attached periphery and removed entire, thus exposing the cephalic ("upper") aspect of the cerebellum (Fig. 700, p. 159). If the head is tilted a little to one side and the other, the fingers may be safely passed under the comparatively firm pons so as to lift the whole mass and expose the remaining cranial nerves (Fig. 681, p. 154). When these and the vertebral arteries are divided (Fig. 803, p. 214) the myel itself may be cut well down in the spinal canal. Lastly, after replacing the parts and tilting the head cephalad, may be divided the attachment of the arachnoid about the foramen magnum, and the mass may now be removed. It is advantageously kept entire till hardened, but the cerebrum is more easily dealt with and commonly more instructive if medisected at once.

§ 61. *Medisecting the Fresh Cerebrum.*—This is to be done with a large knife, thin and very sharp. The mass should rest in a wide dish of brine and be steadied but not actually supported by cotton at the sides. The frontal lobes are held closely together by the arachnoid along a line corresponding with the ventral (concave) margin of the falx (Figs. 800 and 801, pp. 212, 213). This arachnoid must be torn or carefully divided so as to permit the slight divarication of the hemicerebrums and the exposure of the mesal zone of the callosum, recognizable from its white color at the bottom of the intercerebral fissure.

If there are special reasons for obtaining an accurate medisection of the callosum itself or of the pseudocele (Fig. 756, p. 189) the section may begin with the callosum, preferably the genu or cephalic curvature.

Commonly, however, I have found the delicate terma and medicommissure more perfectly preserved when the cerebrum rests upon its dorsum and the chiasma is divided first. In either case the knife should be constantly irrigated.

§ 62. *Weighing the Fresh Brain.*—This may be done in any of three ways.

A. With an animal of moderate size, or a child, or a separated head, the weight of the brain represents the loss of weight of the animal, child, or head after its removal.

B. A vessel partly full of water, salt solution, or brine, is balanced upon the scales;* the brain is lifted from the liquid in which it has been, in the hollowed hands; they and the brain are rinsed with water, and the brain is transferred to the vessel on the scales. If the dura remains the weighing cannot be accurate, even by deducting its weight when removed.

C. After recording the weight required to balance the added brain, then—having first wet the hands with a liquid identical in composition with that in which the brain is immersed—remove the brain and record the loss of weight. Theoretically it should be the same as had to be added before; practically there is usually some difference, and the average of the two may be taken as representing the true weight.

§ 63. *Determining the Volume of a Brain.*—This is done, as with any other mass, in either of two ways.

A. Into a vessel of accurately known capacity pour a given volume of liquid; dip the hands in the same, and transfer to it the brain; then from a graduated vessel add enough more of the liquid to fill the first vessel. The difference between the total capacity of the vessel and the sum of the two volumes of liquid introduced represents the volume of the brain.

B. Set a vessel in a deep pan, dish, or pail. With any liquid (salt solution, water, or alcohol and water) that is lighter than the brain, fill the vessel just to the brim. Let the brain into it gradually; the overflow will represent its volume.

Obviously a combination of the two methods is most satisfactory.

§ 64. *Dividing Nerves and Vessels.*—As a rule this should be done with the scissors, not so much to avoid blunting the scalpels by contact with bone as to avoid the almost inevitable traction and breakage of delicate or important attachments.

§ 65. *Closing Divided Vessels.*—This may be desirable either to prevent the disfigurement of the body or clothing by blood, or to permit the injection of the general vascular system. In the latter case, unless the divided vertebrals and carotids can be tied or caught with *serres-fines*, the regions in which they open may be filled with plaster of Paris. In the former case, plugs of absorbent cotton may be pushed into the spinal canal and the vascular orifices at the base of the skull, and the cranium then filled firmly with the cotton so as to be compressed and crowded down by the calva.

§ 66. *Reuniting the Divided Calva.*—If necessary, at once, or at any time, the two parts of the calva may be united by wires, or even cords, passed through holes at the middle and at each end; such holes may be made with a drill, awl, or wire nail.

§ 67. *Reattaching the Calva.*—Whether reunited or not the two pieces of the calva may be secured by wires through holes at each of the four "corners" (§ 60, *D*). Further stability is gained by stitching the divided edges of the temporal fascia.

§ 68. *Sewing up the Scalp.*—A knot should be tied at the end of the silk and the needle introduced at the root of the ear, at first ecto-entad (from the surface inward), afterward ento-ectad (from within outward); the stitches not too long, and not entangling the hair. Even if the concealment of disfigurement is not essential the operation should be neatly done unless there are special reasons for unusual haste.

