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PREFACE TO FOURTH EDITION.

At the request of the publisher, and with the consent of Dr. Hare, the work of revising this book for the fourth edition has been undertaken by Dr. J. H. Raymond. The original text has almost wholly been retained, alterations being made only where necessary to bring the subject under consideration abreast with the teachings of the day.

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PREFACE TO FIRST EDITION.

At the present time, when the student is forced by the rapid progress of medical science to imbibe an amount of knowledge which is far too great to permit of an attempt on his part to master it, any book which contains the "essentials" of a science in a concise yet readable form must of necessity be of value. The trite saying that "there is no short road to knowledge" is, of course, as true as it is old, and for this reason many of the medical profession have looked with disfavor on books of this character, as being the means by which students might attempt the shorter path.

No one desires more than the writer that the depth and scope of medical education may be increased, but in his belief the evil at present in existence consists in the fact that medical institutions, by granting a degree too early, make the short road to knowledge the only one which the student with the average amount of cerebral gray matter can possibly travel. The evil lies with the small amount of time required for the obtaining of the degree, not with those books which are called into existence by the shortness of the medical curriculum.

The usefulness of arranging the subject in the form of questions and answers will, the writer thinks, be apparent, since the student, in reading the standard works on Physiology, often is at a loss to discover the important points to be remembered, and is equally puzzled when he attempts to formulate ideas as to the manner in which the question could be put in the examination-room.

A manual of this character is in no one way intended to supplant any of the text-books, but to contain, as its title declares, the essence of those physiological facts with which the average student must be familiar.

After considerable thought, it has been considered advisable to exclude points which may be called purely anatomical, and which deprive some of the smaller books on Physiology of the space which might otherwise be occupied by purely physiological statements. The results reached every day by physiological experimenters are many of them so contradictory that no attempt to give individual opinions or teachings has been attempted, the statements made being supposed to represent those facts most generally accepted and taught. The student will, therefore, find statements which are not in accord with those taught by his instructor, and it is for this purpose that the interleaved edition has been published, in order that individual teachings may be noted and remembered. In the compilation of the facts here rehearsed, the standard works of Landois, Yeo, Foster, Dalton, Baker, Hermann, and Chapman have all been consulted.

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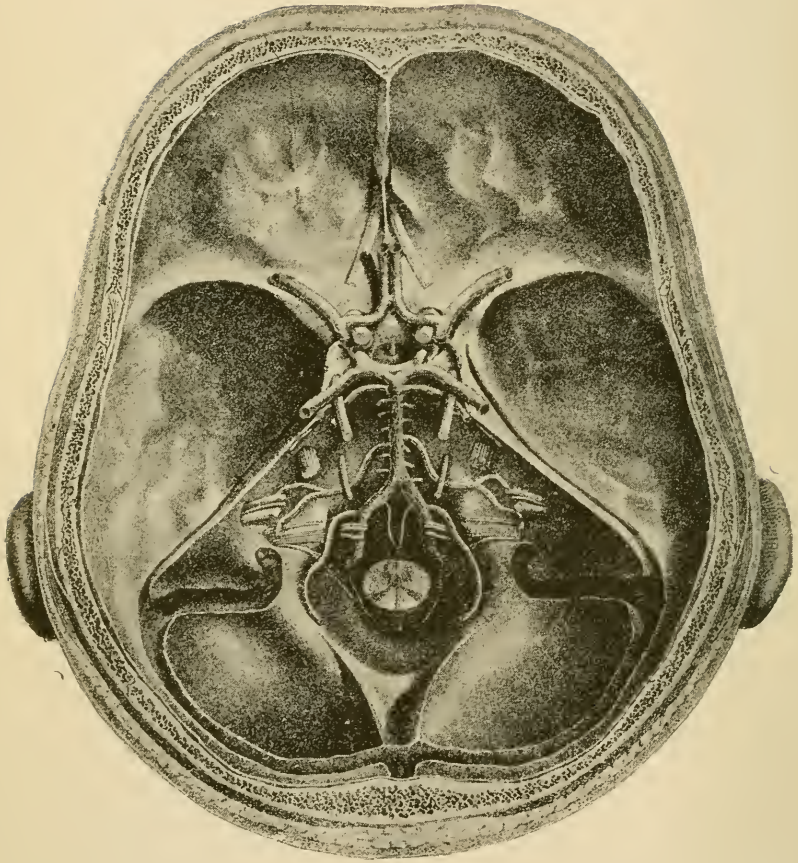
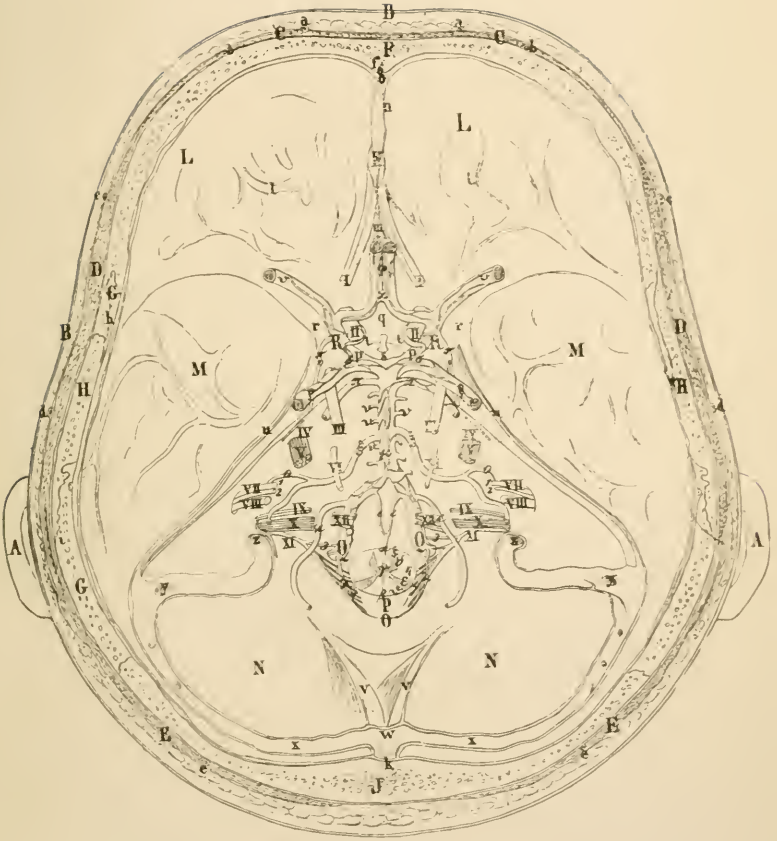
PLATE I.





DESCRIPTION OF THE PLATES.

PLATE I.

POSITION AND COURSE OF THE CRANIAL NERVES WITHIN THE SKULL.

This plate shows the course of the cranial nerves within the skull and through the foramina of the dura mater, and the plexuses of nerves accompanying the arteries at the base of the brain.

The skull being removed by a horizontal section from the glabella to the external occipital protuberance, the brain and tentorium cerebelli are taken out, leaving in view the arteries and roots of the nerves at the base of the brain.

A.—Superior part of the helix of the right and left ears.

B.—Skin and adipose tissue.

C.—Frontal portion of occipito-frontalis muscle.

D.—Temporal muscle.

E.—Occipital portion of the occipito-frontalis muscle. *a*. Frontal artery. *b*. Supraorbital artery. *c*. Anterior, and *d*, posterior temporal arteries. *e*. Occipital artery.

F.—Frontal bone. *f*. Frontal crest. *g*. Groove for the superior longitudinal sinus.

G.—Parietal bone ; *h*, its anterior, and *i*, posterior inferior angles.

H.—Squamous portion of the temporal bone.

I.—Tabular portion of the occipital bone. *k*. Internal occipital protuberance.

K.—Crista galli.

L.—The dura mater covering the anterior cranial fossa, cerebral ridges, and digital impressions, *l*, and the cribriform plate of the ethmoid bone, *m*. *n*. Anterior portion of the falx cerebri with the superior longitudinal sinus, *o*.

M.—Middle cranial fossa, covered by dura mater. *p*. Posterior clinoid processes. *q*. Dorsum ephippii. *r*. Anterior clinoid processes. *s*. Pituitary body and infundibulum. *t*. Diaphragm of the sella Turcica. *u*. Superior petrosal sinus.

N.—Posterior cranial fossa. *v*. Falx cerebelli. *w*. Torcular Herophili. *x*. Lateral sinuses. *y*. Mastoid emissary vein. *z*. Opening of the lateral sinus into the bulb of the internal jugular vein.

O.—Foramen magnum.

P.—Lower portion of the medulla oblongata. α. Anterior median fissure. β. Posterior median fissure. γ. Central gray matter with central canal of the spinal cord. δ. Anterior, and ε, posterior gray horns. ζ. Pyramids. η. Lateral columns. ϑ. Posterior columns.

Q.—Vertebral arteries. ι. Anterior spinal artery. $\varkappa$. Posterior inferior cerebellar artery. λ. Posterior spinal artery. μ. Basilar artery. ν. Branches to the pons. ξ. Anterior inferior cerebellar artery. o. Internal auditory artery. π. Superior cerebellar artery. ρ. Posterior cerebral artery.

R.—Internal carotids. σ. Posterior communicating artery. τ. Anterior choroid artery. υ. Middle cerebral artery. ϕ. Anterior cerebral artery. χ. Anterior communicating artery.

I.—Olfactory nerve.

II.—Optic nerve.

III.—Motor oculi nerve.

IV.—Pathetic nerve.

V.—Trifacial nerve.

VI.—Abducens nerve.

VII.—Facial nerve. 1. Its greater, and 2, lesser portions.

VIII.—Auditory nerve.

IX.—Glosso-pharyngeal nerve.

X.—Pneumogastric nerve.

XI.—Spinal accessory nerve. 3. Its cranial, and 4, spinal roots.

XII.—Hypoglossal nerve.

The carotid and vertebral arteries are accompanied by sympathetic plexuses, derived from the superior and inferior cervical, and sometimes from the superior thoracic ganglia.

PLATE II.

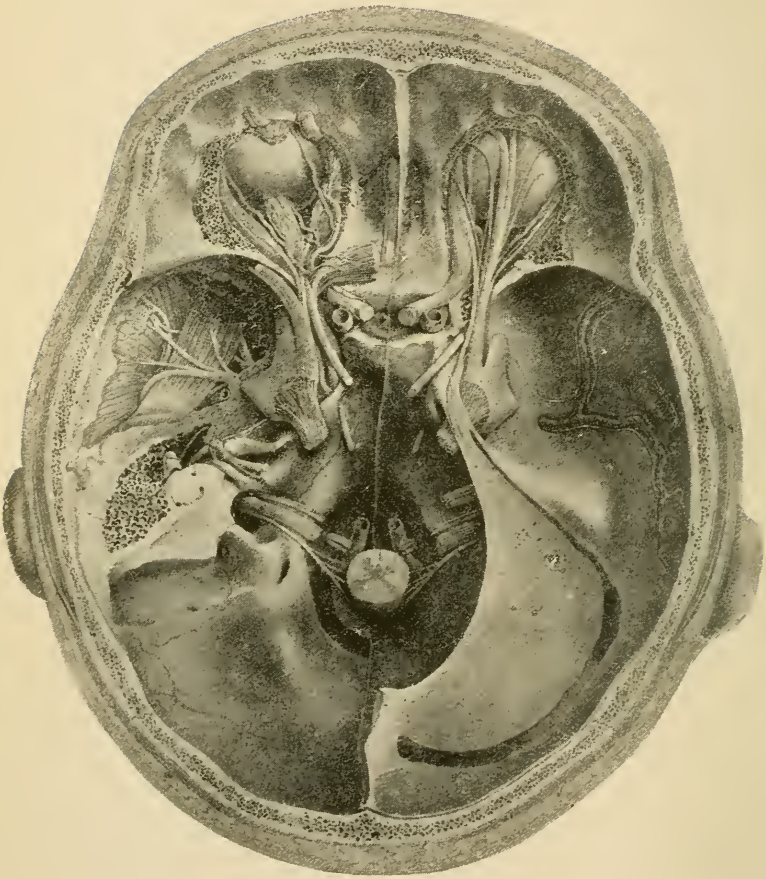


PLATE II.

COURSE OF THE CRANIAL NERVES THROUGH THE FORAMINA OF THE SKULL, AND IN THE ORBIT AND TEMPORAL FOSSA.

On the right side the semilunar ganglion, recurrent branches of the first, second, and third divisions of the trifacial nerve, and the uppermost nerves of the orbit are in view.

To the left are seen the course of the cranial nerves through the foramina of the skull, the deeper nerves of the orbit, and the nerves of the temporal fossa.

The calvarium being removed, the brain, together with the carotid and vertebral arteries, is taken out.

To the right the dura mater and tentorium cerebelli are in their natural position, the lateral and superior petrosal sinuses being opened, but the meningeal layer of the dura mater of the middle cranial fossa is removed, as is also the roof of the orbit, so that not only the triangular plexus, semilunar ganglion, the first, second, and third divisions of the trifacial, with their recurrent branches, but also the course of the supraorbital, lachrymal, and pathetic nerves may be seen.

To the left, the dura mater which covers the base of the skull is removed. The orbit, temporal fossa, tympanic cavity, internal auditory meatus, and facial canal are exposed to view. The supraorbital, lachrymal, and pathetic nerves are cut away, and the levator palpebræ superioris and superior rectus muscles are divided and turned aside.

To the left, therefore, are seen the course of the cranial nerves through the foramina of the skull; the position and course of the optic, nasal, superior branches of the motor oculi and the abducens nerves; the origin and course of the buccal, deep temporal, masseteric and anterior auricular nerves; and finally the connections of the facial and auditory nerves; the course of the chorda tympani through the tympanic cavity, and the position of the greater and lesser superficial petrosal nerves on the upper surface of the petrous portion of the temporal bone.

A.—F., and *a—g*, indicate the same structures as in the preceding plate.

G.—Inferior margin of the parietal bone.

H.—Squamous portion of the right temporal bone. *h.* Left cerebellar fossa. *i.* Foramen magnum. *k.* Left innominate process. *l.* Left jugular process. *m.* Jugular notch. *n.* Left posterior, and *o*, anterior condyloid foramina.

K.—Petrous portion of the left temporal bone. *p.* Sigmoid fossa. *q.* Mastoid foramen. *r.* Mastoid cells. *s.* Semicircular canals partly visible and partly cut away. *t.* Internal auditory meatus. *u.* Tympanic cavity. *v.* Head of the malleus. *w.* Incus. *x.* Posterior lacerated foramen. *y.* Apex of the petrous portion of the temporal bone. *z.* Petro-sphenoidal ligament.

L.—Sphenoid bone. *α.* Clivus Blumenbachii. *β.* Posterior clinoid processes. *γ.* Olivary process. *δ.* Left great wing of the sphenoid bone partly cut away. *ε.* Foramen spinosum. *ζ.* Foramen ovale. *η.* Foramen rotundum. *ϑ.* Roots of the right lesser wing of the sphenoid bone. *ι.* Anterior lacerated foramen. *κ.* Optic foramen, between the roots of the lesser wing of the sphenoid bone.

M.—Cribriform plate of the ethmoid bone. *λ.* Anterior ethmoidal foramen.

N.—Inner surface of the temporal muscle.

O.—Upper border of the external pterygoid muscle.

P.—Condyle of the inferior maxilla.

Q.—Dura mater. *μ.* Anterior portion of the falx cerebri and of the superior longitudinal sinus. *ν.* Opening for the passage of the trunk of the trifacial nerve. *ξ.* Posterior portion of the falx cerebri. *ο.* Right lateral sinus. *π.* Superior petrosal sinus. *ρ.* Dura mater covering the posterior cranial fossa.

R.—Lower portion of the medulla oblongata.

S.—Vertebral artery. On the left it may be seen beneath the condyloid portion of the occipital bone; and on the right it is seen passing through the dura mater.

T.—Internal carotid. *σ.* The second, *τ*, third, and *υ*, fourth flexures of the left internal carotid.

U.—Middle meningeal artery. On the left side it is divided near the foramen spinosum. *φ.* The anterior branch, and *χ*, posterior branch of the middle meningeal artery, which last sends a small petrosal branch into the anterior part of the petrous portion of the temporal bone.

V.—Posterior deep temporal artery, branch of the internal maxillary.

W.—Ophthalmic artery. ϕ. Lachrymal artery. ω. Muscular branches. *aa*. Ciliary arteries. *bb*. Supraorbital artery. *cc*. Ethmoidal artery. *dd*. Ophthalmic artery continuing its course to the inner canthus.

X.—Pituitary body and part of the infundibulum.

Y.—The eyeball.

Z.—External rectus muscle. *AA*. Internal rectus muscle. *BB*. Superior oblique muscle. *CC*. Levator palpebræ superioris muscle. *DD*. Superior rectus muscle.

I.—Olfactory nerve. 1. Olfactory tract, and 2, bulb of the left side. 3. Filaments of the right olfactory nerve, ensheathed by the dura mater, entering the nasal cavity through the cribriform plate of the ethmoid bone.

II.—Optic nerve. 4. Its sheath. On the left side the course of the optic nerve may be seen as far as the eyeball.

III.—Motor oculi nerve. 5. Superior branch, going to the superior rectus and levator palpebræ superioris muscles. 6. Inferior branch.

IV.—Right pathetic nerve. 7. Communicating branch of the first division of the fifth to the pathetic nerve, which runs in its sheath, from whence it soon passes to the internal branch of the supratrochlear nerve. 8. Distribution of the pathetic nerve to the superior oblique muscle.

V.—Trunk and triangular plexus of the trifacial nerve. 9. Semilunar (or Gasserian) ganglion of the fifth pair. 10. Small accessory ganglion, sometimes found in the triangular plexus near the semilunar margin of the semilunar ganglion. 11. First division of the trifacial. 12. Recurrent branch, which runs around the pathetic and divides into two branches, (13), which go as far as the lateral sinus. 14. Lachrymal nerve. 15. Supraorbital nerve. 16. Frontal nerve. 17. Supratrochlear nerve. 18. Two filaments which go to the supratrochlear nerve. 19. Nasal nerve. 20. Sensory root of the ophthalmic ganglion. 21. Long ciliary nerves. 21*. Short ciliary nerves, coming from the ophthalmic ganglion. 22. Nasal nerve. 23. Infratrochlear nerve. 24. Second division of the trifacial. 25. Recurrent branch of the second division of the fifth. 25*. Its junction with the recurrent branch of the third division of the fifth. 26. Third division of the trifacial. On the left side it may be seen

passing through the foramen ovale. 27. Recurrent branch of the third division of the fifth nerve, which runs within the cranium along the posterior margin of the middle meningeal artery, joins the recurrent branch of the second division of the fifth (25*), and gives off a lesser anterior petrosal branch (27*), which accompanies the anterior petrosal artery into the anterior part of the petrous portion of the temporal bone, while it goes to the posterior part of the petrous portion of the temporal bone with the posterior branch of the middle meningeal artery, or a special posterior petrosal branch of this artery. The origin of this recurrent nerve is shown in the first figure of the fourth plate. 28. Superior root of the auriculo-temporal nerve. 29. Masseteric nerve. 30. Posterior deep temporal nerve. 31. External pterygoid nerve. 32. Buccal nerve. 33. Anterior deep temporal nerve.

