case of hydrocele. The skin surrounding the base of the sac is usually covered with a growth of silky hairs.

Myelomeningoceles.—These are common in the lower segments of the spine, less common in the dorsal, and