§ 69. *Other Methods of Removing the Adult Brain.**

§ 70. *By Removal of the Occipital Region of the Cranium.*—At the meeting of the American Neurological Association, June 22d, 1883, as reported in its Transactions, p. 84, as reprinted from the *Journal of Nervous and Mental Disease*, July, 1883, Dr. Spitzka described as follows a method which, he informs the writer, he has known to be employed by some German anatomists. The writer has not tested this method personally, but is disposed to regard it as better adapted to pathological than to anatomical purposes, and as such entitled to be considered in connection with the usual method, and with that described on pp. 789–791 of Vol. V. of the first edition of the REFERENCE HANDBOOK:

"The scalp is divided in the median line, beginning a little in front of the coronal suture, and extending down the neck. If it is desired to remove the spinal cord the incision is extended to the lumbo-sacral region. Two lateral flaps are formed in the head region, the soft parts being peeled from the dorsal aspect of the cervical vertebra and the posterior half of the skull. A circular incision is made [with the saw] in the skull, behind the ears, and completely encircling it down to the foramen magnum, care being taken not to injure the connection between the articular processes of the atlas and the occipital condyles; the posterior half of the skull is removed exactly as the calvarium ordinarily is, by taps of a chisel; sometimes a rongeur forceps suffices to complete the division near the foramen magnum. The adhesion above the lateral [and longitudinal] sinus and torcular Herophili can be readily overcome by a home-made apparatus like the knife [spatula, or round-pointed knife, curved flatwise] shown by Professor Wilder. The advantages of this method are: 1, The spinal cord and brain can be demonstrated *in continuo*; 2, the critical operation of lifting the hemispheres and gouging out or injuring the cerebellum in dividing the tentorium is obviated; 3, the nerves and arachnoidal laminæ at the base may be divided without allowing the brain to drag by its own weight. These nerves are divided from behind forward. As soon as the chiasm is divided, the skull is inclined a little, and the brain allowed to fall into the hands of the operator by its own weight, it being completely separated, except where the olfactory filaments pass through the ethmoid;

* Some trouble will be avoided if, after the pan of liquid has been counterpoised upon the scales by an approximately equal weight, say 500 or 1,000 or 1,500 gm., the exact balancing is accomplished by removing or adding liquid with a syringe.

* See the article *Autopsies*.

but these yield readily, and I have gotten the olfactory bulb intact as often by this as the other method. The removal accomplished, the occipital segment is riveted back, and a stick of wood inserted in the spinal canal and extending to the cranial interior restores the strength to the head support, impaired by the breaking up of part of the vertebral attachments."

§ 71. The method of Féré (as briefly described in a paper "Procedé de coupe du crâne," *Soc. Anat. de Paris Bulletin*, ii., 206–207, March, 1877) is by a circular incision very low down from the eyebrows ventrad of the auditory meatus to a point between the foramen magnum and the dorsal arch of the atlas. This, if successful, would uncover the brain very fully and permit its replacement in the calva after extraction; but it seems inevitable that the petrous bones should give trouble as well as be themselves destroyed.

§ 72. *Removing the Brain from Late Fetuses, Still-Borns, or Young Children.*—This is most conveniently done if the cranium and maxillary region are first cut away from the neck and mandible by cutting with coarse-curved scissors from the corners of the mouth to the nape of the neck. The mass thus obtained is compact and may stand upright in liquid.

A. Instruments and materials required. Coarse forceps; coarse-curved scissors for bone; another sharp pair for soft parts; tracer (Fig. 985); nippers (Fig. 986); large scalpel; narrow-bladed scalpel, preferably a probe-pointed bistoury; four vessels, holding about two litres each; two of water; one of preservative; one of saturated brine; if the weight of the brain is to be ascertained (§ 62) the body should be weighed before the head is removed, and there should be provided a fifth vessel of normal salt solution (15 to 2,000).

B. The scalp should be removed completely, together with the ears, and temporal muscles as far as the zygomas.

C. Cranium and dura. In young subjects these adhere closely; hence, contrary to what is recommended with adults, they should be removed together in pieces. With the tracer-point lift the united pericranium (ectal periosteum) and dura near the left margin of the prefontanel (p. 212, § 388), and with the scissors or scalpel slit the tough membrane so as to expose a little of the brain. Grasp the cut edge with the forceps and with the scissors cut out a piece including pericranium, dura, and intervening area of parietal bone. Continue in this way, using the nippers when necessary, until the entire left hemicerebrum is exposed. More and more care will be required to avoid injuring the delicate brain, either by the instruments or the cut edges of bone.

Leaving the falx undisturbed, expose the right hemicerebrum in the same way, but with even more precaution and holding the head so that the left is more or less completely supported in the brine.

D. Proceed then, *mutatis mutandis*, as directed for the adult (§ 60, G).

§ 73. *Removing the Hemicerebrums Separately.*—The following modification of the method just described has some advantages. After the exposure of the left hemicerebrum cut the veins as before. Let the head tilt to the left so as to expose the callosum. Divide it, as directed above, down to the base of the skull; then the left half of the mesencephal; then the infundibulum and optic nerve; and finally dislodge the olfactory bulb.

These last parts are then to be attended to first on the right side; the falx is easily removed, and the hemicerebrum comes out as soon as the veins are cut. The chief objection to this method is the danger of cutting the mesal aspect of one of the frontal lobes.

§ 74. When there are reasons for not mutilating the head, the removal of a child's brain is much less convenient. The body and legs should be wrapped up so as to be held and turned easily. Unless the child can be held by an assistant, it will be found convenient to let it rest in a sort of trough, like a piece of large roof-gutter; or to roll it up in a sheet of lead, which, upon pressure, will flatten so as to maintain any desired position. The tray or trough must be supported at a level with the rim of the vessel of brine, so that the head may hang over into it when desired. Needle and thread must be provided for sewing up the scalp.