VI.—Abducens nerve. On the left side its course may be seen on the outer side of the internal carotid and through the anterior lacerated (34) foramen. 35. Distribution of the abducens nerve to the external rectus muscle of the eye.

VII.—Facial nerve. 36. Its greater, and 37, lesser portions. 38. The internal, and 39, external communications of the facial with the auditory nerve. 40. Geniculate ganglion. 41. Greater superficial petrosal nerve. 42. Chorda tympani nerve.

VIII.—Auditory nerve.

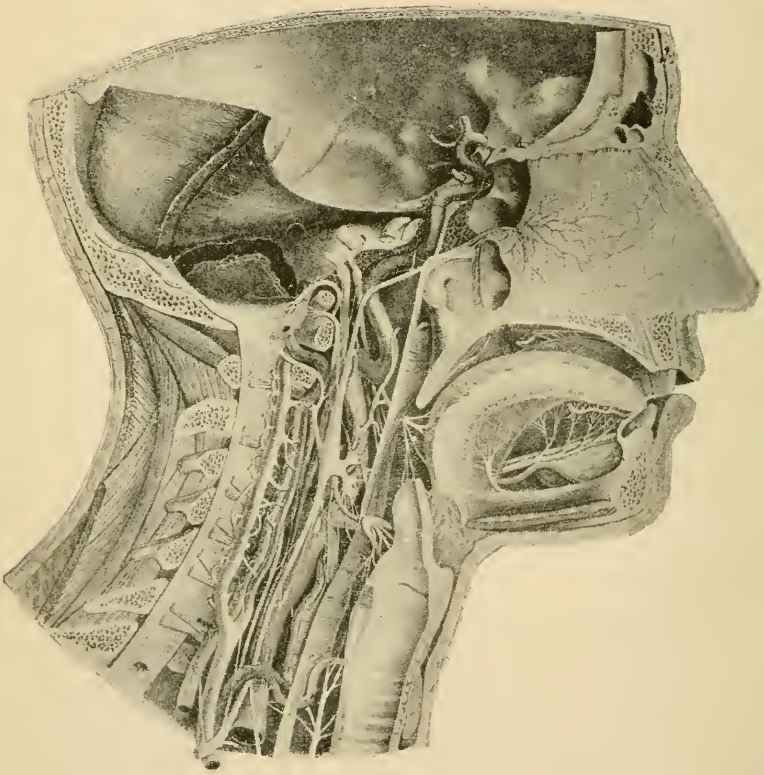
IX.—Glosso-pharyngeal nerve. 43. Lesser superficial petrosal nerve.

X.—Pneumogastric nerve. 44. Superior vagal ganglion, or ganglion of the Root.

XI.—Spinal accessory nerve.

XII.—Hypoglossal nerve.

PLATE III.



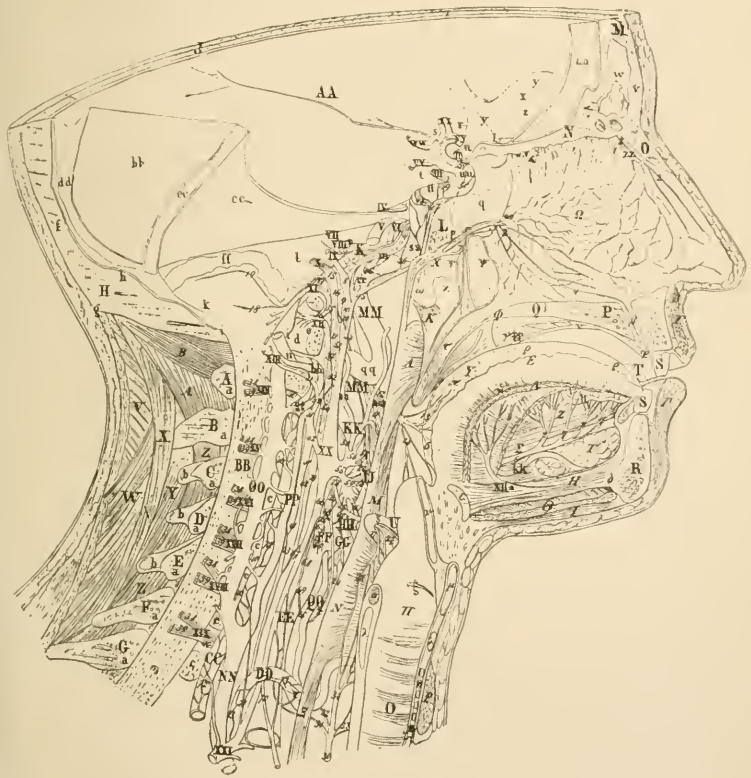


PLATE III.

THIS WITH PLATE IV. GIVES AN INNER AND POSTERIOR VIEW OF THE CRANIAL AND CERVICAL NERVES, AND THE CAROTID AND VERTEBRAL ARTERIES, BOTH WITHIN AND OUTSIDE OF THE CRANIUM, AND OF THE SPINAL CANAL.

The distribution of the nerves of the nasal septum, course of the posterior cranial and superior cervical nerves, and the position of the superior cervical ganglion and sympathetic plexuses on the arteries of the head are illustrated in this diagram.

The right side of the head and half of the cerebrum, cerebellum, medulla and spinal cord are removed by a perpendicular section; the skull and the bodies of the cervical vertebræ, together with the rectus capitis anticus major and minor and longus colli muscles. The basilar process of the occipital and posterior part of the body of the sphenoid bones are removed; the spinal and carotid canals, and the condyloid and posterior lacerated foramina are opened, the osseous and cartilaginous nasal septum cut away, and the mucous membrane of the pharynx and palate and the genio-hyo-glossus muscle are either partly or wholly removed. Therefore the following structures are seen: firstly, the spinal canal covered by the dura mater, and the vertebral vessels and roots of the cervical nerves; secondly, the posterior cranial fossa and the recurrent branch of the vagus nerve, the hypoglossal, spinal accessory, vagus and glosso-pharyngeal nerves, both within and outside of the cranium, and the superior cervical ganglion; thirdly, the cavities of the pharynx and larynx, hard and soft palate and the tongue with its nerves; finally, the common carotid lying between the pharynx and vertebræ, the internal and external carotids and the sympathetic plexuses accompanying the carotid and vertebral arteries.

A.—G.—Cervical vertebræ from the first to the seventh. *a.* Arch of the vertebræ sawed through the centre. *b.* Left apex of the spinous processes. *c.* Posterior root of the transverse processes.

H.—Occipital bone. *d.* Left condyle. *e.* Anterior condyloid foramen. *f.* Tabular portion of the occipital bone. *g.* External, and

h, internal occipital protuberances. *i*. Foramen magnum. *k*. Posterior cranial fossa, covered by dura mater.

I.—Interior portion of parietal bone.

K.—Temporal bone. *l*. Petrous portion. *m*. Carotid canal. *n*. Internal auditory meatus. *o*. Squamous portion of the temporal bone covered by dura mater.

L.—Sphenoid bone. *p*. Its body partly removed. *q*. Sphenoidal sinus. *r*. Lesser wing. *s*. Greater wing, covered by dura mater. *t*. Middle cranial fossa. *u*. Optic foramen.

M.—Frontal bone. *v*. Its vertical plate. *w*. Frontal sinus. *x*. Orbital plate, covered by dura mater. *y*. Digital impressions and cerebral ridges. *z*. Anterior cranial fossa.

N.—Cribriform plate of the ethmoid. *α*. Crista galli sawed through the centre.

O.—Nasal bone.

P.—Palate process of the superior maxillary. *β*. Anterior palatine canal.

Q.—Horizontal plate of the palate bone. *γ*. Posterior palatine canal.

R.—Inferior maxillary, sawed through the centre. *δ*. Genial tubercles.

S.—Incisor teeth.

T.—Left superior canine tooth.

U.—Hyoid bone. *ε*. Body. *ζ*. Greater cornu. *η*. Lateral thyro-hyoid ligament.

V.—Trapezius, **W**, splenius capitis, **X**, biventer cervicis, **Y**, semi-spinalis colli, and **Z**, interspinales muscles. A. Rectus capitis posticus major, and B, minor muscles.

Γ.—Orbicularis oris muscle.

Λ.—Genio-hyo-glossus muscle, partly removed so that the distribution of the lingual and hypoglossal nerves, the course of the ranine and sublingual arteries, and the site of the sublingual gland and Wharton's duct may be seen. Θ. Internal, and ι, external layers of fibres of the genio-hyo-glossus. Ε. Longitudinal, and Ζ, inferior transverse fibres of the lingualis, Η, genio-hyoid, and Θ, mylo-hyoid muscles.

:.—Anterior belly of the digastric.

Κ.—Levator palati, Α, superior, Μ, middle, and Ν, inferior constrictors of the pharynx. Ξ. Longitudinal fibres of the œsophagus.

O.—Trachea. *κ*. Rings of the trachea.

Π. Larynx. *λ*. Cricoid, and *μ*, thyroid cartilages. *ν*. Epiglottis. *ξ*. Ventricle of the larynx. *ο*. Arytænoideus muscle.

P.—Isthmus of the thyroid gland.

Σ.—Wharton's duct. T. Sublingual gland.

Υ.—Tongue. *π*. Circumvallate, and *ρ*, fungiform papillæ. *σ*. Root of the tongue.

Φ —Palate. *τ*. Soft palate. *υ*. Mucous membrane of the hard palate. *φ*. Incisive papilla.

X.—Roof of the pharynx. *χ*. Pharyngeal orifice of the Eustachian tube. *ψ*. Mucous glands of the roof of the pharynx. *ω*. Eustachian eminence.

Ψ.—Left posterior nares. Ω. Membrane of the nasal septum.

AA.—Dura mater. *aa*. Anterior, and *bb*, posterior part of the falx cerebri. *cc*. Tentorium cerebelli. *dd*. Posterior end of the superior longitudinal sinus. *ee*. Superior petrosal sinus. *ff*. Sigmoid portion of the lateral sinus.

BB.—Dura mater of the spinal cord.

CC.—Vertebral artery. *gg*. Its first, *hh*, second, and *ii*, third flexures.

DD.—Inferior thyroid artery.

EE.—Common carotid.

FF.—External carotid.

GG.—Superior thyroid artery.

HH.—Lingual artery. *kk*. Sublingual artery. *ll*. End of the ranine artery.

II.—Facial artery.

KK.—Ascending pharyngeal artery. *mm*. Pharyngeal, and *nn*, basilar branches.

(LL.)—Internal maxillary artery. *oo*. Arteries of the nasal septum. *pp*. Descending palatine artery.

MM.—Internal carotid. *qq*. Cowper's flexure, which is sometimes found. *rr*. Its first, *ss*, second, *tt*, third, and *uu*, fourth flexures. *vv*. Posterior communicating artery. *ww*. Anterior choroid artery. *xx*. Middle cerebral or Sylvian artery. *yy*. Anterior cerebral artery. *zz*. Ethmoidal branch of the ophthalmic artery, anastomosing with the nasal branches of the internal maxillary.

NN.—Trunk of the vertebral vein, which receives the cervical part of the vertebral sinus, **(OO)**, between the fifth and sixth cervical vertebræ. **PP.**—Vertebral vein accompanying the

vertebral artery through the vertebral foramina and connected by many transverse branches with the vertebral sinus.

QQ.—Anastomosis of the superior and inferior thyroid arteries.

I.—Olfactory nerve. 1. Olfactory filaments of the nasal septum inclosed in fibrous sheaths.

II.—Optic nerve.

III.—Motor oculi nerve.

IV.—Pathetic nerve.

V.—Trifacial nerve.

First division. 2. Nasal nerve.

Second division. 3. Nasal nerves. 4. Branch to the hard palate, passing through the anterior palatine canal.

5. Pharyngeal nerves.

Third division. 6. Lingual nerve. 7. Lingual branches.

VI.—Abducens nerve.

VII.—Facial nerve.

VIII.—Auditory nerve.

IX.—Glosso-pharyngeal nerve. 8. The petrous ganglion. 9. Junction with the jugular branch of the superior cervical ganglion. 10. Branch joining the superior pharyngeal branch of the vagus. 11. Pharyngeal branches. 12. Lingual branch. 13. Branches going to the circumvallate papillæ. 14. Branches supplying the mucous membrane between the circumvallate papillæ and the epiglottis.

X.—Pneumogastric nerve. 15. Superior vagal ganglion. 16. Junction with the jugular branch of the superior cervical ganglion. 17. Recurrent branch of the vagus. 18. Its lesser division going to the occipital sinus, and the greater branch, 19, going to the sigmoid sinus. 20. Superior pharyngeal branch. 21. Inferior vagal ganglion, or ganglion of the Trunk. 22. Inferior pharyngeal branch passing to the pharynx between the internal and external carotids. 23. Superior laryngeal nerve. 24. External branch. 25. Its junction with the sympathetic nerve. 26. Internal branch of the superior laryngeal nerve. 27. Branches distributed to the mucous membrane of the larynx and epiglottis. 28. Junction with the inferior laryngeal nerve. 29. Vagus nerve in the neck. 30. Inferior laryngeal nerve. 31. Its inosculation with the sympathetic. 32. Œsophageal branches. 33. Tracheal branches. 34. Laryngeal branch.

XI.—Spinal accessory nerve. 35. Its internal, and 36, external divisions.

XII.—Hypoglossal nerve. 37. Its inosculation with the first cervical nerve and superior cervical ganglion. XII*.—Branches of the hypoglossal to the genio-hyo-glossus and genio-hyoid muscles.

XIII.—XIX.—Seven superior cervical nerves. 38. Their anterior, and 39, their posterior roots. 40. Ganglia on the posterior roots of the cervical nerves. 41. Anterior division of the first, second, third, and fourth cervical nerves. 42. Communicating branches of these nerves, constituting the cervical plexus. 43. Principal root of the phrenic nerve, coming from the anterior division of the fourth cervical nerve.

XX.—Superior cervical ganglion. 44. Carotid nerve. 45. Its internal inferior branch. 46. Carotid plexus. 47. Cavernosus plexus, from which are given off branches to the abducens (48), to the ophthalmic division of the fifth (49), and to the cerebral and ophthalmic arteries (50). 51. Jugular nerve, forming a junction with the glosso-pharyngeal and vagus nerves. 52. Nerve uniting the hypoglossal and first cervical nerves. 53. Trunk inosculating with the cervical plexus. 54. Junction of the superior cervical and inferior vagal ganglia. 55. Sympathetic trunk to the external carotid, which is often composed of two or three branches. 56. Superior part of the trunk, from which branches go to the external carotid (57), and to the carotid plexus (58). (59.) Inferior part of the trunk, which gives branches to the facial (60), lingual (61), and thyroid arteries (62). 63. Branch going to the carotid ganglion (64), which sends very delicate branches to the common carotid artery (65). 66. Branches to the external branch of the superior laryngeal, and 67, to the phrenic nerves. 68. Superior cardiac nerve, arising from the cervical sympathetic trunk by several roots. 69. Its communication with the inferior laryngeal nerve. 70. Middle cardiac nerve, uniting with the superior cardiac nerve.

XXI.—Upper portion of the first thoracic ganglion. 71. Sympathetic branches to the vertebral artery. 72. Sympathetic plexus on the vertebral artery. 73. Sympathetic plexus on the inferior thyroid artery.

PLATE IV.

Fig. I.

This diagram shows the trifacial, lateral nasal, and palatine nerves, the spheno-palatine and otic ganglia, and the facial nerve in the facial canal, seen from the inside.

The skull and posterior part of the head, parts of the neck, and most of the petrous portion of the temporal and the sphenoid bones are removed; the facial canal and tympanic cavity are opened to view, the internal carotid artery and carotid canal, the cartilaginous portion of the Eustachian tube, roof of the pharynx and levator palati muscle, the nasal septum, and posterior part of the hard palate are cut away; the pterygo-palatine fossa and canals are shown, and the mucous membrane of the nose is partly removed.

Therefore the internal auditory meatus, the facial canal, the osseous portion of the Eustachian tube and the tympanic membrane, the ear ossicles and their muscles, the course of the facial nerve through the petrous portion of the temporal bone, the inner surface of the trunk of the trifacial nerve and its ganglion, with its first, second, and third divisions, the otic and spheno-palatine ganglia, the nerves of the palate, and the lateral wall of the nose with the distribution of the nerves of the first and fifth pairs to its mucous membrane are shown.

A.—Petrous portion of the temporal bone. *a.* Bottom of the internal auditory meatus, and *b*, interior of the facial canal. *c.* Superior margin, and *d*, inner surface of the petrous portion of the temporal bone.

B.—Sphenoid bone. *e.* Foramina spinosum, *f*, ovale, and *g*, rotundum opened from within. *h.* Pterygoid process, with the internal plate partly removed. *i.* Hamular process. *k.* Inner extremity of the lesser wings. *l.* Optic foramen.

C.—Lower part of the vertical plate of the frontal bone. *m.* Frontal sinus.

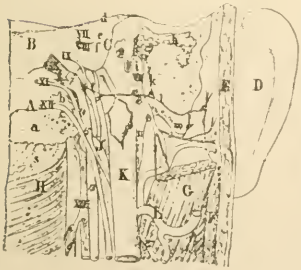
D.—Ethmoid bone. *n.* Posterior ethmoidal cells. *o.* Cribriform plate. *p.* Anterior ethmoidal foramen. *q.* Left nasal fossa.

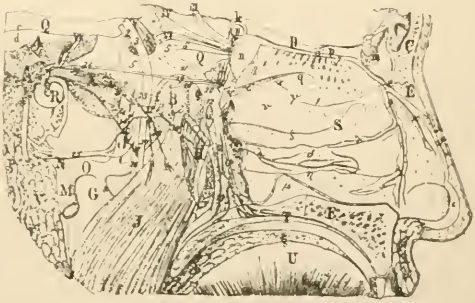
E.—Left nasal bone.

F.—Palate process of the superior maxillary bone.

G.—Ramus of the inferior maxillary bone. *r.* Angle of the inferior maxillary bone.

PLATE IV.





H.—Tensor palati muscle turned forward.

I.—Internal pterygoid muscle.

K.—Tensor tympani, and **L**, stapedius muscles.

M.—Upper end of the external carotid artery.

N.—Temporal artery.

O.—Internal maxillary artery. *s.* Inferior dental artery. *t.* Middle meningeal artery. *u.* Descending palatine artery. *v.* Nasal artery cut.

P.—Posterior auricular artery.

Q.—Dura mater, upper surface of the petrous portion of the temporal bone, and the trifacial, pathetic, motor oculi and abducens nerves. **R.**—Inner surface of the tympanic membrane, and the ear ossicles. *w.* The head, *x*, neck, and *y*, the manubrium of the malleus. *z.* The incus. *α.* Stapes.

S.—Lateral wall of the nasal cavity. *β.* The superior, *γ*, middle, and *δ*, inferior turbinated bones. *ε.* The superior, *ζ*, middle, and *η*, inferior meatuses of the nose. *ϑ.* Lateral cartilage, and *ι*, ala of the nose. *κ.* Mucous membrane covering the superior and upper part of the middle turbinated bones removed to show the course of the olfactory filaments through the grooves of the ethmoidal turbinated bones. λ. Mucous membrane of the anterior inferior regions of the nares is removed, showing the distribution of the nasal branches of the fifth nerve. *μ.* Mucous membrane of the inferior meatus. *ν.* Mucous glands.

T.—Mucous membrane of the hard and soft palate.

U.—The tongue. *ξ.* Lingual papillæ. *ο.* Glands at the root of the tongue.