§ 75. *Ventral Exposure.*—For some purposes, *e.g.*, when the organ is to be kept entire, or when the nerve-roots are to be retained, the young brain may advantageously be exposed from the ventral side; this aspect should be first studied, as shown in Figs. 672 and 806; then the base of the cranium may be nipped away, or cut with the coarse scissors; it will be well to expose one side completely first, so that any errors detected may be avoided on the other. With care the hypophysis (Figs. 689 and 708) may be retained.

This method is less applicable to adult brains, on account of the thickness of the skull; this, however, may be softened by nitric acid (§ 127).

On February 1st, 1884, the writer removed the cranium of a small monkey (*Midas*, No. 342) by means of a dental engine, working a small saw and a burr. It may be predicted that in time the work now done laboriously with saw and nippers will be accomplished more neatly and expeditiously by some apparatus like the electro-osteotome of the late Dr. M. J. Roberts (*Virginia Medical Monthly*, March, 1887).

§ 76. *Brains of the middle and later gestative periods and at term* are most useful for the comprehension of the early and simple condition of the fissures and of the order of their appearance. The best results are obtained by their prompt removal as described in §§ 72–75, and hardening with some zinc-chloride mixture (§ 89). The arterial injection of such brains rarely preserves them well, and the gyres are commonly so pressed together as to interfere with both the removal of the pia and the recognition of their relations.

§ 77. *Early Fetal Brains, Two to Four Months.*—Unless one has acquired considerable skill in manipulating such delicate objects, these should be hardened in place by one of the following methods, or by a combination of them; a five-per-cent. solution of zinc chloride in alcohol is very effective with embryo brains:

A. Injection of the preservative through the umbilical vein.

B. Immersion; if alcohol, or the above solution, is used the specimen should be suspended in it.

C. Injection of the preservative with a hypodermic syringe both into the body in general and into the cavities of the brain.* The cannula should be pushed through the scalp at the margin of the prefontanel (p. 212, § 388), obliquely latero-ventrad so as to traverse the thin parietes and enter the large frontal portion of the paracele (Figs. 667, 716, 747). The success of the injection is shown by the expansion of the opposite half of the head due to the passage of the liquid through the portas ("foramina of Monro") into the corresponding paracele.

The exposure of such brains must be done under or over alcohol; the cranium and dura must be divided together at each cut (§ 72, C). The operation is tedious, but the results are revelations, no matter how often performed; no specimens are more beautiful or instructive; see Figs. 667, 746, 748.

§ 78. Hydrocephalic brains, and those of fetuses between the second and seventh month, are alinjected in place from the aorta or other artery, and also have the more or less abundant neurolymph replaced by strong alcohol. This direct, entocelian alinjection is done as soon as possible after the arterial has begun; it is most conveniently accomplished by making a slit at one margin of the prefontanel large enough to permit the introduction of a cannula and the escape of liquid at its side. The injection need not be continuous, and, of course, should not be under pressure, but may be repeated at intervals of an hour or two.

§ 79. When a hydrocephalic or fetal brain is wanted for a special object involving the integrity of the entire cerebrum or the complete distention of the metepenceph-

* So far as the writer is aware, this was first done by Professor S. H. Gage, May 17th, 1892, upon specimen 2,947.

alic cavities, then the undesired region is cut away, the desired region left in the cranium, and the alcohol injected through the mesocele, continuously, in order to make up for the non-injection of the arteries.

§ 80. Removed embryo and hydrocephalous brains are relieved from pressure during hardening by inflating the cavities; Fig. 715. The buoyancy of even an adult normal brain is sometimes increased by injecting air into the arteries through a bulb syringe.

§ 81. *Preservative Liquids.*—Alcohol is a perfect preservative, but it bleaches the cinerea, and in any mixture with water strong enough to be effective the brain sinks and becomes distorted. The specific gravity of the mixture may be increased by glycerin, zinc chloride, or other heavy soluble salts (§ 82–84). Strong alcohol may be injected into the cavities and blood-vessels of the brain (§§ 91–108).

§ 82. *Alcohol and Glycerin.*—One of my most perfect and instructive fetal brains (1,820; Fig. 751, p. 187) was first placed in equal parts of alcohol and glycerin; after two days half the mixture was replaced by alcohol; after two days more alcohol alone was used, and this was renewed on the following. The mixture merits systematic trial.

§ 83. *Alcohol and Zinc Chloride.*—A five-per-cent. solution of this salt in ordinary (ninety-five-per-cent.) alcohol is very effective with embryo and fetal brains, whether by injection or immersion.

§ 84. *Ammonium Dichromate.*—Our use of this has not been sufficiently extensive for a general statement, but, at the suggestion of Professor Gage, it was employed in association with alcohol very successfully in the preparation of the specimen represented on pp. 176 and 184 (Figs. 732 and 744). In equal parts of alcohol and water the salt was dissolved in the portion of 2.5 gm. to the litre. In addition to the thorough hardening of the substance and the unusually perfect maintenance of the membranous and plexal attachments, the color differentiation was sufficient, although the subsequent prolonged preservation in alcohol alone has nearly bleached the cinerea. This salt merits further trial in various combinations.

§ 85. *Potassium Dichromate.*—This is the essential ingredient of Müller's liquid (§ 86). Dr. Stroud has determined that, at the temperature of 20° C. (68° F.), a saturated solution of potassium dichromate contains about ten per cent. of the salt; at boiling the per cent. is forty-four. His method of using it is to effect the solution rapidly in boiling water; when cool, enough water is added to float the brain just below the surface.

The specimens in this solution or in Müller's liquid should be kept in the dark, *i.e.*, in metal pans with metal covers, or in a dark room.

As soon as the brain is firm to the touch it may be soaked for a day in water and then in alcohol, at first about forty per cent., then stronger, until the alcohol ceases to be colored, after which it may be kept in alcohol of not less than eighty per cent.*

The alcohol that is so colored may be used for the same purpose with other brains, or for the storage of specimens not requiring it to be either colorless or very strong.

§ 86. *Müller's Liquid.*—This consists of two parts of potassium dichromate and one part of sodium sulphate in one hundred parts of water. Beyond increasing the buoyancy of the liquid, the sodium sulphate seems to have no special value for either microscopic or macroscopic purposes and is often omitted. Sufficient buoyancy may be attained by increasing the per cent. of the essential ingredient (§ 85).

§ 87. *The Incompatibility of Alcohol with Potassium Dichromate.*—A chemist to whom the matter was submitted states that when alcohol and potassium dichromate are mixed in any proportion the salt will be at least partially reduced, and there will also be formed, from the alcohol, various compounds, as acetic acid, acetic aldehyde, etc. These processes take place in either the light or the dark, but more rapidly in the light.

§ 88. *Zinc-Glycerin Mixture.*—After careful consideration of prior suggestions, and prolonged experimentation, P. A. Fish published (1893, p. 393; 1894. p. 101) the formula of a liquid which, "though not ideal in its effects, seems to answer the requirements of economy, fixation of the structural elements, differentiation of tissue, a minimum amount of distortion, firmness of texture, and rapidity of action.

"The formula is as follows:

Water	400 c.c.
Ninety-five-per-cent. alcohol	400 c.c.
Glycerin	250 c.c.
Zinc chloride	20 gm.
Sodium chloride	20 gm.

"The specific gravity of the mixture should be about 1.04, a little greater than that of the brain itself (1.038). The slightly greater density of the fluid is believed to be more advantageous than otherwise, since it buoys the brain until the tissue has begun to harden and can partially support its own weight. The pressure is nearly enough equal on all sides to prevent any noticeable change of form. It is recommended that the cavities of the brain be filled with the mixture (celinjected) and if practicable the blood-vessels also injected. After an immersion of about three days the specimen should be transferred to equal parts of the foregoing mixture and seventy-per-cent. alcohol for a week or more, where on account of the lesser specific gravity it should rest upon a bed of absorbent cotton; it is finally stored in ninety-per-cent. alcohol."

§ 89. *Zinc-Formalin Mixture.*—Two years later Fish published (1895, *a* and *b*) the results of two experiments with an agent then comparatively little known. Referring to the zinc-glycerin liquid he says: "Experiments with formalin (forty-per-cent. formic aldehyde) show that practically as good results may be obtained at less cost when the following mixture is employed:

Water	2,000 c.c.
Formalin	50 c.c.
Zinc chloride	15 gm.
Sodium chloride	100 gm.

The brain is left in the mixture for a week or ten days (a longer stay is not detrimental); when practicable the cavities and blood-vessels are injected with the same to insure a more uniform hardening."

Respecting the subsequent treatment Dr. Fish writes me that he recommends a course slightly different from that indicated in the papers quoted. For storage, a five-per-cent. solution of formalin, *i.e.*, 50 c.c. to 1,000 of water.* In this it may remain indefinitely if properly covered. For museum purposes it may be placed successively for a few days each in alcohol, 50, 70, 90, and 95 per cent.

§ 90. *Saline Alcohol.*—Dr. Stroud, the successor of Dr. Fish, continued experiments with the same important end in view and devised a liquid which dispenses with the irritating zinc chloride, combines the two liquid preservatives, alcohol and formalin, and overcomes the difficulty due to the slight solubility of the sodium chloride in an alcoholic mixture by employing a somewhat larger portion of another salt, sodium acetate. The formula as published in 1896 is as follows:

Sodium acetate	130 gm.
Sodium chloride	110 gm.
Formal [formalin] (forty-per-cent. formaldehyde)	20 c.c.
Alcohol (ninety-five per cent.)	460 c.c.
Water	540 c.c.

Dissolve the sodium acetate and the sodium chloride in the water. Cool and filter, then add the alcohol. With

* The specimens may be more completely decolorized by absolute alcohol (W. C. Krauss), by hydrogen peroxide (Unna, *Arch. für mikros. Anat.*, xxx., 48, 1887), or by a one-per-cent. solution of chloral hydrate (Lee, "Microtomist's Vade Mecum").

* As the formalin does not prevent the freezing of the water, cold must be guarded against.

alcohol free of tax the cost is about fourteen cents per litre.

For a human brain is required about 3 litres, *i.e.*, three times the above formula. For a sheep's brain, about 400 c.c., or half the formula.

Brains should remain in brine to soak out the blood for a time dependent on their size. They should remain in the saline alcohol for ten or fifteen days, but a longer period is not harmful. Then they may be transferred to increasing percentages of alcohol.

During the last four years there have been prepared by the saline-alcohol scores of human brains and hundreds of brains of sheep and other animals, and it has proved wholly satisfactory for macroscopic purposes, whether for dissection or permanent preservation. The structural and color distinctions between alba and cinerea are well maintained.