V.—Parotid gland.

(I.)—Olfactory nerve. 1. Olfactory filaments of the wall of the nose which have fibrous sheaths and run through grooves in the upper and middle turbinated bones, forming a network and sending delicate branches to the mucous membrane.

II.—Optic nerve.

III.—Motor oculi nerve.

IV.—Pathetic nerve.

V.—Trifacial nerve. 2. Common trunk. 3. Its lesser, and 4, its greater roots. 5. Semilunar ganglion. 6. First or ophthalmic division of the fifth nerve. 7. Nasal nerve. 8. Branch to the nasal septum severed (*vid.* Plate III., 2). 9. Branch to the lateral surface of the nares. 10. External

branch (*vid.* Plate VIII., 7). 11. Second or superior maxillary division of the fifth. 12. Naso-palatine nerve. 13. Posterior palatine nerves. 14. The anterior palatine nerve. 15. Superior, and 16, inferior nasal nerves. 17. Spheno-palatine ganglion (Meckel's). 18. Greater deep petrosal nerve. 19. Greater superficial petrosal. 20. Vidian nerve. 21. Ascending branches, and 22, branch from the ganglion to the nose. 23. Third or inferior maxillary division of the fifth. 24. Recurrent branch piercing the otic ganglion and accompanying the middle meningeal artery within the cranium (*vid.* Plate II., 27). 25. Auriculo-temporal nerve, arising by two roots, between which passes the middle meningeal artery. 26. Inferior dental nerve. 27. Lingual nerve. 28. Junction of the chorda tympani and lingual nerves. 29. Internal pterygoid nerve. 30. Branches to the tensor palati, and 31, to the tensor tympani muscles, coming from the pterygoid nerve and piercing the otic ganglion. 32. Otic ganglion. 33. Lesser superficial petrosal, coming from the tympanic nerve. 34. Sympathetic root of the otic ganglion. 35. Branch to the tensor tympani leaving the otic ganglion. 36. Branch proceeding to the auriculo-temporal nerve.

VI.—Abducens nerve.

VII.—Facial nerve. 37. Genu of the facial nerve. 38. Greater superficial petrosal nerve. 39. Junction with the lesser superficial petrosal nerve, which arises from the tympanic nerve. 40. Branch to the stapedius muscle. 41. Chorda tympani.

Fig. II.

Showing, from behind, the course of the facial, glosso-pharyngeal, pneumogastric, spinal accessory, and hypoglossal nerves in the cranial bones, and of the auricular branch of the vagus in the petrous portion of the right temporal bone.

The occiput of the right side of the head is removed by a transverse section, opening the condyloid and posterior lacerated foramina, and the facial canal and auricular fissure from behind.

Therefore the course of the hypoglossal, spinal accessory, vagus and glosso-pharyngeal nerves through the foramina of the skull, the ganglia of the vagus and glosso-pharyngeal nerves, the auricular branch of the vagus and its junction with the facial nerve are seen.

A.—Occipital bone. *a*. Basilar process. *b*. The condyle. *c*. Anterior condyloid foramen.

B.—Body of the sphenoid bone covered by dura mater.

C.—Petrous portion of the temporal bone. *d*. Its superior internal margin. *e*. Inner surface. *f*. Internal auditory meatus. *g*. Cavity of the tympanum, *h*, mastoid cells, and *i*, posterior part of the facial canal from behind. *k*. Canal for the chorda tympani. *l*. Auricular fissure. *m*. Mastoid process. *n*. Styloid process. *o*. Stylo-mastoid foramen. *p*. Upper part of the head of the malleus. *q*. The body, and *r*, the short process of the incus.

D.—Posterior surface of the ear.

E.—Skin and adipose tissue.

F.—Sterno-cleido-mastoid muscle, cut perpendicularly.

G.—Posterior belly of the digastric muscle, also divided.

H.—Posterior surface of the roof of the pharynx. *s*. Acinous mucous glands of the pharynx. *t*. Superior constrictor muscle of the pharynx.

I.—Internal carotid.

K.—Internal jugular vein, cut off above so that the course of the auricular branch of the vagus nerve may be seen.

L.—Occipital, and **M,** posterior auricular arteries.

VII.—Facial nerve. 1. Chorda tympani. 2. Posterior auricular nerve. 3. Small branches going to the posterior belly of the digastric muscle.

VIII.—Auditory nerve.

IX.—Glosso-pharyngeal nerve. 4. The petrous ganglion. 5. Branch joining the auricular branch of the vagus. 6. Pharyngeal branches of the glosso-pharyngeal nerve.

X.—Pneumogastric nerve. 7. Superior vagal ganglion. 8. Recurrent branch of the vagus, divided transversely. 9. Auricular branch of the vagus. 10. Its communication with the facial nerve in the facial canal. 11. Its communication with the posterior auricular nerve. 12. Its auricular branches. 13. Inferior vagal ganglion.

XI.—Spinal accessory nerve. 14. Its internal, and 15, its external divisions.

XII.—Hypoglossal nerve.

XIII.—Carotid nerve and the upper part of the superior cervical ganglion.

PLATE V.

ILLUSTRATION OF CRANIAL AND CERVICAL NERVES, THE NERVES ACCOMPANYING THE CAROTID AND VERTEBRAL ARTERIES, BOTH WITHIN AND OUTSIDE OF THE CRANIUM, AND THE SPINAL CORD SEEN FROM THE OUTSIDE.

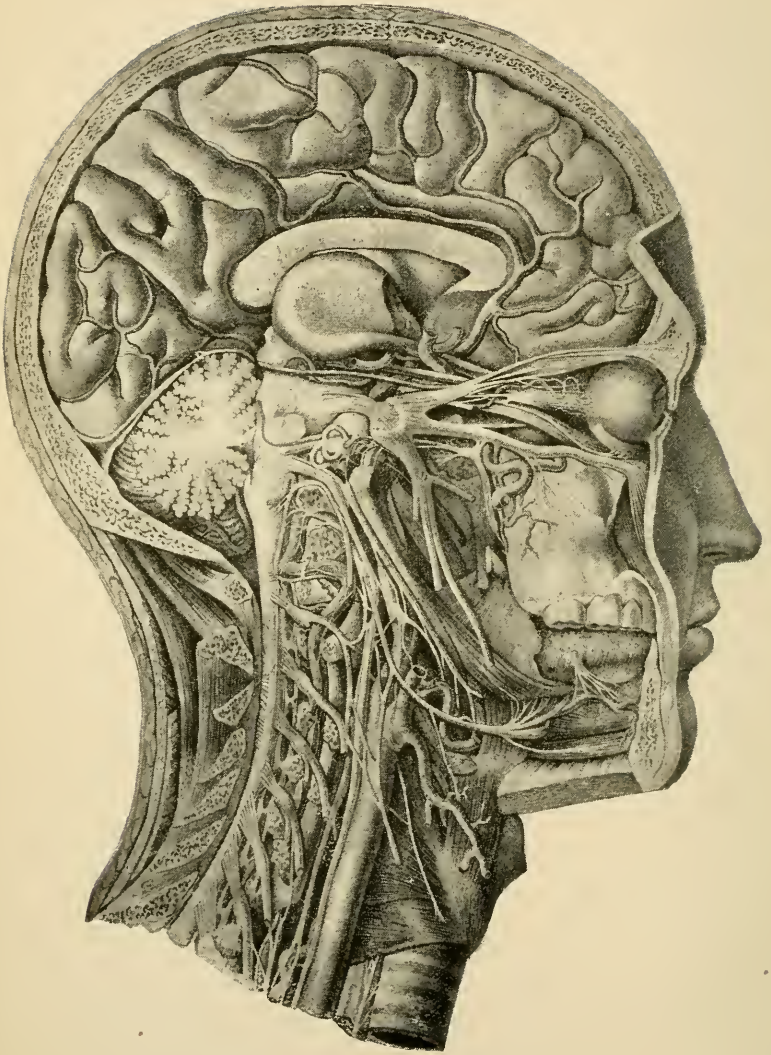
This plate shows, firstly, the origin of the cranial and cervical nerves of the right side, with the exception of the first and sixth pairs; secondly, the course of the cervical nerves between the cervical vertebræ, the spinal ganglia, the breaking up of the nerves into their anterior and posterior divisions, and their inosculations amongst themselves and with the superior cervical ganglion; then the course and part of the distribution of the third, fourth, fifth, ninth, tenth, eleventh, and twelfth pairs of nerves outside of the cranium, and the roots of the ophthalmic and spheno-palatine ganglia and the sympathetic plexuses on the vertebral and internal carotid arteries.

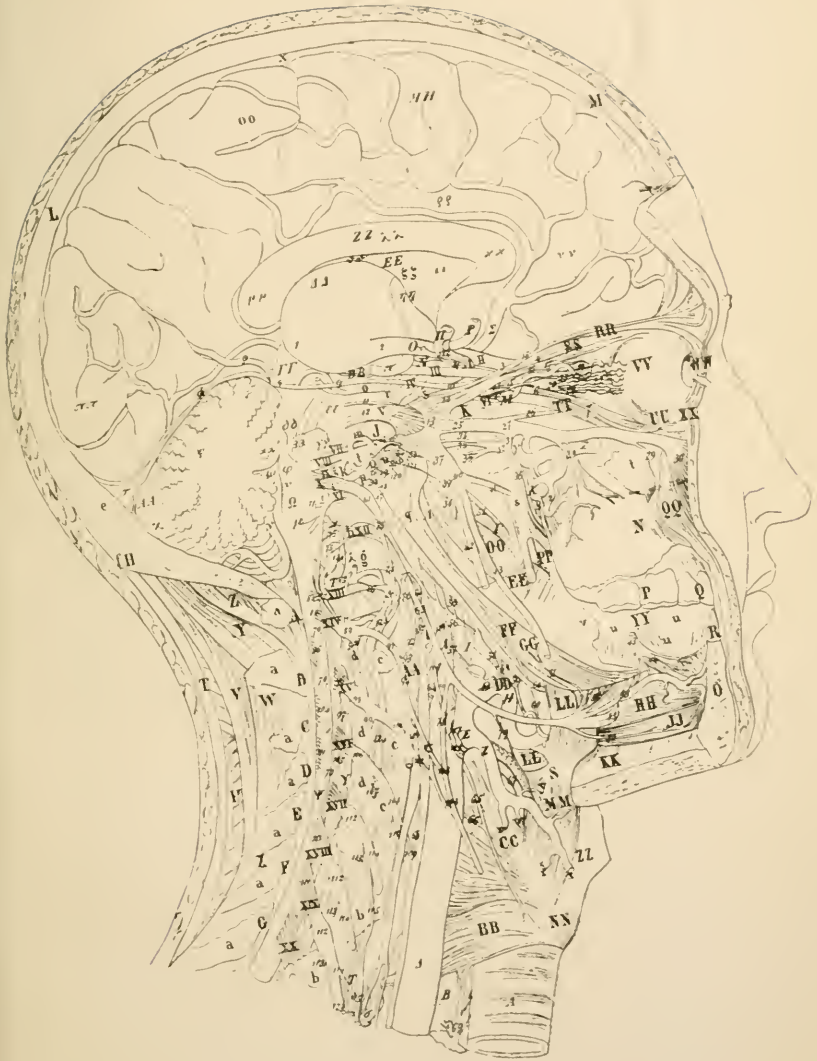
To show these parts the scalp, occipital, frontal, parietal, mastoid and petrous portions of the temporal, the greater and lesser wings of the sphenoid, the malar and posterior portions of the inferior maxillary bones of the right side, the spinous and transverse processes, and the arches of the cervical vertebræ, together with the skin and superficial muscles of the neck, the muscles and vessels of the face and temples, and the thyroid and salivary glands are removed; the intervertebral, condyloid, and posterior lacerated foramina, spinal canal, internal auditory meatus, carotid canal, Eustachian tube, pterygo-palatine fossa, Vidian canal and the antrum of Highmore are opened; the right half of the cerebellum and cerebrum, together with the corpus striatum, is removed; while the spinal cord, medulla oblongata, pons Varolii, crus cerebri, right optic thalamus and corpora quadrigemina remain intact.

A.—G.—Cervical vertebræ from the first to the seventh. *a.* Left portion of the spinous processes. *b.* Right transverse processes. *c.* Anterior, and *d*, posterior roots of the transverse processes.

H.—Occipital bone. *e.* Its tabular portion. *f.* External occipital protuberance. *g.* Right condyle. *h.* Anterior condyloid foramen. *i.* Posterior lacerated foramen.

PLATE V.





I.—Petrous portion of the right temporal bone. *k*. The posterior, *l*, external, and *m*, superior semicircular canals. *n*. Cochlea. *o*. Fenestra ovalis, and *p*, fenestra rotunda. *q*. Base of the styloid process.

K.—Body of the sphenoid bone. *r*. Clivus Blumenbachii. *s*. Internal plate of the pterygoid process.

L.—Parietal bone sawed through near the sagittal suture.

M.—Frontal bone.

N.—Superior maxillary bone. *t*. Antrum of Highmore.

O.—Inferior maxillary bone.

P.—Molar, and **Q**, bicuspid teeth of the upper jaw.

R.—Right inferior canine tooth.

S.—Greater cornu of the hyoid bone.

T.—The trapezius, **U**, splenius, **V**, biventer cervicis, **W**, Semispinalis colli, **X**, interspinales, **Y**, rectus capitis posticus major, and **Z**, minor muscles of the left side.

AA.—Right rectus capitis anticus major muscle.

BB. and **CC.**—Inferior, **DD**, middle, and **EE**, superior constrictor muscles of the pharynx.

FF.—Stylo-pharyngeus muscle.

GG.—The stylo-hyoid, **HH**, genio-hyo-glossus, **JJ**, genio-hyoid, and **KK**, mylo-hyoid muscles. **LL.**—The hyo-glossus muscle, partly cut away to show the course of the lingual artery and lingual branch of the glosso-pharyngeal nerve.

MM.—The thyro-hyoid, and **NN**, crico-thyroid muscles.

OO.—Levator palati muscle. **PP.**—Tendon of the tensor palati muscle.

QQ.—Levator anguli oris muscle.

RR.—The levator palpebræ superioris, **SS**, superior, and **TT**, inferior recti, and **UU**, inferior oblique muscles of the eye.

VV.—The eyeball.

WW.—The upper, and **XX**, lower lids, cut through perpendicularly.

YY.—The tongue. *u*. Fungiform papillæ. *r*. Mucous membrane of the cheek.

ZZ.—The larynx. A.—Trachea.

B.—Œsophagus.

Γ.—Eustachian tube.

Δ.—Common carotid.

E.—External carotid.

Z.—Superior thyroid artery. *w*. Superior laryngeal artery. *x*. Thyroid branches severed. *y*. Muscular branches.

H.—Lingual artery.

Θ.—Origin of the facial artery.

I.—Ascending pharyngeal artery.

K.—Internal maxillary artery. *z*. Posterior dental artery. *α*. Infra-orbital artery. *β*. Descending palatine artery. *γ*. Nasal artery.

Λ.—Internal carotid. *δ*.—Its first, *ε*, second, *ξ*, third, and *η*, fourth flexures.

M.—Ophthalmic artery.

N.—The posterior communicating, O, anterior choroid, Π, middle cerebral, and P, anterior cerebral arteries of the right side. Σ. Anterior cerebral artery of the left side.

T.—Vertebral artery. *ϑ*. Its first, *ι*, second, and *κ*, third flexures. *λ*. Spinal branches. *μ*. The right, and *ν*, left posterior inferior cerebellar arteries. *ξ*. Internal auditory artery. *ο*. Right superior cerebellar artery. *π*. The right, and *ρ*, left posterior cerebral arteries. *σ*. Inferior thyroid artery.

Υ.—Dura mater of the spinal cord.

Φ.—Tentorium cerebelli. *τ*. Superior petrosal sinus.

X —Dura mater of the brain.

Ψ.—Cervical spinal cord.

Ω.—Medulla oblongata. *υ*. Striæ medullares. *φ*. Sinus rhomboidalis.

AA.—Cerebellum. *χ*. Inner surface of the left hemisphere. *Ψ*. Arbor vitæ. *ω*. Fourth ventricle. *αα*. Valve of Vieussens, or superior medullary velum. *ββ*. The inferior, *γγ*, middle, and *δδ*, superior cerebellar peduncles. *εε*. Right side of pons.

BB.—Right crus cerebri.

ΓΓ.—Corpora quadrigemina.

ΔΔ. Right optic thalamus.

EE.—Fornix. *ζζ*. Right crus of the fornix. *ηη*. Foramen of Monro. *ϑϑ*. Body of the fornix. *ιι*. Septum lucidum.

ZZ.—Corpus callosum divided longitudinally through the centre. *κκ*. Its genu, *λλ*, body, and *μμ*, splenium.

HH.—Inner surface of the left cerebral hemisphere. *νν*. The frontal, *οο*, parietal, and *ππ*, occipital lobes. *ρρ*. Gyrus fornicatus.

II.—Optic nerve. 1. Its origin from the optic thalamus. 2. Optic tract. 3. Orbital portion of the optic nerve.

III.—Motor oculi. 4. Superior branch to the superior rectus and levator palpebrae superioris muscles. 5. Inferior branch. 6. Motor root of the ophthalmic ganglion. 7. Branch to the inferior oblique muscle.

IV.—Pathetic nerve. 8. Its origin. 9. Course of the pathetic nerve above the pons and external to the crus cerebri. 10. Its course along the upper border of the ophthalmic division of the trifacial nerve.

V. Trifacial nerve. 11. Its lesser, and 12, greater roots. 13. Semilunar ganglion. 14. First or ophthalmic division of the fifth. 15. Supraorbital nerve. 16. Lachrymal nerve cut away. 17. Nasal nerve. 18. Sensory root of the ophthalmic ganglion. 19. Long ciliary nerves. 20. Ophthalmic ganglion. 21. Its sympathetic root. 22. Short ciliary nerves. 23. The superior, and 24, inferior fasciculi of ciliary nerves. 25. Second division or superior maxillary nerve. 26. Subcutaneous malæ nerve severed. 27. Infraorbital nerve. 28. Posterior dental nerves. 29. Anterior dental nerve severed. 30. The inferior palpebral, lateral nasal, and superior labial nerves. 31. Naso-palatine nerve. 32. Sphenopalatine ganglion. 33. Greater superficial petrosal nerve. 34. Greater deep petrosal nerve. 35. Posterior superior nasal nerve. 36. Palatine nerves. 37. Third division or inferior maxillary nerve. 38. Auriculo-temporal nerve. 39. Masseter nerve. 40. Posterior deep temporal nerve. 41. Buccal nerve. 42. Inferior dental nerve. 43. Lingual nerve, the lingual part of it being reflected to show the distribution of the hypoglossal nerve. 44. Lingual branches.

VI.—Abducens nerve severed.

VII.—Facial nerve. 45. Genu of the facial nerve. 46. Its junction with the greater superficial petrosal nerve.

VIII.—Auditory nerve.

IX.—Glosso-pharyngeal nerve. 47. Petrous ganglion. 48. Tympanic nerve. 49. Branch joining the carotid nerve. 50. Branches to the fenestra rotunda, and 51, to the fenestra ovalis. 52. Branch going to the Eustachian tube. 53. Lesser superficial, and 54, lesser deep petrosal nerves. 55. Branches uniting with the branches of the superior cervical ganglion, and with branches from the inferior vagal ganglion. 56. Carotid plexus. 57. Branches running between the

internal and external carotids to the carotid ganglion. 58. Pharyngeal branches. 59. Branches to the stylo-pharyngeus muscle. 60. Lingual branches.