§ 91. Experiments are making with a saline-alcohol in which the components have a simpler ratio, and the results will be announced as soon as practicable.

§ 92. *Entocelian Injection.*—To fill with a hardening and preservative liquid cavities surrounded by flexible walls would seem to be a natural device both for the better preservation of the mass and for the maintenance of the forms and relations of the cavities.*

A small glass syringe may be employed for injecting preservative liquids into the brain cavities, either directly or by attaching a rubber tube and cannula.

§ 93. Seldom, if ever, excepting perhaps with very small or thin-walled specimens (*e.g.*, the brain of *Cryptobranchus* shown on p. 170, Fig. 717) is a single or momentary introduction of the preservative sufficient.

§ 94. *Continuous Injection.*—This involves, first, the elevation of the reservoir of preservative to a height (upon a shelf or at the end of a cord) sufficient to insure steady and adequate pressure; secondly, the avoidance of damage from the clogging or twisting of tubes or the overflow of the liquid that has escaped after traversing the vessels or the cavities. The various requirements may be met by simple arrangement of pinchcocks and flexible wire supports of copper or lead.

§ 95. Without conceding the existence of other natural orifices from the paraceles (lateral ventricles) (p. 171, Fig. 721), both human and animal brains present outlets for the escape of the injected liquid so as to obviate the danger of rupturing the thinner parietes under any pressure that might be required for filling the cavities. With animals the myelocele (central canal of the spinal cord) is pervious through life. With a cat, for example, where 4 cm. of the myel remained attached to the brain, alcohol injected into the diacele (third ventricle) with a syringe escaped from the myelocele in a stream 8 to 10 cm. long, although the orifice of exit was 42 mm. from the tip of the metacele and 66 from the place of injection. With human brains (excepting early stages when the myelocele would probably be sufficiently pervious) there is an ample outlet at the metapore (foramen of Magendie), (p. 154, § 78). The same is the case with apes and some monkeys. Hence the cannula, instead of fitting loosely, may be tied into the infundibulum, or made large enough to fit it closely. In the latter case the cannula may need a rubber collar to prevent its entrance so far as to lacerate the medicommissure or parietes. This precaution may be rendered superfluous by using a cannula which is bent upon itself at a right angle, in the form of a capital letter L turned one quarter way around, thus, ⌐; the shorter arm enters the orifice (for tying in the infundibulum a slight enlargement of the point is desirable); the longer rests upon the base of the brain and has attached to it the tube connected with the syringe or injection reservoir This tube should be short and slender; in the intervals of injecting it may be compressed, or plugged with a glass or cork.

§ 96. Entocelian injection, whether repeated or continuous, may be accomplished from any artificial orifice. The most favorable place is the mesocele (aqueduct) after transection of the brain; the cannula may be selected so as to fit it closely. With the cerebellar portion of the brain the metapore would serve as the outlet; with the cerebral it might be necessary to tie the infundibulum to prevent too ready escape therefrom; with a small stream at a slight elevation above the brain it is probable that any excess would be provided for by oozing along the rima.

§ 97. *Entocelian Alinjection per Luram.*—Four points are to be kept in mind: (1) The smallness of the orifice (Fig. 672), which may be enlarged, if desired, with the probe or by clipping the infundibulum shorter; (2) the general dorso-caudal direction of the passage (Fig. 687); (3) the danger of wounding the parietes, and especially the medicommissure; the cannula should therefore be short, the tube small and flexible, and the cannula pushed through a disc of rubber so as not to enter more than 1 cm.; (4) the weakness of the encephalic substance after death; hence no more pressure should be exerted than suffices to fill the cavities and cause a slight elevation of the tips of the temporal lobes. The alinjection can should be just above the level of the brain, and the cannula fit loosely in the lura so that the excess of alcohol may escape.

§ 98. *Combined Arterial and Entocelian Alinjection.*—This very effectual method of preserving a brain removed in the dura for any macroscopic purpose was employed with the specimens shown in Fig. 720. A separate reservoir must be used for the entocelian alcohol (§ 97), or the branch tube leading to the lura must be small and kept compressed so that—when the cavities are once filled—the flow will be very slight.

§ 99. *Arterial Injection of the Preservative.*—This is somewhat fully described in §§ 101–108, and is exemplified in Figs. 670 and 801. As compared with immersion it has the great advantages of rapidity and thoroughness. Any preservative may be employed, and alcohol may be used at full strength. A low temperature is needless, and even perhaps undesirable.

Barring a slight shrinkage, the natural conditions and relations are maintained.

It must be admitted, however, that sometimes the gyres are somewhat crowded against each other, so that the pial folds are less readily and safely extracted, and the fissural relations less easily determined. This applies particularly to infant brains.