X.—Pneumogastric nerve. 61. Superior vagal ganglion. 62. Branch to the carotid plexus. 63. Inferior vagal ganglion. 64. Superior laryngeal nerve. 65. External branch to the crico-thyroid muscle. 66. Junction of this branch with a filament from the superior cervical ganglion. 67. Internal branch of the superior laryngeal nerve. 68. Trunk of the vagus in the neck. 69. Inferior or recurrent laryngeal nerve, sending branches to the œsophagus, trachea, and larynx.

XI.—Spinal accessory nerve. 70. Its spinal, and 71, cranial roots. 72. Course of the spinal root between the roots of the posterior division of the first cervical nerve. 73. Its internal division, uniting with the trunk of the vagus. 74. Its external division.

XII.—Hypoglossal nerve. 75. Its roots passing over the vertebral artery. 76. A branch joining the first cervical, and 77, the vagus nerves. 78. Descendens noni branch. 79. Thyro-hyoid branch. 80. Branch to the genio-hyoid, and 81, the stylo-glossus muscles. 82. Branches to the hyo-glossus, and 83, the genio-hyo-glossus and the muscles of the tongue proper.

XIII.—First cervical nerve. 84. Its posterior root, which is crossed by the spinal accessory nerve. 85. The posterior division cut away. 86. Anterior division. 87. Muscular branch.

XIV.—Second cervical nerve. 88. Posterior root. 89. Spinal ganglion. 90. Posterior division severed. 91. Anterior division. 92. Branch joining the first cervical nerve and superior cervical ganglion. 93. Branch to the rectus capitis anticus major muscle. 94. Descending communicating branch. 95. Communicans noni branch.

XV.—Third cervical nerve. 96. The posterior root divided and reflected to show the course of the spinal root of the spinal accessory nerve. 97. Branch joining the posterior root of the fourth cervical nerve. 98. Spinal ganglion. 99. Posterior division severed. 100. Anterior division. 101. Junction with the superior cervical ganglion. 102. Communicans noni branch. 103. Ansa hypoglossi.

XVI.—Fourth cervical nerve. 104. Posterior root divided. 105. Its junction with the posterior root of the fifth cervical nerve. 106. Spinal ganglion. 107. Posterior division severed. 108. Anterior division. 109. Branch to the longus colli muscle. 110. Trunk of the anterior division severed.

XVII.—Fifth cervical nerve.
XVIII.—Sixth cervical nerve.
XIX.—Seventh cervical nerve.

111. Posterior root. 112. Spinal ganglion. 113. Posterior division severed. 114. Anterior division severed. 115. Roots of the phrenic nerve.

XX.—Posterior root of the eighth cervical nerve.

XXI.—Superior cervical ganglion. 116. Sympathetic branches to the carotid ganglion. 117. Carotid ganglion. 118. Filaments to the common and external carotid arteries. 119. Branch to the carotid plexus. 120. Superior external branch of the carotid nerve, from which the greater deep petrosal nerve is given off. 121. Inferior internal branch of the carotid nerve. 122. Sympathetic nerves on the internal carotid within the cranium.

XXII.—Cervical sympathetic trunk. 123. Vertebral branch from the inferior cervical and superior thoracic ganglia. 124. Sympathetic plexus on the vertebral artery.

PLATE VI.

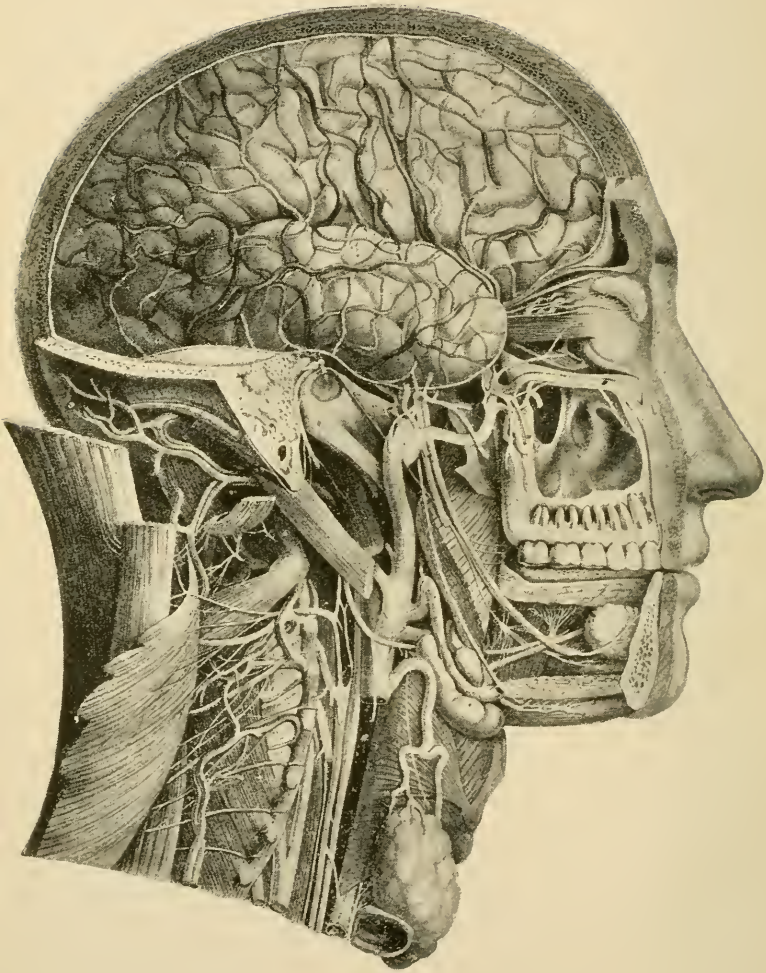
COURSE OF SOME OF THE NERVES OF THE FIFTH PAIR THROUGH THE ORBIT, SUPERIOR MAXILLARY BONE AND TEMPORAL FOSSA; OF THE FACIAL AND CHORDA TYMPANI THROUGH THE PETROUS PORTION OF THE TEMPORAL BONE; OF THE POSTERIOR DIVISIONS OF THE CERVICAL NERVES IN THE MUSCLES OF THE NECK, AND THE SYMPATHETIC NERVES ACCOMPANYING THE EXTERNAL CAROTID ARTERY AND ITS BRANCHES.

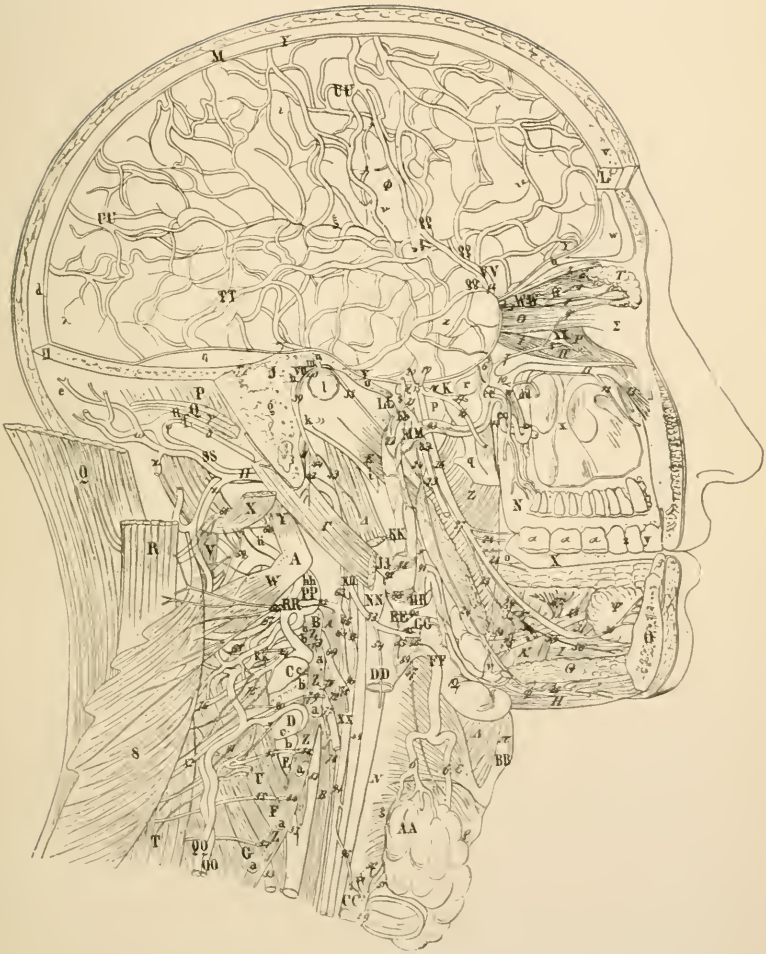
This plate, which shows the nerves of the right side of the head, illustrates first the course of the lachrymal from the first, subcutaneous malæ and infraorbital from the second, and the lingual and mylohyoid from the third division of the fifth; then the facial nerve through the facial canal, and chorda tympani through the tympanic cavity, and the distribution of the posterior divisions of the cervical nerves to the muscles of the neck, and finally the sympathetic plexus around the external carotid, and the roots of the submaxillary ganglion.

The skull is divided by a perpendicular section near the sagittal suture, and the right side of it, with the dura mater, is removed; the greater wing of the sphenoid, malar, and periorbital bones, most of the right half of the superior and inferior maxillæ, the squamous portion and external part of the mastoid process of the temporal bone, the platysma, sterno-cleido-mastoid, sterno-hyoid, sterno-thyroid, omohyoid, and external pterygoid muscles are cut away; and the second and third layers of cervical muscles are turned aside. Therefore, the following structures are partly or wholly exposed to view: the external surface of the brain, the parts of the eye adjacent to its outer wall, the frontal and maxillary sinuses, the parts of the oral cavity and temporal fossa adjoining the inner surface of the inferior maxillary bone, the tympanic membrane and mastoid cells, submaxillary and thyroid glands, larynx, trachea, pharynx, and œsophagus, and the muscles of the neck with the vessels and nerves.

A.—G.—Cervical vertebræ from the first to the seventh. *a*. Transverse processes. *b*. Superior, and *c*, inferior articular processes.

PLATE VI.





H.—Occipital bone. *d.* Left upper part of the tabular portion of the occipital bone. *e.* Lower part of the tabular portion of occipital bone.

I.—Temporal bone. *f.* Mastoid foramen. *g.* Mastoid cells. *h.* Facial canal. *i.* Styloid process. *k.* Stylo-mastoid foramen. *l.* Membrana tympani. *m.* Incus. *n.* Malleus. *o.* Eustachian tube.

K.—Sphenoid bone. *p.* Body. *q.* External pterygoid plate. *r.* Sphenoidal cells. *s.* Foramen spinosum. *t.* Foramen ovale. The foramen rotundum is covered by dura mater.

L.—Frontal bone. *u.* Its orbital, and *v*, vertical plates. *w.* Frontal sinus.

M.—Right parietal bone, sawed through near the sagittal suture.

N.—Superior maxillary bone. *x.* Inner wall of the antrum of Highmore. *y.* Canine tooth. *z.* Bicuspid teeth. *α.* Molar teeth.

O.—Inferior maxillary bone, sawed through perpendicularly near the right canine tooth (*β*).

P.—Insertion of the sterno-cleido-mastoid muscle.

Q.—Splenius capitis muscle cut transversely near its insertion (*γ*). **R.** Trachelo-mastoid muscle similarly cut (*δ*). **S.** Complexus and biventer cervicis muscles, detached and turned aside from their origins. **T.** Semispinalis colli. **U.** Upper part of the multifidus spinæ. **V.** Rectus capitis posticus major. **W.** Inferior, and **X**, superior oblique muscles. **Y.** Rectus capitis lateralis. **Z.** Intertransversales muscles.

Α.—Rectus capitis anticus major. Β. Scalenus anticus.

Γ. Posterior belly of the digastric. Δ. Stylo-hyoid. Ε. Stylo-glossus. Ζ. Internal pterygoid.

Η. Anterior belly of the digastric. Θ. Mylo-hyoid. Ι. Genio-hyoid. Κ. Hyo-glossus.

Λ. Thyro-hyoid. Μ. Crico-thyroid.

Ν Inferior constrictor of the pharynx. ε. Its cricoid, and ζ, thyroid origins.

Ξ. Levator palpebræ superioris and superior rectus muscles. Ο External rectus muscle. Π. Inferior rectus muscle. Ρ. Inferior oblique muscle.

Σ. Eyeball. Τ. Lachrymal gland.

Υ. Dura mater. φ. Lateral sinus.

Φ. Cerebrum. Θ. The frontal, ι, parietal, κ, temporo sphenoidal, and λ, occipital lobes. μ. External part of the fissure of Sylvius. ν. Its vertical, and ξ, horizontal limbs.

x. The tongue. *o*. Mucous membrane of the cheek.
ψ. Sublingual gland. Ω. Submaxillary gland. *Wharton's duct.
AA. Thyroid gland.
BB. Larynx. *π*. Thyroid cartilage. *ρ*. Cricoid cartilage.
CC. Œsophagus.
DD. Upper part of the common carotid.
EE. External carotid.
FF. Superior thyroid artery. *σ*. Its thyroid branches.
GG. Lingual artery.
HH. Facial artery. *τ*. Ascending palatine artery. *υ*. A muscular branch. *φ*. Submental artery.
II. Occipital artery. *χ*. Descending cervical branches. Ψ. Meningeal branch. *ω*. Distribution of the artery to the occiput.
KK. Posterior auricular artery.
LL. Temporal artery.
MM. Internal maxillary artery. *aa*. Inferior dental artery. *bb*. Middle meningeal artery. *cc*. Posterior dental artery. *dd*. Infraorbital artery. *ee*. Descending palatine and nasal arteries.
NN. Internal carotid. *ff*. Lachrymal branch of the ophthalmic artery. *gg*. Network of the middle cerebral arteries.
OO. Profunda cervicis artery.
PP. Vertebral artery. *hh*. Its first, and *ii*. second flexures.
QQ. Profunda cervicis vein. **RR.** Vertebral vein. *kk*. Deep venous plexus of the neck.
SS. Occipital vein. *ll*. Mastoid emissary vein.
TT. Lateral veins of the brain, emptying into the lateral sinus.
UU. Superior veins of the brain, emptying into the superior longitudinal sinus.
VV. Veins of the fissure of Sylvius.
WW. Ophthalmic vein. **XX.** Inferior ophthalmic vein.
III.—Motor oculi nerve. 1. Branch to the inferior oblique muscle.
(V.)—Trifacial nerve.
First division. 2. Supraorbital nerve. 3. Lachrymal nerve. 4. Its superior, and 5, inferior branches. 6. Second division of the fifth. 7. Subcutaneous malæ nerve. 8. Malar branch severed. 9. Orbital branch going to the lachrymal gland and often joining the inferior branch of the lachrymal nerve. 10. Infraorbital nerve. 11. Posterior dental nerve. 12. Anterior dental nerve. 13. Trunk of the infraorbital nerve

passing through the infraorbital canal. 14. Pharyngeal nerve. 15. Third division of the fifth. 16. Buccal nerve. 17. External pterygoid nerve. 18. Anterior deep temporal nerve. 19. Posterior deep temporal nerve. 20. Masseter nerve. 21. Roots of the auriculo-temporal nerve, surrounding the middle meningeal artery. 22. Trunk of this nerve divided. 23. Inferior dental nerve, divided near the inferior dental foramen. 24. Mylo-hyoid nerve. 25. Its branches to the mylo-hyoid and the anterior belly of the digastric muscles. 26. Lingual nerve. 27. Junction of the lingual and chorda tympani nerves. 28. Branches to the mouth. 29. Branches to the inferior maxillary ganglion. 30. Sublingual branch. 31. Lingual branches. 32. Submaxillary ganglion. 33. Its motor root coming from the chorda tympani. 34. Its sympathetic root. 35. Branches to the submaxillary gland, and 36, to Wharton's duct. 37. Branches joining the lingual nerve.

VII.—Facial nerve. 38. Chorda tympani. 39. Its origin, and 40, course between the malleus and incus. 41. Posterior auricular nerve. 42. Branches to the digastric, and 43, stylo-hyoid muscles. 44. Trunk of the facial nerve divided.

(X) —Pneumogastric nerve. 45. Superior laryngeal nerve. 46. Internal branch. 47. External branch, going to the crico-thyroid muscle. 48. Trunk of the vagus nerve in the neck. 49. Inferior or recurrent laryngeal nerve. 50. Œsophageal branches. 51. Tracheal branches. 52. Laryngeal branch.

XII.—Hypoglossal nerve. 53. Curve of the hypoglossal. 54. Descendens noni branch, and 55, branch to the thyro-hyoid muscle divided. 56. Branch to the genio-hyoid muscle. 57. Branches to the hyo-glossus muscle. 58. Branches to the genio-hyo-glossus muscle and to the muscles of the tongue proper.

(XIII.)—First cervical nerve. 59. The internal branch of the posterior division, sending filaments to the rectus capitis posticus major and minor, obliquus capitis inferior, and complexus muscles. 60. The external branch of the posterior division, sending a branch to the obliquus capitis superior and rectus capitis lateralis muscles, and a branch over, (61), the obliquus capitis superior to the splenius capitis and trachelo-mastoid muscles.

(XIV.)—Second cervical nerve. 62. Anterior division. 63. Its ascending, and 64, descending inosculating branches. 65. Branch to the rectus capitis anticus major muscle. 66. External branch of the posterior division, going to the trachelomastoid and complexus muscles. 67. The internal branch of the posterior division, which sends branches, (68), to the complexus and biventer cervicis muscles, and passes beneath and within the complexus muscle, pierces the biventer, and becomes the occipitalis major nerve.

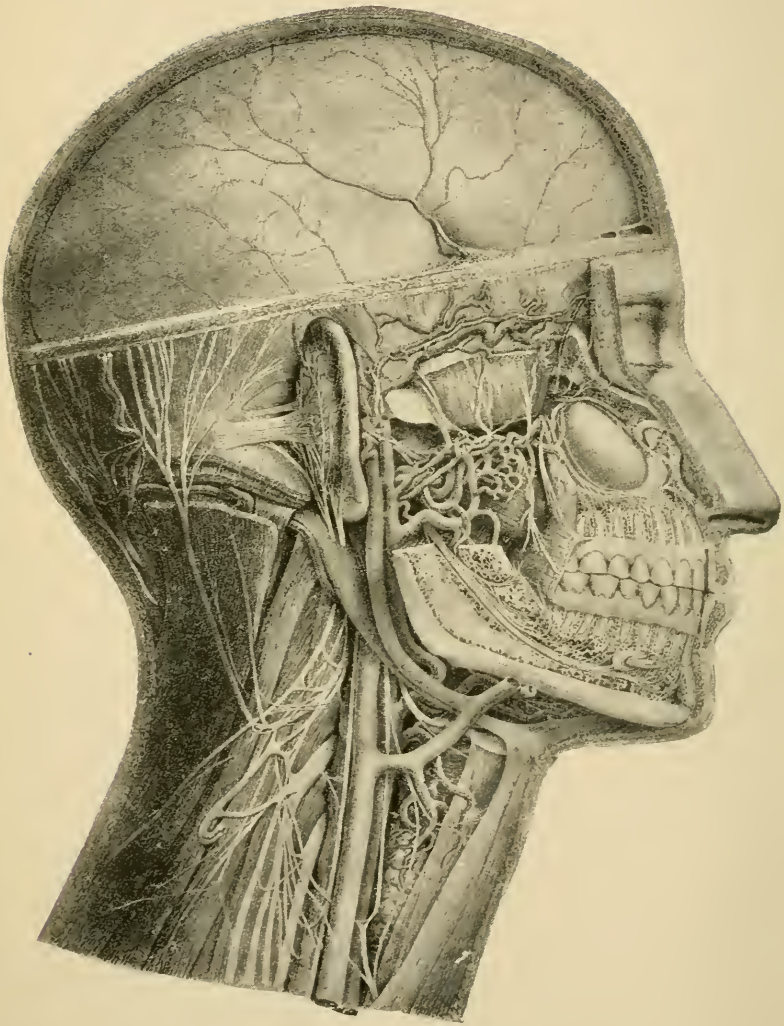
(XV.)—Third cervical nerve. 69. Anterior division, from which the greater part of the occipitalis minor, (70), auricularis magnus, (71), and superficialis colli, (72), come. 73. The external branch of the posterior division, going to the scaleni muscles, divided. 74. The internal branch of the posterior division, which supplies branches to the complexus, biventer cervicis, semispinalis colli and multifidus spinæ muscles, and goes beneath and within the complexus muscle, pierces the biventer, and sends a cutaneous branch to the neck.

(XVI.)—Fourth cervical nerve. 77. Anterior division. 78. Principal root of the phrenic nerve. 79. The external branch of the posterior division divided. 80. Internal branch of the posterior division. 81. Muscular branches. 82. Descending superficial cervical nerve.

(XVII.—XIX.)—The fifth, sixth, and seventh cervical nerves. 83. The anterior divisions. 84. The external branches of the posterior divisions divided. 85. The internal branches of the posterior divisions.

XX.—Superior cervical ganglion. 86. Inosculating branches with the first cervical, and 87, second cervical and hypoglossal nerves. 88. Sympathetic nerves accompanying the external carotid, 89, superior thyroid, 90, lingual, 91, facial, 92, occipital, and 93, internal maxillary arteries. 94. Trunk of the cervical sympathetic. 95. Middle cardiac nerve divided.

PLATE VII.



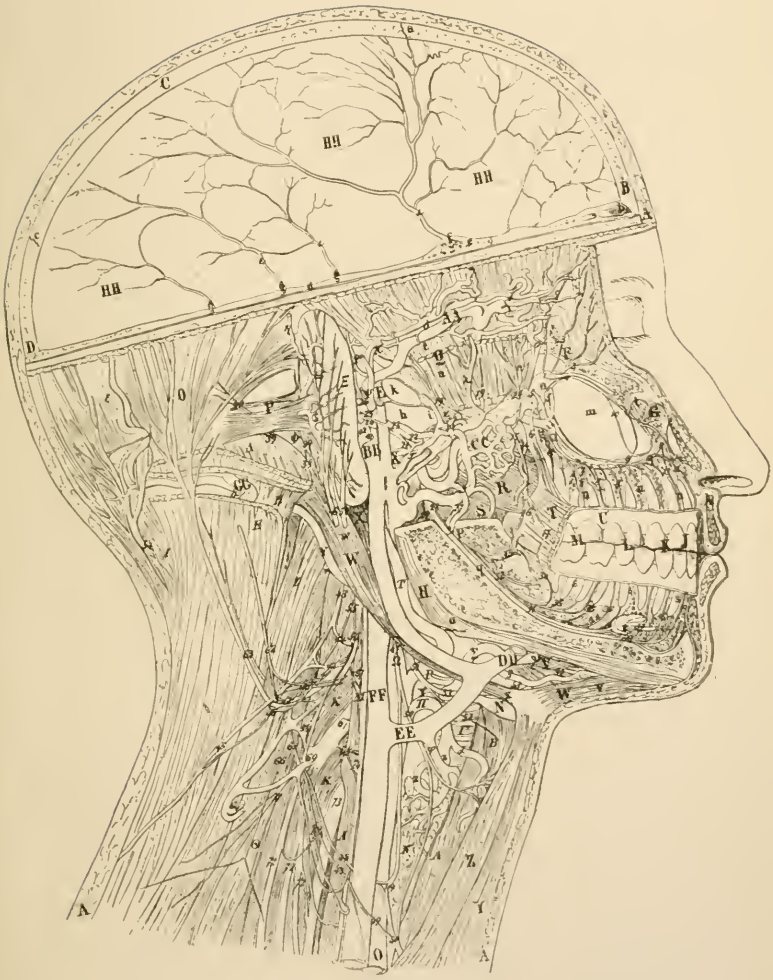

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PLATE VII.

THE NERVES OF THE TEMPORAL FOSSA, SUBCUTANEOUS MALÆ, DENTAL, DESCENDENS NONI, EXTERNAL BRANCH OF THE SPINAL ACCESSORY, AND THE CERVICAL PLEXUS.

This plate shows the right side of the head with the course of the subcutaneous malæ through the malar foramina, the distribution of the dental nerves to the superior and inferior maxillæ, the relation between the nerves of the temporal fossa and the internal maxillary vessels, the course and inosculations of the descendens noni and external branch of the spinal accessory, and the position and distribution of the superficial cervical plexus.

The right side of the skull, zygomatic arch with the temporal fascia, the ramus of the inferior maxilla, and the masseter, platysma, sterno-cleido-mastoid and trapezius muscles are removed; the muscles together with the vessels and nerves of the face are in part cut away, and the malar and dental canals are opened to view.

Hence, the dura mater and middle meningeal artery, the mucous membrane of the antrum of Highmore, the fangs of the teeth, and the muscles, vessels, and nerves of the temporal fossa and of the neck situated under the parts removed are seen.

A.—Skin, divided in the median line from the nose and glabella to the neck.

B.—Frontal bone. *a.* Coronal suture. *b.* Right frontal sinus.

C.—Parietal bone. *c.* Lambdoid suture. *d.* The lower part of the right parietal bone. *e.* Its anterior inferior angle. *f.* Meningeal canal in the anterior inferior angle divided transversely. *g.* Meningeal grooves.

D.—Tabular portion of the occipital bone.

E.—Temporal bone. *h.* Glenoid fossa. *i.* Eminentia articularis. *k.* Root of the zygomatic process divided.

F.—The malar bone, partly removed, to show the malar foramina.

G.—Superior maxillary bone. *l.* Infraorbital foramen. *m.* Mucous membrane of the antrum of Highmore. *n.* Alveoli and fangs of the teeth.

H.—Inferior maxillary bone. *o.* Angle of the inferior maxillary.

p. Dental foramen. *q*. Inferior dental canal. *r*. Mental foramen. *s*. Alveoli and fangs of the teeth.

I.—The incisor, **K,** canine, **L,** bicuspid, and **M,** molar teeth.

N.—Hyoid bone.

O.—Occipital portion of the occipito-frontalis muscle. **P.** Retrahens aurem muscle.

Q.—Temporal muscle. *t*. Its superficial, and *u*, deep portions.

R.—The external, and **S,** internal pterygoid muscles.

T.—Posterior part of the buccinator muscle. **U.** Mucous membrane of the gums.

V.—Mylo-hyoid muscle.

Δ.—Insertion of the sterno-cleido-mastoid muscle.

Ε.—Splenius capitis muscle, of which a small part is removed, to show the course of the occipital artery. Ζ. Splenius colli muscle. Η. Upper part of the trachelo-mastoid muscle, seen beneath the splenius capitis. Θ. Levator anguli scapulæ muscle. Ι. Upper part of the biventer cervicis muscle. Κ. Scalenus medius, and Λ, scalenus anticus muscles. Μ. External margin of the rectus capitis anticus major muscle.

Ν.—The thyroid gland.

Ξ.—The pinna, turned forward to show the distribution of the auricular nerves.

Ο.—Common carotid.

Π.—Superior thyroid artery. *γ*. Superior laryngeal artery. Ζ. Thyroid branches. *α*. Muscular branch.

Ρ.—Lingual artery, arising by a common trunk with the facial.

Σ.—Facial artery. *β*. Submental artery. *γ*. Trunk of the facial, divided transversely.

Τ.—External carotid, passing between the inferior maxillary bone and temporal vein.

Υ.—Occipital artery. Δ. Arteria princeps cervicis. ε Terminal branch.

Φ.—Posterior auricular artery. *ζ*. Auricular branches. *η*. Occipital branch, divided transversely.

Χ.—Internal maxillary artery. Θ. Inferior dental artery. *ι*. Meningeal branches of the middle meningeal artery. Its anterior larger branch passes through a canal in the anterior inferior angle of the parietal bone. *κ*. Masseteric artery divided. *λ*. Posterior deep temporal artery. *μ*. Buccal artery.

ν. Anterior deep temporal artery. ξ. Posterior dental artery. o. Infraorbital artery.

Ψ.—Temporal artery. The divided branches of the transverse facial artery are seen amongst the internal maxillary veins (τ). π. Middle temporal artery, which divides into two branches, ascending (ρ) and transverse (σ).

Ω.—Internal carotid.

AA.—Deep temporal plexus of veins.

BB.—Temporal vein composed of two trunks which intercommunicate. The superficial trunk joins the facial vein and the deep trunk empties into the internal jugular vein.

CC.—Pterygoid plexus. τ. Internal maxillary vein. υ. Deep facial vein divided.

DD.—Facial vein, divided near the inferior maxillary bone.

EE.—Common trunk of the facial veins. ϕ. Superior thyroid vein.

FF.—Internal jugular vein. **GG.**—Occipital vein.

HH.—External surface of the dura mater.

(V.)—Trifacial nerve.

Second division. 1. Subcutaneous malæ nerve. 2. Its temporal, and 3, zygomatic branches. 4. Infraorbital nerve. 5. Posterior dental nerves. 6. Buccal branch. 7. Dental branches. 8. Branches to the gums. 9. Inosculation of the anterior and posterior dental nerves. 10. Middle dental nerve. 11. Anterior dental nerve. 12. Dental branches, and 13, branches to the gums. 14. Branch to the nose.

Third division. 15. Buccal nerve. 16. Its posterior buccal branches, and 17, anterior buccal branch divided. 18. Anterior deep temporal nerve. 19. Posterior deep temporal nerve. 20. Masseteric nerve divided. 21. Internal, and 22, external roots of the auriculo-temporal nerve. 23. Its trunk. 24. Branch of the auricular joining the facial. 25. Anterior auricular nerve divided. 26. Superficial temporal nerve. 27. Lingual nerve. 28. Inferior dental nerve. 29. Mylo-hyoid nerve. 30. Its muscular branches. 31. Dental branch. 32. Posterior inferior, and 33, anterior inferior dental nerve. 34. Branches to the mouth, 35, to the teeth, and 36, to the gums. 37. Mental branch divided.

(VII.)—Facial nerve. 38. Posterior auricular nerve. 39. Branches to the retrahens aurem muscle. 40. Branch to the occipital portion of the occipito-frontalis muscle. 41. Cervico-facial

division of the facial nerve. 42. Temporo-facial division of the facial nerve, inosculating with the auriculo-temporal nerve.

(XI.)—Spinal accessory nerve. 43. External division. 44. Branches to the sterno-cleido-mastoid muscle. 45. Branches to the trapezius muscle. 46. Branch inosculating with the third cervical nerve.

(XII.)—Hypoglossal nerve. 47. Descendens noni branch. 48. Descendens noni branches, uniting with branches of the third and fourth cervical nerves. 49. Ansa hypoglossi, sometimes on the jugular vein and sometimes between it and the common carotid artery. 50. Branches to the sterno-hyoid, omo-hyoid, and sterno-thyroid muscles. 51. Curve of the hypoglossal nerve. 52. Branch to the thyro-hyoid muscle. 53. Lingual branch.

(XIII.)—Second cervical nerve. 54. Occipitalis major nerve, piercing the biventer cervicis muscle and ascending to the occiput. 55. Descending inosculating branch of the anterior division of the second cervical nerve.

(XV.)—Third cervical nerve. 56. Anterior division. 57. Branch to rectus capitis anticus major muscle. 58. Branches of communication with the fourth cervical, 59, the spinal accessory, and 60, the descendens noni nerves. 61. The occipitalis minor nerve, divided into two branches, of which the anterior lesser one, (62), is cut out; the posterior greater one, (63), sends its filaments to the anterior region of the occiput. 64. Auricularis magnus and superficialis colli nerves divided. 65. Distribution of the auricularis magnus to the posterior surface of the pinna. 66. Branch to the splenius capitis et colli muscle.

(XVI.)—Fourth cervical nerve. 67. Anterior division. 68. Branch to the rectus capitis anticus major muscle. 69. Ascending, and 70, descending inosculating branches. 71. Branches to the levator anguli scapulæ and splenius colli muscles. 72. Supraclavicular branches.

(XVII.)—Fifth cervical nerve. 73. Its anterior division.

(XVIII.)—Trunk of the sympathetic in the neck, (74).

PLATE VIII.

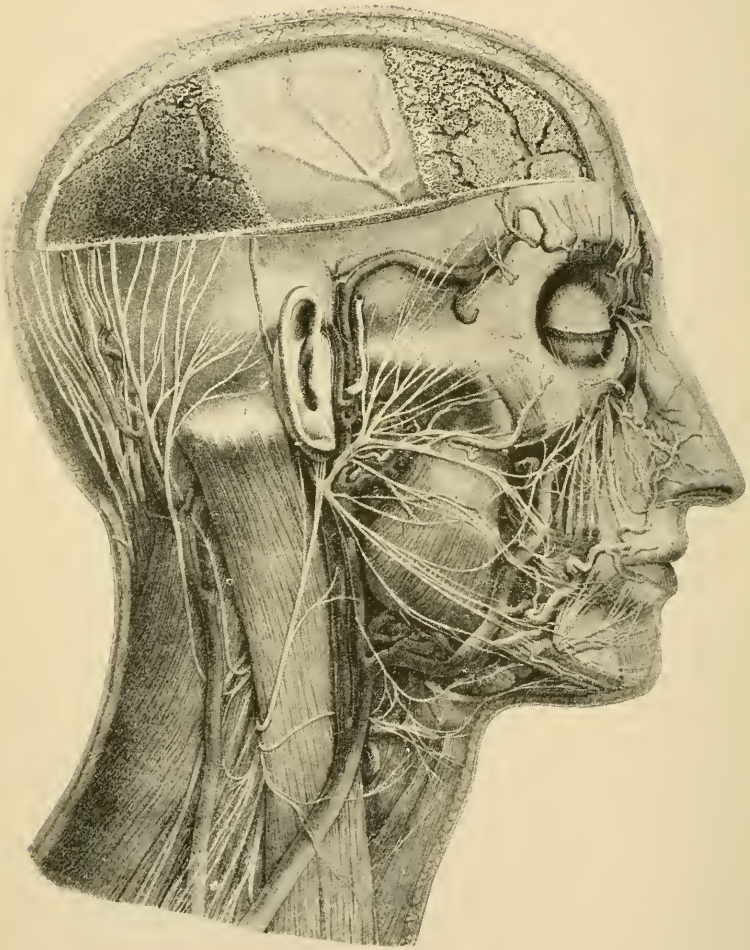


PLATE VIII.

DISTRIBUTION OF THE NERVES OF THE FACE AND NECK UNDER THE SUBCUTANEOUS MUSCLES OF THE FACE, THE PLATYSMA, AND THE TRAPEZIUS.

The right side of the head, with the exit and distribution of the first, second, and third divisions of the fifth nerve in the face, the course and ramifications of the facial nerve under the subcutaneous muscles of the face, and the course and distribution of the superficial cervical nerves under the platysma and trapezius muscles are seen.

The skin and adipose tissue of the right side, occipito-frontalis aponeurosis, the pericranium and external table of the skull are removed by layers, the diploë being removed to the vitreous table on the anterior portion of the parietal bone; the parotid gland is taken out piece-meal, the muscles of the face are partly, and the platysma and trapezius wholly removed.

Therefore we see, firstly, the layers of the scalp and skull; secondly, the muscles, vessels, and nerves found under the parotid gland and subcutaneous muscles of the face and neck, then the exit of the nerves from the cranium into the face, and finally the distribution of the nerves under the subcutaneous muscles.

A.—Section of the skin and adipose tissue in the median line.

B.—Aponeurosis of the occipito-frontalis muscle, likewise divided.

C.—Pericranium.

D.—The skull. *a.* The outer table. *b.* Diploë of the frontal bone. *c.* Frontal diploic veins. *d.* Diploë of the posterior part of the parietal and superior part of the occipital bones. *e.* Parietal diploic veins. *f.* Coronal suture. *g.* Vitreous table of the anterior portion of the parietal bone, the inner surface of which is traversed by arterial grooves.

E.—Temporal fascia, covering the temporal muscle. *h.* The inner, and *i*, outer layers of the temporal fascia. The outer layer is removed at the position of the middle temporal vein, so that its course may be seen. *k.* Semilunar opening in the superficial layer, through which the middle temporal vein passes. *l.* Opening in the deep layer for the passage of the

deep temporal vein. *m*. Malar foramina in the temporal fascia.

F.—Eyelids.

G.—Malar bone. *n*. External malar foramina. *o*. Zygomatic arch.

H.—Superior maxillary bone. *p*. Infraorbital foramen.

I.—Nasal bone.

K.—Nasal cartilages: *q*, superior lateral, *r*, lower lateral, and *s*, sesamoid.

L.—Inferior maxillary bone. *t*. Mental foramen. *u*. Ramus of the inferior maxillary bone.

M.—Hyoid bone

N.—The pinna.

O.—Origin of the zygomaticus major muscle. **P.**—Levator anguli oris muscle. **Q.**—Buccinator muscle. **R.**—Depressor anguli oris, and **S,** depressor labii inferioris muscles divided near their origins. **T.**—Levator labii inferioris muscle.

U.—Temporal muscle, divided transversely. **V.**—Masseter muscle. *v*. Its deep, and *w*, superficial portions.

W.—Sterno-cleido-mastoid muscle.

X.—Trapezius muscle, divided near its origin. **Y.**—Splenius capitis et colli muscle. **Z.**—Levator anguli scapulæ muscle. Α.—Biventer cervicis muscle.

Β.—Sterno-hyoid muscle. Γ.—Superior belly of the omo-hyoid muscle. Δ.—Superior extremity of the sterno-thyroid muscle. Ε.—Thyro-hyoid muscle.

Ζ.—Insertion of the stylo-hyoid muscle. Η.—Digastric muscle. *x*. Its anterior belly. *y*. Central tendon. *z*. Suprahyoid aponeurosis.

Θ.—Superior thyroid artery.

Ι.—Facial artery. *α*. Muscular branch. *β*. Mental branches. *γ*. Buccal branches. *δ*. Anastomosis of a buccal branch with the transverse facial artery. *ε*. Inferior, and *ζ*, superior coronary arteries. *η*. Anastomosis with the infraorbital artery. *θ*. Artery of the nasal septum. *ι*. Lateralis nasi artery. *κ*. Branch anastomosing with the ophthalmic artery.

Κ.—Ophthalmic artery. *λ*. Frontal artery. *μ*. Nasal artery. *ν*. Supraorbital artery.

Λ.—Temporal artery, partly covered by the trunk of the temporal vein. *ξ*. Transverse facial artery.