§ 100. This is not the occasion for a complete history of injection processes or for the presentation of claims to originality. The transmission of preservative liquids to the tissues by a constant pressure apparatus connected with the vessels by which blood reached the parts during life is really so simple as well as effectual that it is hard to account for its comparatively infrequent suggestion and adoption. Without previous acquaintance with what had been done by others,* on October 7th, 1883, with the co-operation of Prof. S. H. Gage, I began upon the body of a young chimpanzee (No. 265) an alinjection of the entire body, which was prolonged for ten days and was completely successful. In November, 1885, a manatee (No. 844), 150 cm. long, was prepared in like manner. All the cats used by the general class in physiology are alinjected and packed away till wanted. Still-born children are commonly so preserved, and I recommend that, with alcohol obtained free of tax, all anatomical material in medical dissecting rooms be thus rendered

* The method was first employed by me, as assistant to the late Prof. Louis Agassiz, at Nahant, Mass., in July, 1867, for permanent preparations of great vascular sinuses in rays. Since that time it has been applied in the anatomical laboratory of Cornell University to the preparation and study of hollow organs of all kinds, stomach, cecum, heart, uterus, kidney, and brain. In 1880 I first learned that the injection of alcohol into hearts was advised in 1860 by Hyrtl, and in 1879 by Mojsisovics; the former ascribes the idea to William Hunter. I am not aware that injection of a preservative into the brain cavities was practised or suggested by any one prior to December 14th, 1881, when I employed it upon a child's brain.

* Arterial alinjection of the brain is named or implied by Ecker ("Cerebral Convolutions," p. 45); by Mondino (Trans. Roy. Micros. Society, 1885, p. 904); by Foster and Langley ("Pract. Physiology," p. 215); by Key and Retzius ("Studien," I., p. 104); and by the editors of the tenth edition of "Quain," vol. iii., Fig. 88. It was done in 1883 for Marshall upon a Bushman (Philos. Trans., cliv., p. 501); the dates of its performance for Flower and Owen are mislaid.

innocuous, free from unpleasant odor, and fit for prolonged and thorough examination.

§ 101. *Location of the Arteries.*—Nearly opposite the hyoid bone, or the cephalic margin of the larynx, each common carotid divides into an ectocarotid ("external") and an entocarotid ("internal"). In the adult they differ little in size, but may be distinguished in that the ectocarotid branches at once and lies farther ventrad, while the entocarotid continues unbranched to the cranium and is accompanied by the vagus nerve.

If the neck was severed close to the head the two arteries may be dealt with independently. If at the level of the chin (as in the head shown in Fig. 670) the common carotid may be followed up between the muscles, using the tracer rather than the scalpel as much as possible. But if the neck is entire, and especially if it is to be kept so, the ectocarotid may be exposed as for surgical ligation by an incision along the ventral ("anterior") margin of the sternomastoid from the lobule of the ear. In any case the ligature must be applied close to the bifurcation of the common carotid or the superior thyroid artery may not be included. As to the vertebral artery, unless there are special reasons for not injuring the vertebræ, the transverse process may be nipped away in order to expose the vessel. The cannula is to be inserted in one, and the other tied after the arteries have been cleared. Since the two arteries unite to form the basilar it makes no difference which has the cannula, excepting that there is some convenience in placing it and the carotid cannula on the same side (Fig. 803).

§ 102. *Securing the Cannulas.*—Preferably one cannula is to be inserted in the carotid, whichever is the longer, and another in the vertebral of the same side. Each is to be very securely tied; if there is no shoulder at the cannula point, then tie also around the rubber tubing at its base. All the knots should be the so-called "surgeon's," one end of the thread being passed through twice instead of once; W. and G., Fig. 41.

§ 103. *Clearing the Vessels.*—Inject "normal salt solution" (sodium chloride, 15 gm.; water, 2 litres) into a vertebral and entocarotid artery (preferably on the same side) until the liquid runs clear from the other arteries. Place in the alinjection can about 5 litres of twenty-two-per-cent. alcohol, strained through absorbent cotton or filter paper; raise the can to about 1 metre. In connecting the tubes let all air bubbles escape. Small arteries that leak must be tied or secured with *serres-fines*. The liquid should escape in six to eight hours and be quite bloody. If the last of it is nearly free from blood, the strong alcohol may be used; if not, repeat, using half the quantity of twenty-two-per-cent.

§ 104. The strong (ninety-five-per-cent.) alcohol may now be used at the same pressure; it will pass through at a rate varying from one-third to eight-tenths of a litre per hour, and be reduced to seventy-five or eighty per cent. At the end of the third day, and perhaps earlier, the strength of the alcohol will be but little reduced; the pressure may then be lessened by lowering the can to one-half the height. By the sixth day the loss in strength may be no more than three per cent., and the discoloration insignificant. The alinjection may then be discontinued, and the head medisected (§ 109) or otherwise prepared. If desired, a colored injection mass may be thrown into the arteries of either the face (ectocarotids) or the brain (entocarotids and vertebrals), or all.

§ 105. *Turning the Head.*—There are reasons for believing that the position of a head under injection should be changed daily, in order that no one region of the cerebral surface shall be more than twenty-four hours in close contact with the cranial wall.

§ 106. *Repeated Alinjection.*—It is probable that the injection of, say, 1 litre of ninety-five-per-cent. alcohol, morning, noon, and night, for a week would harden a brain very well, but accurate experiments on this point have not been made as yet under the writer's observation. If it be tried especial care should be taken to exclude air bubbles (§ 107), to keep the brain wholly submerged or its base covered with a layer of absorbent cotton dipping into the alcohol. Such injections may be made conveniently with an ordinary rubber-bulb syringe. Repeated injection will conduce to the preservation of the celian parietes and of the plexal attachments, but is less effectual than continuous for maintaining the size and form of the cavities.