M.—Internal maxillary artery. *o*. Buccal artery. *π*. Mental artery. *ρ*. Infraorbital artery. *σ*. Superficial perforating branch of the anterior deep temporal artery.

N.—Posterior auricular artery.

Ξ.—Occipital artery.

O.—Facial vein. A great portion of the trunk of this vein is removed, so that the exit of the infraorbital nerve may be seen. *τ*. Frontal vein. *υ*. Supraorbital vein. *φ*. Dorsalis nasi vein. *χ*. Anterior extremity of the ophthalmic vein. *Ψ*. Lateralis nasi vein. *ω*. Deep facial vein. *aa*. Infralabial vein. *bb*. Submental vein.

Π.—Temporal vein, which is sometimes double. *cc*. Superficial temporal vein. *dd*. Middle temporal vein, which anastomoses with the supraorbital, (*ee*), subcutaneous temporal, (*ff*), and deep temporal, (*gg*), veins. *hh*. Auricular veins. *ii*. Muscular veins. *kk*. Internal maxillary vein.

P.—Trunk of the external jugular vein.

Σ.—Superficial cervical vein. *ll*. Occipital vein. *mm*. Anastomosing branch with the deep cervical plexus. *nn*. Cervical branches.

T.—Submaxillary gland.

(V.)—Trifacial nerve.

First division. 1. Frontal branches of the supraorbital nerve, at times passing over and at times under the supraorbital vein. Many branches issue between the frontal notch and the superior palpebral aponeurosis, only one issues through the frontal foramen from the orbit. 2. Superior palpebral branch of the frontal nerve coming through a foramen of the aponeurosis, and 3, the supratrochlear nerve coming through another. 4. Frontal, and 5, superior palpebral branches of the supratrochlear nerve. 6. Infratrochlear nerve. 7. External branch of the nasal nerve.

Second division. 8. Subcutaneous branches of the temporo-malar nerve, coming through openings in the temporal fascia. 9. Their junction with the facial nerve. 10. Zygomatic branches of the subcutaneous malæ nerve divided. 11. Infraorbital nerve. 12. Inferior palpebral branches. 13. Junction with the facial nerve. 14. Superior, and 15, inferior lateral nasal branches. 16. Internal, and 17, external supe-

rior labial branches. 18. Buccal branches. 19. Junction with the facial nerve.

Third division. 20. Mental nerve. 21. Mental branches. 22. Internal, and 23, external inferior labial branches. 24. Buccal branches. 25. Junction with the facial nerve. 26. The anterior buccal branches of the buccal nerve. 27. Their junction with the facial nerve. 28. Branches of the auriculo-temporal, communicating with the facial nerve. 29. Superficial temporal branch of the auriculo-temporal nerve.

VII.—Trunk of the facial, seen in the infraauricular fossa. 30. Temporo-facial division of the facial nerve. 31. Temporal, 32, malar, and 33, superior buccal branches. 34. Cervico-facial division of the facial nerve. 35. Inferior buccal branches. 36. Supramaxillary branch. 37. Inframaxillary branch. 38. Its inosculation with the superficialis colli. 39. Intercommunication of the branches of the facial, forming the *pes anserinus*. Many branches of the facial nerve are cut through near the muscles of the face, which are removed.

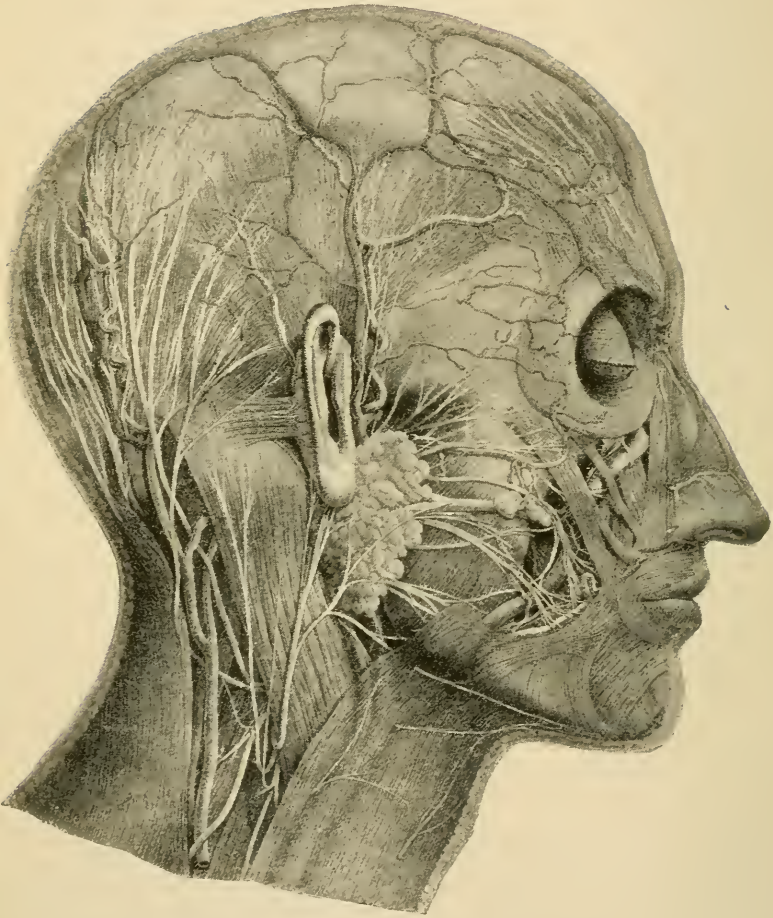
(XI.)—Spinal accessory nerve. 40. Its external division, going to the trapezius muscle.

(XIV.)—Second cervical nerve. 41. Occipitalis major nerve, piercing the biventer cervicis muscle. 42. Cervical cutaneous branch divided. 43. Occipital branches.

(XV.)—Third cervical nerve. 44. Occipitalis minor. 45. Auricularis magnus nerve. 46. Its facial branch divided, and 47, its auricular branch. 48. The middle, and 49, inferior branches of the superficialis colli. 50. Cutaneous branches divided. 51. Branches going to the levator anguli scapulæ muscle. 52. Junction with the fourth cervical nerve.

(XVI.)—Fourth cervical nerve. 53. Supraclavicular branches. 54. Phrenic nerve.

PLATE IX.



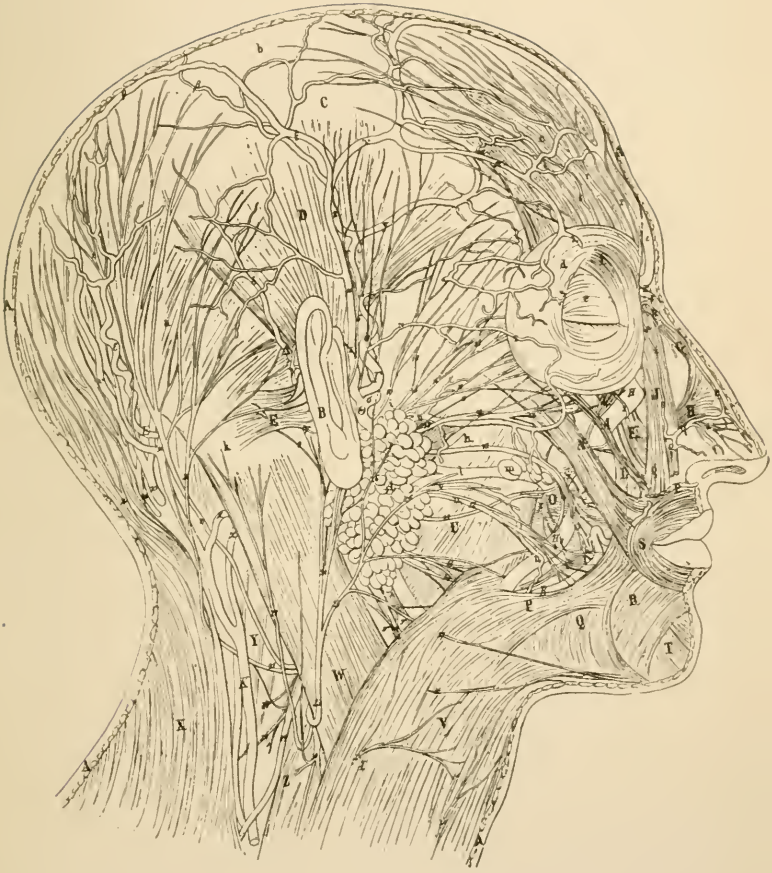


PLATE IX.

COURSE OF THE SUBCUTANEOUS CRANIAL NERVES. THE SUPERFICIAL DISTRIBUTION OF THE FACIAL, FIRST, SECOND, AND THIRD DIVISIONS OF THE TRIFACIAL, AND THE SUBCUTANEOUS RAMIFICATIONS OF THE SECOND, THIRD, AND FOURTH CERVICAL NERVES ON THE RIGHT SIDE OF THE HEAD.

The skin of the right side of the head and neck is removed, bringing the subjacent parts into view.

Therefore the parotid gland, Stenson's duct, and the subcutaneous muscles, vessels, and nerves of the head, face, and neck may be seen.

A.—Skin and adipose tissue divided in the median line.

B.—Pinna, with the helix turned forward to show the retrahens aurem muscle and posterior auricular nerve.

C.—Epicranial muscle. *a.* Its occipital portion, *b*, aponeurosis, and *c*, frontal portion.

D.—Attolens aurem muscle.

E.—Retrahens aurem muscle.

F.—Orbicularis palpebrarum muscle. *d.* Its orbital, and *e*, palpebral portions.

G.—Pyramidalis nasi muscle. **H.** Compressor nasi muscle. **I.** Levator labii superioris alæque nasi muscle. *f.* Its nasal, and *g*, labial portions.

K.—Levator labii superioris proprius, **L,** levator anguli oris, **M,** zygomaticus major, **N,** zygomaticus minor, **O,** buccinator, **P,** risorius, **Q,** depressor anguli oris, **R,** depressor labii inferioris, **S,** orbicularis oris, and **T,** levator labii inferioris muscles.

U.—Masseter muscle. *h.* Its superficial, and *i*, deep portions.

V.—Platysma muscle. **W.** Sterno-cleido-mastoid muscle. *k.* Its superior tendinous extremity.

X.—Trapezius, and **Y,** splenius capitis et colli muscles. **Z.** Levator anguli scapulæ muscle.

A.—Parotid gland. *l.* Stenson's duct. *m.* Accessory parotid gland.

B —Facial artery. *n*. Masseteric branch anastomosing with a branch of the transverse facial artery. *o*. Buccal branch, also anastomosing with a branch of the transverse facial artery. *p*. Artery of the nasal septum. *q*. Lateralis nasi artery. *r*. Dorsalis nasi artery. *s*. Angular artery. *t*. Anastomosis with the ophthalmic artery.

Γ.—Temporal artery. *u*. Superior, and *v*, inferior branches of the transverse facial artery. *w*. Zygomatico-orbital artery. *x*. Anastomosing branch with the transverse facial artery. *y*. Anterior, and *z*, posterior superficial temporal arteries. α. Anastomoses with the supraorbital, and β, occipital arteries.

Δ. Posterior auricular artery. γ. Auricular branches. δ. Occipital branch.

E. Occipital artery. ε. Terminal occipital branch.

Z. Ophthalmic artery. ζ. Supraorbital artery, passing through the frontal muscle and then ascending upon it. η. Dorsalis nasi artery. ϑ. Branch anastomosing with the facial artery.

H. Facial vein. ι. Frontal vein. κ. Dorsalis nasi vein. λ. Branch of the supraorbital vein, perforating the orbicularis palpebrarum muscle and anastomosing with the facial vein.

Θ Temporal vein. μ. Superficial temporal vein. ν. Its anterior, and ξ, posterior branches. ο. Anastomoses with the frontal, π, supraorbital, and ρ, occipital veins. σ. Middle temporal vein. τ. The trunk of the temporal vein is here double, but usually only one trunk is found.

I. External jugular vein, covered by the platysma muscle.

K. Superficial cervical vein. υ. Occipital vein. φ. Anastomosing branch with the deep cervical plexus. χ. Cervical branches.

(V.)—Trifacial nerve.

First division. 1. Frontal branches of the frontal nerve, passing through the fibres of the frontal muscle, then going to the vertex subcutaneously. 2. Frontal branches of the supratrochlear nerve.

Second division. 3. Inferior palpebral branch of the infraorbital nerve. 4. Laterales nasi branches of the infraorbital nerve.

Third division. 5. Anterior auricular branch, and 6, temporal branches of the auriculo-temporal nerve. 7. The anterior buccal branches of the buccal nerve. 8. Branches of the buccal joining the facial nerve.

(VII.)—Facial nerve. 9. Posterior auricular nerve. 10. Temporal, 11, malar, 12, superior buccal, and 13, inferior buccal branches 14. Supramaxillary, and 15, inframaxillary branches. 16. Branch piercing the platysma muscle. 17. Inosculation with the middle superficialis colli nerve. 18. Intercommunicating branches of the facial nerve

(XI.)—Spinal accessory nerve. 19 Its external division, going to the trapezius muscle.

(XIV.)—Second cervical nerve. 20. Occipitalis major nerve, piercing the biventer cervicis and part of the trapezius muscles. Branches of this nerve accompany the occipital artery and vein to the vertex.

(XV.)—Third cervical nerve. 21. Occipitalis minor, one branch of which pierces the border of the trapezius muscle and ascends to the anterior part of the occiput; another branch passes amongst the branches of the superficial cervical vein, joins the occipitalis major nerve and goes to the vertex. 22. Anterior cervical cutaneous branches. 23. Auricularis magnus nerve. 24. Its auricular branches. 25. Facial branch of the auricularis magnus. 26. Facial cutaneous branches divided. 27. Cutaneous branches piercing the platysma muscle. 28. Superficialis colli nerves piercing the platysma muscle. 29. Branches to the levator anguli scapulæ muscle.

(XVI.)—Fourth cervical nerve. 30. Its anterior division.

ESSENTIALS OF HUMAN PHYSIOLOGY.

What is physiology?

Physiology is the study of vital phenomena which are always present in living things be they animal or vegetable. As a consequence of this we divide physiology into two subdivisions, known as animal physiology and vegetable physiology, but it should be remembered that the line of demarcation between animals and vegetables in the lower forms of life is very ill-defined. The word physiology is derived from the Greek word φύσις, nature, and λόγος, a discourse, and in its original meaning was applied to the study of natural history in general. Physiology is really synonymous with the term biology, since it is necessary for the study of either one that vital properties be present in the thing studied. The term biology, however, has a wider scope with certain persons, as under some circumstances it is divided up into morphology, which treats of the forms and structure of living bodies, while physiology attempts to explain the modes of activity exhibited by them during their lifetime. In other words, morphology stands in the same position in reference to physiology as does anatomy. The term *vital phenomena* is applied to the changes which constantly go on in all living bodies, the primary causes of which are not at all understood; in other words, while we note the ultimate object of each function we can give no cause for the setting in motion of that function.

What is the chemical basis of the body?

Of the sixty-nine elements known to chemists, a very small number, comparatively speaking, are found in any quantity in living animal matter, although traces of them are frequently present. Oxygen, carbon, hydrogen, and nitrogen are present in very large proportions in every tissue, and together make up about 97 per cent. of the whole body, while the sulphur, phosphorus, chlorine, fluorine, silica, potassium, sodium, magnesium, calcium,

and iron are indispensable to the economy, but are widely distributed and occur in much smaller quantities. Since to investigate the chemical composition of a tissue must require analysis, the composition of the tissues during life is, strictly speaking, unknown, since by the very analysis death is produced. An important point to be remembered is that all animal bodies, be they simple or complex, are made up of protoplasm more or less differentiated according to the function which it is to fulfil.

What two great groups of substances make up the body?

Physiological chemistry teaches us that we have in the body two sets or groups of substances known as *nitrogenous* and *non-nitrogenous*. The nitrogenous perform the most important functions, and, indeed, form all the active portions of the organism. As the simplest representative of these nitrogenous bodies may be mentioned protoplasm itself. Derived from this and entering into the formation of it are albumens, serum-albumens, and, thirdly, by the outcome of still further differentiation we have albuminoids, chiefly represented by gelatine. Last of all are those products which, though nitrogenous, differ from the others in that they are intermediate or effete products of tissue manufacture or waste, as, for example, *urea*, uric acid, kreatin, and kreatinin. The non-nitrogenous substances consist chiefly of the carbohydrates, which contain hydrogen and oxygen in the proportion found in water, as, for example, starch and sugar. Then we have substances containing oxygen in less proportion than the above, namely, fats. Salts occur all through the tissue, as does also water.

PROTEIDS.

All compounds included in the group of proteids contain carbon, hydrogen, nitrogen, oxygen, and sulphur.

They are amorphous, with variable solubility in water and acids, usually soluble in alkalies, almost insoluble in alcohol and ether. They are precipitated from their solutions by excess of strong mineral acids, by acetic or hydrochloric acid, potassium ferrocyanide, and the basic acetate of lead, mercury bichloride, tannin, and potassium carbonate in powder.

The following table, taken from Gamgee's *Physiological Chemistry*, is of great importance, and gives the points to be remembered most tersely. This will be, of necessity, frequently referred to later on.

Soluble in pure water

Class 1.—*Albumens* are proteid bodies which are soluble in water, and which are not precipitated by alkaline carbonates, by sodium chloride, or by very dilute acids. If dried at a temperature below 40° C. they become transparent and yellow, break with vitreous fracture, and are soluble in water. Coagulation occurs between 65° and 73° C.

1. Serum-albumen, not precipitated from its solutions by the addition of ether.
2. Egg-albumen, precipitated from its solution by agitation with ether.

Class 2.—*Peptones*, proteid bodies exceedingly soluble in water. Solutions are not coagulated by heat when precipitated by sodium chloride, nor by acids or alkalies; precipitated by a large excess of absolute alkali and by tannic acid in the presence of much caustic potash or soda. A trace of a solution of copper sulphate produces a beautiful rose color.

Insoluble in pure water, but soluble in weak solutions of common salt

Class 3.—*Globulins*, proteid substances which are insoluble in pure water but soluble in dilute solutions of NaCl. These solutions are coagulated by heat They are soluble in dilute hydrochloric acid, being converted by alkalies into alkali-albumen.

1. Vitellin, not precipitated from its solution when saturated with common salt.
2. Myosin, precipitated from its solution by weak common salt. When saturated with sodium chloride it coagulates at 55° to 60° C. Solutions in common salt are not coagulated by a solution of fibrin-ferment.
3. Fibrinogen, soluble in weak solutions of NaCl, precipitated from them completely on the addition of NaCl when this amounts to twelve or sixteen per cent. Solutions coagulate on the addition of fibrin-ferment and at the temperature of 60° C.
4. Paraglobulin, soluble in weak solutions of NaCl, and precipitated from weak alkaline solutions by the addition of a small quantity of NaCl. A further addition of this body redissolves the precipitate, which is again precipitated, although not so completely as before. When the amount of NaCl in solution exceeds twenty per cent. paraglobulin is completely precipitated when the solution is saturated with ammonium sulphate. Its solutions are not precipitated by the addition of the fibrin ferment It coagulates at different temperatures according to the amount of salts present and the mode of heating, but generally between 68° and 80° C.

Class 4.—*Derived albumens*, proteid bodies insoluble in pure water and in solutions of NaCl, but readily soluble in dilute HCl and in dilute alkaline solutions. Solutions are not coagulated by heat.