§ 107. *Exclusion of Air Bubbles during Arterial Injection.*—This is accomplished by letting the alcohol run until no bubbles appear either in the cannula or in a glass tube which is introduced near the can. The can itself should always be at a higher level than the adjoining tube, especially when it is lowered for the introduction of fresh alcohol, since bubbles are then most apt to be formed; on this account the tube should be of ample length.

§ 108. *Filtration.*—Whatever liquid is to be injected into the encephalic vessels must be carefully filtered through filtering paper, or through absorbent cotton crowded into the pipe of a funnel. This necessity applies to unused alcohol as well as to that which has already passed through tissues.

§ 109. *Medisection of the Head.**—Determine the plane of section by the following mesal points, some of which, of course, are subject to variation: (1) Interval between the central incisors in each jaw; (2) dimple at tip of nose; (3) occipital protuberance (inion); (4) myel; (5) vertebral centrum; (6) notch in cephalic margin of larynx; (7) dimple of chin; (8) middle of top of head. This last is ascertained by carrying a piece of inelastic cord over the top of the head, securing each end in an auditory meatus by crowding cotton in with it, and then finding the middle of the cord. At each mesal point make a short but deep incision. Knot one end of a cord long enough to surround the head and neck at the meson; place the knot entad of the central maxillary ("upper") incisors, and carry it over the nose, head, neck, and chin, back to the mandibular incisors, between which it may be secured by a wedge or otherwise. With the arthrotome divide the scalp, etc., along one side of the cord. Remove the cord, and at the occipital convexity (about at the line from 7 in Fig. 670) bore a hole at the meson deep enough to permit a screw to be firmly fixed.

§ 110. *Adjusting the Head.*—Place the head in the saw-box and mark with a pencil the points where the bottom and one side are in contact with the occipital region and the vertex; at these points bore a hole in the kerf large enough to admit one of the screws. Replace the head in as nearly as possible the same position; pass the spatula through the kerf above the hole in the side opposite the vertex, and adjust the head so that the end of the spatula is in the cut in the scalp. While steadied in that position pass the gimlet or awl through the hole and bore into the skull for a short distance, 3 to 5 mm.; insert the screw at this point. Repeat the operation for the occipital region. This screw should bring the head firmly against the bottom of the box. If it is necessary or desirable to remove the head in order to bore the holes, when the head is replaced the holes may be found by means of the probe end of the tracer.

§ 111. *Packing.*—Draw through the kerfs in the two sides a cord just large enough to fit tightly, and pull it down so that it coincides with the cut in the skin of the face. Pack the cotton first in the angle between the two screws; then under the neck, keeping the whole constantly adjusted by means of the thread and the kerf at the neck side of the box. When firmly packed, pour over the cotton some water until no more is absorbed.

§ 112. *Sawing.*—Remove the cord from the kerf; insert the saw so that the handle is close to the side of the box, and make the first few strokes by drawing only—then

* The following instruments and materials should be provided: Saw (§ 140); saw-box (§ 141); scalpel, the handle of which is smoothly rounded; small, narrow-bladed scalpel, arthrotome, and tracer; two screws, slender rather than thick, and 5–8 mm. longer than the thickness of the side and bottom of the saw-box; gimlet to fit the screws; short, stout awl, medium size; spool of stout saddler's thread; spatula; cotton, or cotton waste or tow or bits of cotton cloth, previously soaked in water and well squeezed, enough to fill the saw-box quite firmly; large agate pans or other suitable vessels; jars and alcohol.

saw in the usual way; a fine stream of alcohol (any per cent. above forty-eight) should irrigate the blade during the entire operation. The back of the saw should be retained as long as possible, and screws not removed until nearly reached by the saw. Let a *gentle stream* of water flow over the sawn surfaces.

§ 113. *Removal of Either Half of the Hardened Brain.**

—A. Remove the falx and falcula (*falx cerebelli*). At the base divide the infundibulum close to the tuber, leaving the hypophysis to be removed separately. Note the location of the optic nerve, and divide by carrying the scalpel point latero-cephalad from the infundibulum for 1 to 2 cm., close to the dura, lest the olfactory crus be injured. Dislodge the olfactory bulb with the syringotome, turn it just over the margin of the hemicerebrum, and secure it by a small pin at either side.

B. *Transection of the Hemicerebrum.*—Recognize, if possible, the dorsal end of the central fissure, nearly dorsad of the splenium. Place a strip of paper or a cord across the hemicerebrum between points about 5 mm. caudad of the fissure and the splenium. The half-head should be in alcohol or the blade should be flooded. The vertex should be toward the operator. Note on the empty half-head the angle formed by the tentorium with the meson, or observe on the preparation in hand. Push the scalpel into the brain close to the tentorium, and with a gentle sawing movement carry its point as far as it will go; continue the movements dorsad, making sure that the broad edge of the haft of the scalpel does not bruise the brain. The completion of the transection is announced by the loosening of the occipital region. Probably the greatest difficulty will be the division of the extreme ventral part. To remove the occipital part, push the probe end of the tracer or a very narrow-bladed scalpel into the brain 10–12 mm. caudad of the section plane, near the tentorium and between two fissures; the direction should be dorso-laterad at an angle of 45°, thus nearly perpendicular to the ental surface of the cranium toward which it is pointing. Dislodge the tip of the occipital lobe by coaxing with the scalpel handle; lift the whole piece slightly with the inserted instrument; it will come out for a certain distance, and then be checked by veins, which may be divided with scissors.