1. Acid-albumens, obtained by the action of dilute acids, especially HCl, on solutions of proteids, and by action of strong acids upon solid proteids. They occur as first products in the action of gastric juice. NaCl added to saturation precipitates them.
2. (*a*) Alkali-albumens, obtained by the action of dilute alkalies upon the proteids, possessing the properties of acid-albumen with the exception that in the presence of an alkaline phosphate the solutions are not precipitated by neutralization. They occur as the first products of pancreatic digestion

(*b*) Casein, the chief proteid constituent of milk, has the same properties as alkali-albumen, but when treated with a strong solution of caustic potash potassium sulphide is formed; with alkali-albumen it is not formed.

Class 5.—*Fibrin* is insoluble in water and in weak solutions of NaCl, and becomes swelled up in cold hydrochloric acid of one-tenth per cent. solution, but does not dissolve unless pepsin is added and heat is applied.

1. What tests have we for proteids?

The *nitric acid test*, which consists in heating the liquid and adding nitric acid until the reaction is strongly acid, when a precipitate occurs. *Remember*, that this is not an infallible test for all proteids, as, for example, the peptones, which will not respond to it.

2. What is the xantho-proteic reaction?

Heat with concentrated nitric acid, when, if a proteid be present, a yellow tint appears, which becomes reddish-orange on the addition of alkalies.

3. What is Millon's reagent?

It is made by dissolving in the cold one part of mercury in its weight of concentrated nitric acid, the solution being completed by applying gentle warmth; two volumes of distilled water are then added, and the fluid decanted. This test gives a red color with liquids containing proteids, which is more marked when they are heated to 60° C. or 70° C.

CARBO-HYDRATES.

These include the starches and sugars.

What test have we for starch?

Starch, when added to free iodine, strikes a blue color which disappears on the application of heat, but returns if the liquid be

suddenly cooled. If heated to the temperature of 210° C. starch is converted into dextrin, and, as we shall learn later, the digestive fluids change starch into glucose or grape sugar.

Sugars are substances having a more or less sweet taste, usually soluble in water, destroyed by strong H_2SO_4, which abstracts water from these compounds, and leaves only the carbon. The most important of this group are glucose, lactose, saccharose, and glycogen. On fermentation they yield CO_2 and alcohol.

What test have we for sugars?

Trommer's test, which depends upon the fact that sugar in an alkaline solution acts as a reducing agent. To the saccharine fluid about one-fourth of its bulk of caustic potash or soda is added, and a dilute solution of copper sulphate. A slight clouding occurs which disappears on shaking, but boiling strikes a brick-red color.

Fats are widely distributed in plants and in animals. They contain very little oxygen, and are soluble in ether, benzole, chloroform, and in boiling alcohol. When fats are boiled with solutions of the alkaline hydrates or carbonates they undergo saponification, and are decomposed into glycerin and fatty acids. The latter immediately combine with the alkali and form soap.

Fats also undergo emulsification, in which process they are broken up into a condition of extremely fine subdivision.

THE BLOOD.

What is the function of the blood?

In all animals, except those which form the lowest class, a liquid medium corresponding, in function at least, to the blood of man, circulates. It serves in the distribution of nutritious materials to the various parts of the system and, equally important, it collects those substances which have resulted from the changes which are constantly going on in the tissues and bears them to those organs whose function it is to discharge them from the body. Quite as important is the constant intercourse which it keeps up between the tissues and the air, supplying them with oxygen.

What is the color of the blood in the different portions of the circulatory system?

The color of the blood as it occurs in the systemic arteries is of a bright scarlet-red, while in the corresponding veins it is of a dark bluish color. In the pulmonary artery it is dark blue, in the pulmonary veins scarlet.

What is the cause of this variation?

The cause of this variation is due to the oxygen of the air, which, entering into a chemical combination with the hæmoglobin of the red blood corpuscles, produces oxyhæmoglobin, which gives up some of its oxygen to the tissues of the body as it passes through the capillaries, and returns in the veins partly decomposed into reduced hæmoglobin, which gives to the venous blood its dark hue.

Is the entire amount of oxyhæmoglobin reduced in venous blood?

No. The reduction of hæmoglobin amounts to only about five per cent.

Are the red blood corpuscles red or yellow?

They are red, for their coloring matter, hæmoglobin, is red when isolated and crystallized.

The color of the red corpuscles when seen singly is yellowish-red.

The difference in color between those seen *en masse* and those seen singly is due to the refraction of light.

What is the reaction of the blood?

The reaction is alkaline, owing to the presence of sodium carbonate and disodic phosphate, Na_2HPO_4.

Does it always retain its alkalinity?

Always during life, but after blood is shed its alkalinity rapidly diminishes, and the greater the alkalinity of the blood is, the more rapidly this change occurs. Finally, the reaction becomes strongly acid, this change coming at about the time of coagulation.

What is the odor of the blood?

The odor which the blood possesses differs in the various animals, and in some animals is very characteristic. This odor depends upon the presence of volatile fatty acids.

What is the taste?

It is saline in taste, which is dependent upon the salts contained in it.

What is the specific gravity of the blood?

The specific gravity is 1055, the extreme limits being from 1045 to 1075. The specific gravity of the blood corpuscles alone is 1105, that of the plasma 1027. As a consequence of this, blood corpuscles tend to sink to the bottom of the receptacle into which the blood is drawn.

What is the temperature of the blood?

It varies from 98° F. at the surface of the body to 107° in the hepatic vein.

Of what does the blood consist?

Blood, when flowing in a normal condition through the blood-vessels, consists of an almost colorless fluid, *the plasma*, in which are suspended small solid bodies, known as red and white blood corpuscles and blood-plates. The liquid portion of the blood (the blood plasma or liquor sanguinis) is of a pale straw color when free from blood corpuscles or other coloring matter, and is the liquid which keeps the corpuscles afloat. The blood plasma is not identical with the serum of the blood, since radical changes take place in its composition during coagulation, and the serum results after the clot is formed. Serum will not of itself form a clot, plasma will; in other words, one of the differences between liquor sanguinis, or plasma, and serum, is that the first contains fibrinogen, while the second does not.

Is there any variation in the character of the blood in different parts of the circulatory system?

The arterial blood contains more oxygen and less CO_2, and is more coagulable. The blood of the portal vein varies with the stages of digestion, during which time it is richer in water, albuminous matters, and sugars, with a diminished number of corpuscles. In the hepatic vein the sugar is increased, but the albumin and fibrinogen diminished.

What are the two varieties of blood corpuscles?

Red and white.

What others have we?

Very small ones, known as microcytes, and the so-called blood-plates.

What is the function of these microcytes?

Most physiologists believe them to be young red blood corpuscles, others that they are worn-out red blood corpuscles.

What is the function of the blood-plates?

It is not known, but they are found in large numbers in thrombi, and possibly take part in the process of coagulation by helping to form fibrin-ferment. They do not become red corpuscles.

Describe the white corpuscles.

They are small protoplasmic cells, differing in no way from the pale round cells found in most portions of the body, and occur in large quantities in the lymph. For this reason they are sometimes called lymphoid cells or leucocytes. They possess a finely granular structure and nuclei, and these nuclei may often be recognized near the centre of the cell. The nuclei may be made more marked by the action of certain reagents, notably acetic acid. They possess an amœboid movement, and so are enabled to migrate not only through the bloodvessel wall, but also through the tissues. They are somewhat larger than the red disks, and do not possess a cell wall.

What do you mean by diapedesis?

The passage of the white blood corpuscles through the blood-vessel wall. The white corpuscles constantly pass through normally, but in very large numbers in inflammation. The red only under morbid conditions, as in injury or inflammation.

What are the relative positions of the red and white corpuscles in the blood stream of the smaller arterioles and capillaries?

The red move along rapidly in the centre, while the white slowly roll along the walls. If inflammation occurs, they stop and block

the vessel. The layer of blood in which the white corpuscles lie is called the "still layer."

Where are the white corpuscles formed?

According to the best physiologists, in the lymphatic glands and the spleen, and very similar cells develop in the connective tissues through multiplication by division.

What are their functions?

1. To destroy pathogenic bacteria (the phagocytosis theory of Metschnikoff).

2. To take part in the process of blood-coagulation by forming fibrin-ferment (thrombin).

3. To aid by their disintegration the normal composition of the blood-plasma as to proteids.

Describe the red blood corpuscles.

The red blood corpuscles give the red color to the blood of all vertebrated animals except the amphioxus, but are not found in the blood of invertebrates. They differ in their shape in almost all animals, in the mammalia they are biconcave disks. Their size differs in each class of animals, but the size of the animal has no relation to the size of the corpuscle, for in the frog all the corpuscular elements are of great size. They are soft and elastic, and bend and alter their shape when necessary to pass through a narrow bloodvessel, but return immediately to their normal shape as soon as the pressure is removed. If blood be withdrawn from the body, even for a few moments, and then returned to the circulation, death of the corpuscles takes place, and in a short time evidences of their destruction may be noticed by the presence of hæmoglobin in the urine.

What is one of the peculiarities of the red blood corpuscles outside the body?

They form themselves into rouleaux, which resemble very closely the appearance of a large number of coins placed side by side. This peculiarity is due rather to a physical law than to any action of the corpuscles themselves, since it has been found that small disks of cork will do very much the same thing when placed in water.

Have the red blood corpuscles any nuclei?

Not in adult life, but owing to their biconcave shape the refraction is such that under the microscope a dark spot is apparently situated near their centre. In the young embryo nucleated red corpuscles are found.

Are the red blood corpuscles few, or are they exceedingly great in number?

Their quantity is enormous; a cubic millimetre contains between four and five millions. Approximate mathematical estimates show that the red blood corpuscles of an adult present an aggregate surface of about three thousand square yards, while the surface they represent for the absorption of oxygen in the lungs in one second is about eighty square yards.

How are they formed?

In adult life from the erythroblasts of the red marrow of the bones; in the embryo they are also formed in the liver and spleen.

What is the end of the life history of the red blood corpuscles?

Many physiologists regard the liver as one of the chief places where the disintegration of the red blood corpuscles takes place, and this is supported by the facts that the bile-pigments are formed from hæmoglobin and that the blood of the hepatic vein contains fewer red blood corpuscles than the blood of the portal vein. The spleen is also regarded as one of the organs in which the red blood corpuscle is disintegrated. It is probable that they are destroyed largely while in the general circulation, and do not require any special organ for their destruction.

What are the functions of the red corpuscles, and their relative number to the white corpuscles?

The function of the red blood corpuscles is entirely different from that of the white blood corpuscles. The red blood corpuscle contains in its stroma a large amount of hæmoglobin which, when exposed to the air in the lung, takes up oxygen, thereby forming the chemical compound known as oxy-hæmoglobin. By these means the tissues, even in the most distantly removed parts of the

body from the lung, receive their oxygen, the exchange of oxygen from the corpuscles to the tissues taking place in the capillaries. By this means, oxidation, with the resulting tissue break-down, and the development of heat, takes place in every portion of the body.

The relative number of the white blood corpuscles to the red has been much discussed, some observers giving it as 1 to 300, while others state that it is 1 to 700. The proportion varies so much in different parts of the circulation that no estimate is of any great value.

Do changes ever occur in the relative number of red and white corpuscles in health?

Very frequently, since many circumstances arising in every-day life may produce great changes in this respect. The variation may be all the way from 1 in 50 to 1 in 1200. Pregnancy decreases the proportion; meals also have a very powerful effect on their relative numbers. Certain diseases also alter the proportion greatly.

What is hæmoglobin?

It is the substance which gives the red color to the corpuscles, and carries by their aid the oxygen to the tissues.

What is hæmatin?

A result of the decomposition of hæmoglobin by acids or alkalies in the presence of oxygen.

Hæmin is a compound of hæmatin and HCl.

Hæmatoidin is a crystallizable substance found in old blood-clots and comes from hæmoglobin. It is identical with the bile-pigment, bilirubin.

What are the gases of the blood?

Chiefly oxygen, carbonic acid, and nitrogen. The oxygen exists, as before stated, in chemical combination with the hæmoglobin, and is also in small amounts simply absorbed by the blood plasma.

Carbonic acid occurs in less amount in arterial blood than in venous blood.

Nitrogen exists in the blood in very small amount, and appears to be simply absorbed.

From 100 volumes of blood may be obtained—

	O.	CO_2.	N.
Of arterial blood (from a large artery),	20 vols.	40 vols.	1 to 2 vols.
Of venous blood (from right side of heart),	8–12 "	46 "	1 to 2 "

Does CO_2 unite with the hæmoglobin?

No. It is held in solution chiefly by the plasma, and in very small amount in the red blood corpuscles.

What is the quantity of the blood?

The quantity of blood in a human male adult is equal to one-thirteenth part of the body weight.

Coagulation of Blood.

Blood, on being withdrawn from a vessel, is perfectly fluid, but rapidly becomes thick, and then forms a clot resembling a solid gelatinous mass.

What is this clotting due to?

The formation of fibrin, in part at least, from fibrinogen.

Does fibrin exist already formed in the blood?

No.

How is it produced?

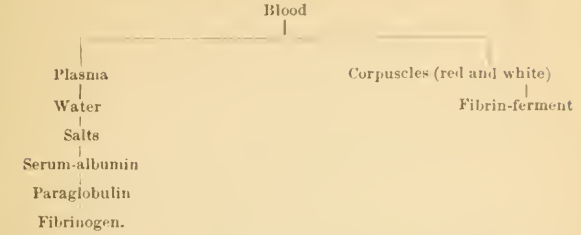
There is no perfectly satisfactory theory of coagulation. The most generally accepted one is that of Hammarsten, that the reaction between fibrinogen and fibrin-ferment (thrombin) produces fibrin.

It is also necessary that calcium salts be present, for without them fibrin cannot be formed from fibrinogen. Fibrin-ferment does not exist in the blood until after it is shed; then the disintegration of the white blood corpuscles occurs and the ferment is formed.

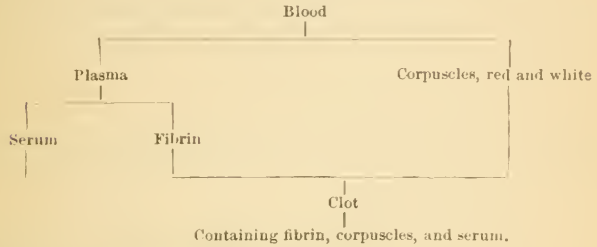
How is the clot made up?

The fibrin forms in fibrils, which entangle the blood corpuscles as in a spider's web, and thereby form a complete blood-clot.

The blood in the body is made up as follows:



Blood when it has undergone coagulation is as follows:



What changes take place after the clot is formed?

The clot leaves the sides of the vessel, and on its surface there appear small transparent drops of yellowish liquid known as serum. These drops running together form a layer of yellowish fluid.

In what way is the serum expelled from the clot?

The fine fibrils of fibrin ramifying all through the clot contract, and squeeze out the serum. These fibrils also entangle the corpuscles.

How long does this contraction and displacement of the serum last?

From twenty-four to thirty-six hours.

How is blood defibrinated?

By beating it with twigs or a glass rod. The fibrin adheres in sticky masses to the rods, and the remaining fluid will not clot. The corpuscles are left, most of them in the serum.

What conditions hinder or delay coagulation?

The addition of small quantities of alkalies or of concentrated solutions of neutral salts of alkalies, notably magnesic sulphate; the addition of egg-albumin, syrup, glycerine, and much water; and by covering the blood with oil, or by cold at freezing point.

What hastens coagulation?

Coagulation is accelerated by contact with any foreign body, by heating from 39° to 55° C., and by constant agitation.

What do you mean by the buffy coat?

In blood which is drawn from a body during inflammation the fibrin coagulates slowly, and the corpuscles subside to the bottom of the vessel, so that the upper stratum of the clot is not red but only yellowish, containing scarcely any red blood corpuscles. This occurs physiologically in horses' blood.

What prevents coagulation of the blood in the bloodvessels?

This is not positively known; some relationship exists between living tissues and the blood.

Under what circumstances does clotting in the bloodvessels occur?

As soon as the endothelial layer of the bloodvessels is in any way injured.

How long after death does the blood coagulate in the body?

From ten to twenty-four hours.

Do pathological changes ever take place in the blood?

Yes. *Plethora* is an increase in the quantity and quality of the blood, the red corpuscular elements being greatly increased in number

Anæmia is a decrease in the corpuscular elements of the blood, without necessarily any increase in the liquids.

Leucocythæmia or *leukæmia* is a term applied to a condition in which, together with other changes, the white blood corpuscles are very much increased in number, from 10,000 to 1,000,000 in a cubic millimetre of blood. In some cases the white corpuscles are as numerous as the red.

Uræmia cannot be considered a disease of the blood, but simply an accumulation of urea in that fluid, owing to kidney disorders.

THE HEART.

What is the simplest form of heart?

The early embryonic heart, which is merely a tubular heart with one cavity and an outer circular and inner longitudinal layer of fibres.

Does the muscular fibre of this tubular heart afford walls to both the auricle and ventricle after the septum is formed?

Yes, but the muscular fibres of the auricle do not change to any extent, while the ventricular fibres become much altered.

What separates the auricular fibres at this time from the ventricular fibres?

Fibro-cartilaginous rings at the opening in the septum.

What is the function of the heart?

To propel blood through the body.

How many cavities has it?

Four.

What is the weight of the adult male heart?

Nine ounces.

What is the weight of the adult left ventricle as compared to the right?

About twice as heavy.

What is the difference between the right and left side of the heart?

The right side of the heart takes the venous blood from the vena cavæ and pumps it through the lungs to the left side of the heart. This circulation is much more limited, of course, than that produced by the left side, and is known as the *pulmonic circulation.*

The left side of the heart receives the arterialized blood from the lung and drives it into the general arteries. This is known as the *systemic circulation*.

Which is the strongest, the right or left side of the heart?

The left side is not only much stronger, but its walls are much thicker on account of the greater amount of work which it is forced to perform.

What is the difference between the contraction of the auricles and the contraction of the ventricles?

The contraction of the ventricles takes place synchronously from all sides, so that the pressure within is equal in any direction. The auricles contract peristaltically from the opening of the supplying vessel toward the auriculo-ventricular orifice.

Which have the thickest walls, the ventricles or the auricles?

The ventricles, owing to the greater force which they are required to put out.

What is the function of the auricles?

To act as a reservoir for the blood while the ventricles are contracting, and force the blood through the auriculo-ventricular openings, and so supply the ventricles.

Has the heart any suction power enabling it to aid the circulation not only by pushing but by sucking?

According to the latest researches it has not.[1]

What is the endocardium?

The membrane lining the heart.

Is it limited to this viscus or not?

It is continuous with the endothelial lining of the bloodvessels.

Has the endocardium bloodvessels

No, it has not.

[1] The muscular arrangement of the heart is probably already known to the student; if not, he must turn to his anatomical text-books.

What are the valves of the heart?

They are fibrous flaps arranged in one of two ways, which open and shut the orifices which they guard. The edges of the auriculo-ventricular valves are attached by what are known as chordæ tendineæ to the walls of the ventricles.

In what way are the valves attached to the heart?

They are fixed to the fibrous rings, made up of yellow elastic tissue and fibrous tissue which surround the openings.

Do the valves have any muscular fibres in them?

According to Reid and Gussenbauer, the auriculo-ventricular valves do; the fibres come from the auricles.

Have the valves bloodvessels?