C. *Mesencephalic Transection.*—From Figs. 706 and 708 note that (1) the crusta projects considerably ventrad of the mesal cut surface and (2) that the greatest width of the crus is not more than 15 mm. Hold the scalpel with the flat side at an angle of about thirty degrees with the meson, let the ink mark be at the ventral margin of the crus, and cut dorsad with sawing strokes. Place the specimen so that the depths of the incision are illuminated, and divide whatever may appear; the hemicerebrum will float up, and be readily removed if the dorsal margin be first disengaged and the prominence of the temporal lobe kept in mind.

D. *Removal of the Metepencephal.*—If the tentorium is to be retained, divide it by cutting laterad from a point just caudad of the angle between the natural, curved margin and the cut, straight margin; it is more convenient to remove it entirely. The half-head may now be placed upon a tray and supported, or held by an assistant. Crowd the edge of the round scalpel handle between the dura and the myel for 2–3 mm., beginning at whatever point a slight interval already exists, and continue the separation by gentle, yet firm pressure; special difficulties will be encountered at and near the occipital foramen, requiring perhaps the scalpel edge. Do the same for the cerebellum and pons, keeping in mind the natural curvatures of the surfaces and the locations of the larger nerves, especially the trifacial, the auditory and facial. Specific directions are hardly needed or possible for the rest of the operation.

§ 114. *Arterial Alinjection of a Brain in the Dura.*—If the dura has been retained, at three places upon each side, frontal, temporal, and cerebellar (or occipital if the metepencephal has been removed), pin to the dura pieces of broad, stout tape (or strips of cloth 2 to 3 cm. wide) 10 to 15 cm. long. In place of pins there may be used garment-clasps with serrated edges.

§ 115. For temporary purposes, *e.g.*, examination of the base, preparation for injection, and the single injection of a mass, etc., the brain, supported as directed in §§ 18–19, may be steadied and raised or lowered as required, within any vessel of appropriate size. If of wood, the strips of cloth may be secured by tacks (artists' "thumb tacks" are most convenient); if of glass or metal then an elastic band (*e.g.*, a rubber ring from a jar, or an elastic tape) may be stretched about the rim and the strips passed under it. The vessels must be washed out (§ 103), and the small arteries tied or secured with *serres-fines*.

§ 116. *Dry Preparations.*—The methods of making these have been considered by Fish, who has also devised improvements. The following abstracts are largely derived from his papers, 1893, 1894, and 1897.

§ 117. *Fish's Improved Castor-oil Method.*—The value of this is attested by Figs. 983 and 984, and by numerous excellent preparations in the museum of Cornell University, brains, infant limbs, and entire small animals. "The essential factor is the complete dehydration of the specimen." If originally hardened in any other than an alcoholic mixture it is placed successively for at least one week each, in fifty-per-cent. alcohol, seventy, eighty, and ninety-five per cent. If carried through too hurriedly there will be more shrinkage. It is then placed in oil of turpentine until translucent, the time required varying according to the size of the specimen. The superfluous turpentine is then allowed to drain off for a few hours and the specimen is placed in castor oil. Here it may remain indefinitely or until all the tissues are thoroughly infiltrated. Draining off the superfluous oil requires a day or two and the specimen then receives a coat of an

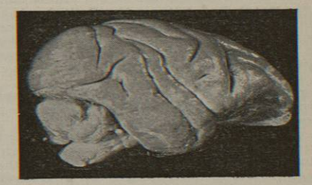

FIG. 983.—Right Side of the Brain of a Monkey, *Macacus cynomolgus*. Prepared by the Castor-Oil Method. × 1. (From Fish, 1893.)

alcoholic solution of white shellac with a camel's-hair brush. This is repeated at short intervals until the surface is firm and glossy.

§ 118. *Laskorsky's method* is here translated from the abstract in the *Neurologisches Centralblatt*, vi., 341–342:

A. Rinse the fresh specimen in water to remove blood.

B. Place in a mixture of water, 100 parts; alcohol (ninety-five-per-cent.), 20 parts; boric acid, 5 parts; let it remain in a cool place [for at least three days; time not given].

C. Remove the pia.

D. In a saturated solution of zinc chloride in alcohol let the brain remain five or six days; the bottom of the vessel should be covered with cotton.

E. For fifteen to twenty days soak in a mixture of glycerin, 100 parts; alcohol, 20 parts; carbolic acid, 5 parts; boric acid, 5 parts.

† The following instruments and materials should be provided: A pan to contain the half-head (about 11 × 4 in.), half full of alcohol of forty-eight to fifty-six per cent., this strength sufficing to float the separated pieces so that they may be extricated without injury (of course, water would do this, but would rapidly soften the brain); a large scalpel, the blade at least 5 cm. long and the haft 1.5 to 2 cm. more—a round-pointed "shoe knife" will serve; a medium-sized scalpel, marked with ink across the blade on each side 15 mm. from the tip; syringotome. Unless one is very familiar with the topography of the parts a model or preparation of the hemiencephal is desirable, also a hemicranium of the same side—if possible two, one dry, the other wet, with the falx, tentorium, etc. (Figs. 670, 800, 801).