None near the edges. Only as far as the muscular fibres run.

What is the function of the valves?

To prevent the regurgitation of blood from a heart cavity, or bloodvessel, back into the area from which it has been propelled.

What two sets of valves have we?

The auriculo-ventricular and semilunar.

Where are they situated?

The semilunars guard the opening of the aorta and pulmonary artery.

At the right auriculo-ventricular orifice we have the tricuspid valve, at the left auriculo-ventricular we have the mitral or bicuspid valve.

How many cusps make up the semilunars?

Three at each opening.

Are there any valves at the opening of the cavæ into the right auricle?

No.

Why are they not needed?

Because the peristaltic action of the auricle prevents a tendency to regurgitation, except in rare conditions. For the same reason

we have no valve at the opening of the pulmonary vein into the left auricle.

What are the chordæ tendineæ?

The chordæ tendineæ are small bands running from the muscular fibres of the heart wall to the edges of the valves.

What is the function of the chordæ tendineæ?

To prevent the everting of the auriculo-ventricular valves into the auricles by a sudden pressure of blood during ventricular systole.

In what way is the heart nourished?

By means of its coronary arteries, which are peculiar in that they do not anastomose.

Where do these arteries arise?

From the aorta near the sinus of Valsalva.

What is the condition of the openings of these arteries during the period of systole?

They are closed by the aortic valves.

Are the veins of the heart called coronary veins?

No. They are called cardiac veins.

What other cause produces an onward flow of the blood through the coronary arteries than the *vis a tergo* from the systolic driving out of blood into the aorta?

The lateral pressure exercised on the vessels by the surrounding heart muscle.

What effect has ligation of one or both coronary arteries?

The heart in two minutes changes its rhythmical movements into twitchings and soon ceases all movement.

What is this change due to?

Both to failure of nutrition and to failure in the removal of effete matters from the heart by the blood, as a consequence of which the heart is poisoned by the poisons generated by itself.

What are the columnæ carneæ?

They are small ridges of muscular tissue lying on the ventricular wall.

What are the musculi papillares?

They are small teat-like muscular projections arising from the inner portion of the ventricular wall, to which the chordæ tendineæ are generally attached.

What is their function?

As the ventricle contracts and the heart shortens they pull the chordæ tendineæ tense and take up the slack, as it were.

In what way does the blood circulate through the heart?

Entering the right auricle from the cavæ, it passes through the right auriculo-ventricular opening into the right ventricle, then through the pulmonary artery into the lungs, from the lungs through the pulmonary veins to the left auricle, and through the left auriculo-ventricular orifice to the left ventricle, from the ventricle through the aorta, and so on through the arterial system.

How much blood is sent out of the left ventricle ordinarily in the adult at one contraction?

About four to six ounces.

How much force does the heart put out at each systole?

Enough to lift three foot-pounds.[1] Of this the left ventricle does two and a quarter pounds. In twenty-four hours the heart puts out enough force to lift one hundred and twenty-four foot-*tons*, or enough to lift one ton one hundred and twenty-four feet.

What are the movements of the heart?

The chief movements are those of contraction, or systole, and expansion, or diastole.

The two auricles contract synchronously, thereby filling the ventricles, then the ventricles contract together, and then follows diastole. Following ventricular diastole there is a *pause*.

[1] A foot-pound represents the force required to lift one pound one foot.

Systole, diastole, and the pause, therefore, make up one cardiac revolution or cycle.

Does the heart change its position during contraction or expansion?

Yes, somewhat; for, with contraction, the base of the heart descends, the base of the ventricle goes toward the left but the whole heart rotates a little to the right, and the apex is tilted a little forward. The vertical movement of the apex amounts to nothing.

At what time does the impulse of the heart take place against the chest?

During systole.

What is the object of the pericardium?

It acts as a protecting membrane surrounding the heart. The visceral layer covers the heart and is in turn covered by a reflexion of the membrane which forms the parietal layer. These two surfaces secrete a sufficient quantity of liquid to lubricate their surfaces as they move on one another.

When the heart is slowed or quickened, is the change in speed due to a change in systole or diastole, or both?

Systole remains unaltered, diastole is prolonged when slowing occurs, shortened when quickening occurs.

How many heart sounds have we?

Two; the long, dull "lub," and the short, sharp "dup."

What are the sounds of the heart due to?

The first sound is due to the vibration of the auriculo-ventricular valves made tense by the systolic force of the ventricles. and also the sudden contraction of the muscular fibres of the heart walls. The striking of the apex against the chest wall does *not* even help the first sound, since it can be heard after the wall is

removed. The second sound is produced by the closure of the aortic valves.

At what rate does the heart beat?

Before birth, per minute, the beats are 140–150.
During first year, per minute, the beats are 125–135.
During third year, per minute, the beats are 95–100.
During eighth, ninth, and tenth to fourteenth year, 85–90.
In the adult, about 72.
In very old age, or decrepitude, the pulse once more becomes fast.

In which sex is the pulse most rapid?

In females.

What effect has posture on the pulse?

The erect posture causes a more rapid pulse than the recumbent.

What other conditions influence its rate?

Respiratory changes, drinking water in small repeated swallows, and many similar conditions.

What is the intrinsic nervous mechanism of the heart?

The intrinsic nervous mechanism of the heart consists in three centres, which have been proved to exist in the heart of the frog, and are generally received as the centres for the mammalian heart. The three centres are:

1. The motor ganglion, or that of Remak.
2. The accelerator, or second motor ganglion, or that of Bidder.
3. The inhibitory ganglion, or that of Ludwig.

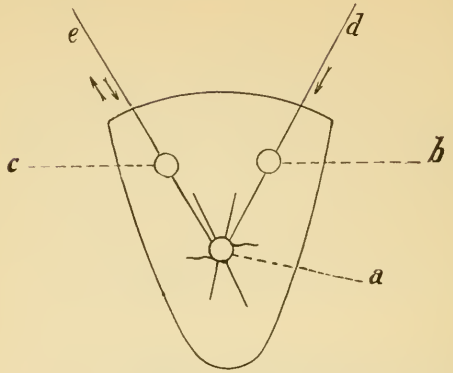
Fig. 1. will serve to illustrate the matter:

The motor ganglion (*a*) sends out through its radiating fibres impulses which drive the heart.

The accelerator motor ganglion (*b*), when it acts, quickens the irradiation of these impulses.

The inhibitory ganglion (*c*) prevents the heart from beating too fast.

FIG. 1.



a. The motor centre, that of Remak. *b*. The accelerator motor centre, that of Bidder. *c*. The inhibitory centre, that of Ludwig. *d*. The accelerator nerves. *e*. The pneumogastric or inhibitory nerves. The arrows represent direction in which impulses travel

What keeps up the contraction of the muscle?

The constant circulation of the blood over the endothelium, thereby stimulating and sending reflex impulses to the motor ganglion.

What are the extrinsic cardiac nerves?

The accelerators and the pneumogastric or inhibitory nerves, which arise in the base of the brain and are governed by centres there.

What is their function?

They govern the ganglia in the heart muscle.

Are the pneumogastric nerves and the accelerators, strictly speaking, antagonists?

They are not, for the accelerators do not act all the time, while the pneumogastrics do, and the vagi can always overcome readily any accelerator influence.

What effect on the heart has stimulation of the pneumogastrics

It slows the pulse and produces large and full diastole.

What effect has section of the vagus?

It produces an exceedingly rapid pulse.

What effect has stimulation of the accelerators?

Stimulation of the accelerators makes a very rapid pulse.

What is the depressor nerve, and what is its function?

The depressor nerve is given off from the superior laryngeal nerve and the trunk of the vagus in the rabbit, and passes into the cardiac plexus. It conducts impulses from the heart to the vasomotor centre, and lowers the activity of that centre, thereby relaxing the bloodvessels somewhat. In this way the heart when overworked, owing to the increased resistance of high blood-pressure (vasomotor spasm), can be relieved as soon as is necessary.

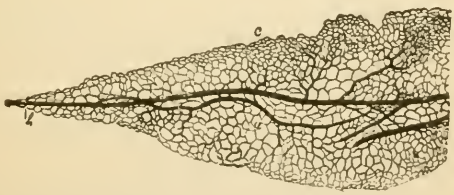
What is the function of the so-called pressor fibres of the laryngeal nerves?

They stimulate the vasomotor centre, causing a rise of blood-pressure. They are, therefore, the direct opponents of the depressor fibres.

What are the functions of the bloodvessels?

The bloodvessels carry blood to and from the various tissues and organs. They are divided up into three divisions, known as: 1,

FIG 2.



Capillary network of fat tissue. (KLEIN.)

arteries and arterioles; 2, capillaries; 3, veins. Of these three, the capillaries are most important in their function, since they not only carry blood, but owing to the peculiarity of their walls,

bring the blood into intimate relation with the tissues. The fluid which escapes from the capillaries is known as lymph, and the function of lymph is to irrigate and nourish.

What is the difference between arteries and veins?

Arteries differ from veins in having thicker walls, owing to a greater development of their outer coats.

Remember! The fact that arteries do not contain valves is not a differential point, since some veins contain no valves.

Also that they are not differentiated by the kind of blood they carry, but by their structure; the pulmonary artery carries venous blood, while the pulmonary veins carry arterial blood.

How many coats have the arteries?

They have three coats, known as the *outer*, or *tunica adventitia;* the *middle*, or *tunica media;* the *inner*, or *tunica intima*. The last of these is made up of transparent *endothelium*, composed of irregular, long, fusiform cells held together by a cement substance which is stained black by nitrate of silver ($AgNO_3$). Outside the endothelial coat lies a very thin, more or less fibrous layer, the *sub-endothelial;* and outside of this is the *elastic lamina*, which in the smallest arteries amounts to nothing more than a structureless or fibrous membrane, whilst in the other vessels its function is most important. It is known as the *fenestrated membrane*. The *tunica media* contains much unstriped muscular fibre, which increases in amount as the vessel grows larger. Most of these fibres are circular, completely surrounding the vessel, while a much smaller number run longitudinally. The *tunica adventitia*, or the outer coat in the smallest arteries, is a structureless membrane which changes into a fibrous membrane as the vessel increases in size.

What are the functions of these coats?

The *endothelial layer* forms a smooth surface over which the blood may pass, and the importance of this will be understood when it is remembered that rough surfaces aid in the coagulation of the blood. The *muscular coat* regulates the amount of blood received by each part and governs the *elastic coat*. This is neces-

sary, since it is manifest that the heart cannot regulate the blood-supply of each portion of the body.

Does the muscular coat aid in the propulsion of the blood?

No; it must be distinctly remembered that in the higher animals, *particularly in man*, the muscular coat probably aids very slightly in the propulsion of blood.

In what way do these coats aid in arresting hemorrhage?

The muscular coat aids, in conjunction with the elastic coat, in the prevention of extensive hemorrhage by contracting the opening in the bloodvessel, turning in its edges so that the opening is greatly decreased in calibre.

What other function has the elastic coat?

A more important function of the elastic coat is the prevention of sudden pressure in any portion of the body by yielding partially to a sudden strain or controlling a tendency to too great a dilatation. It, therefore, equalizes blood-pressure during diastole and systole, and were it not for this important coat the arteries would be entirely emptied during diastole and filled to bursting during systole.

What is the function of the outer fibrous coat of the larger bloodvessels?

To protect the bloodvessels from injuries from the exterior and to give the bloodvessel walls support. If it were not for the fibrous coat a ligature applied to a vessel would cut through.

What have we in some veins which do not occur in arteries?

Valves which flap back against the wall of the vessel as the blood flows onward, but which prevent any reflux should the current be reversed by any cause.

How are these valves arranged, singly or in pairs?

In pairs.

Is there any difference in the capacity of the various portions of the vascular system?

The combined calibre of the branches of an artery exceed in their capacity that of the parent trunk, and so soon as the muscular coat of an artery is past the capacity of the vascular system is enormously increased. The capillaries are capable of holding eight hundred times as much blood as the aorta. The veins diminish in area as they come toward the heart, whilst the arteries increase as they go toward the periphery. The capacity of a vein is always greater than that of a corresponding artery: even at the heart the capacity of the venæ cavæ is twice as great as that of the aorta.

FIG. 3.

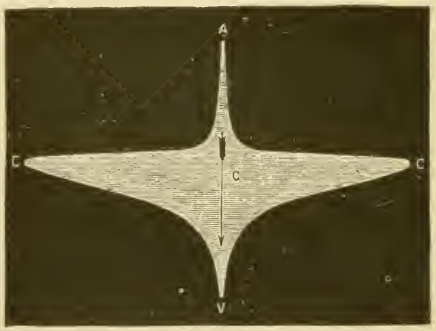


Diagram intended to give an idea of the aggregate sectional area of the different parts of the vascular system. A. Aorta. C. Capillaries V. Veins. The transverse measurements of the shaded part may be taken as the width of the various kinds of vessels, supposing them to be fused together. (YEO.)

What do you mean by blood-pressure?

The pressure under which the blood stream is kept by the action of the heart and the walls of the bloodvessels.

Is the blood pressure always constant in man and animals?

The blood pressure varies from many causes, and differs in nearly all animals. In the rabbit it can support a column of mercury from two to three and a half inches in height, in the dog from four to five and a half inches, in the horse from eight to twelve inches, while in man the pressure will hold a column of mercury as high as five and three-fourths inches. The pressure in the human aorta is estimated at four pounds and four ounces, in the horse eleven pounds and nine ounces, in the radial artery of man at four drachms, in the pulmonary artery two pounds and two ounces. But it must be remembered that these figures represent the maximum amounts at the moment of ventricular systole. The pressure is least in the capillaries, greatest in the aorta. The venous pressure is only one-tenth that of the arterial pressure.

What is the influence of the nervous system on blood pressure?

Nerves supply all the arteries and arterioles, and even the capillaries and veins, and belong to the so-called sympathetic system.

What are these nerves called?

Vaso-motor nerves.

How are they arranged and governed?

By a centre in the medulla oblongata known as the *vaso-motor centre*, which is situated near the calamus scriptorius and the corpora quadrigemina, the tension of the vascular system is governed. Fibres from this centre pass down in the neck through the spinal cord, and find exit with the anterior roots of the spinal nerves. The vaso-motor centre is probably always at work, and to aid it we have scattered through the spinal cord, and in various portions of the body, lesser centres under its control, but capable of originating impulses themselves.

What proof have we that this is so?

If the cervical sympathetic be cut on one side in the rabbit, or in any animal, that side of the head becomes very rapidly deeply suffused and congested, and remains in this condition for many hours. Finally, however, the color returns almost to normal, and

congestion goes down. The first dilatation was due to the fact that the governing centre in the medulla by the section, was cut off from that side, and the minor centre not being accustomed to send out powerful impulses, is unable to govern its tributary bloodvessels. In a short time, however, the local centre gathers power, and once more exerts not only its previous influence over the vascular supply of that side, but also is enabled to supplement the action of the higher centre in the medulla, which, before the section, constantly aided it in its efforts.

What effect has stimulation of the vaso-motor system on blood pressure?

It raises it by contraction of the bloodvessels all over the body.

What effect has depression of the vaso-motor system on blood pressure?

It lowers it by dilatation of the bloodvessels.

What effect has division of a vaso-motor nerve on its tributary vessels?

It produces palsy, or relaxation, of its tributary muscles in the wall of the bloodvessel, and, as a consequence, a local or, if the vessels are large enough, indirectly a general fall in blood pressure, by drawing a large amount of blood from the general system. Stimulation of a nerve, on the other hand, produces a contraction of these muscles and a rise of pressure. Blushing is a good example of vaso-motor disturbance of the nervous apparatus governing the vascular system.

What effect has galvanization of a sensory nerve on general blood pressure?

It raises it.

What effect has it on bloodvessels of a leg in which the sensory nerve is galvanized?

It dilates them and locally lowers pressure.

What effect has asphyxia on blood pressure?

It increases it by stimulation of the vaso-motor centre in the medulla by the increased amount of CO_2 in the blood.

What effect has section of the spinal cord on blood pressure?

It produces a great fall in pressure, due to the cutting off of the vaso-motor centre in the medulla from the vascular system all through the body.

What effect has paralysis of the vaso-motor nerves supplying the abdominal bloodvessels?

A general fall in blood pressure all over the body.

Why is this so?

Because these bloodvessels are capable of holding all the blood in the body, and so starve the rest of the vascular system.

What other causes increase arterial pressure?

Increased heart action, whereby more blood is driven out into the bloodvessels in a given space of time. The increase in heart action may be by increased rate or force, the result is the same.

What are the physical forces of the circulation?

Liquid always goes away from pressure, and the pressure depends on the ease of escape and the forces from behind. If a tube be elastic, and its distal end open and small, it will be found that though the liquid enters it in jerks at the proximal end, it will leave the distal end in a steady stream, but if the tube is rigid the liquid moves in jerks along its whole length. This is the *key* to the circulation.

Under what conditions is the blood placed after being driven out of the ventricle into the arterial system?

Just before the arteries are changed into capillaries they are known as arterioles; it is in these arterioles that we still have the muscular coat quite powerfully developed and governed by the vaso-motor system. These muscular coats are kept at a certain degree of tonicity, producing thereby a considerable narrowing of the blood paths, and they, therefore, prevent the blood from flowing out into the capillary system too rapidly. On the other hand, the force given to the blood by the heart has so distended

the arterial system, particularly in the larger trunks, that the elastic coats have been greatly stretched, and no sooner does the pressure from the heart muscle cease than they contract on the blood. Pressed upon in this manner on all sides, the blood endeavors to find some mode of exit, and is prevented from regurgitating back into the ventricle, in health, by the valves at the aortic opening. As a consequence, the blood obeys the physical law already mentioned, and passes in the direction of least resistance, namely, through the contracted arterioles.

What is the function, therefore, of the arterioles?

To prevent too rapid a flow into the capillary system, which, if permitted, would immediately starve both the arteries and veins of their proper amount of blood, since, as before noted, the capacity of the capillaries is extremely great.

What aids blood flow in the capillaries?

Capillary attraction and pressure due to muscular movements of the body. Also to the action of the heart and arterial coats.

What aids blood flow in the veins?

Lateral pressure exerted by contraction of the voluntary muscles of the body, the indirect action of the valves in the veins, and, to a slight degree, the heart force. Also, the suction produced by movements of the thorax in respiration (not the heart).

Does the blood find it more difficult to return through the veins than to descend through the arteries?

No; the circulation in this respect resembles a U-shaped tube filled with mercury, in which the column rises on one side, due to pressure or displacement on the other. In other words, the blood descending in the femoral artery shoves the blood up the corresponding vein.

Is there difference in the rapidity of the flow of the blood in the arteries, capillaries, and veins?

Yes; in the artery the flow is very rapid and in spurts, in the capillaries it is many times slower and generally moves in a steady

stream. In the veins the rapidity of the flow increases as the blood nears the heart, but moves in a steady stream, and does not attain the speed of the blood in the arteries.

What is the pulse?

The pulse is caused by a wave of force which travels along the column of blood in an artery as a direct result of a single contraction of the heart; in other words, each pulse represents a heart beat, but not the blood thrown out at that beat. The stroke given by the heart in propelling the blood onward is expended in causing not only the forward movement of the whole mass of blood, but also the lateral expansion already spoken of. As a consequence of this, each pulse is like an expansion wave, causing the vessel to expand by reason of the increased tension and force produced by the heart from behind.

Is the rapidity of the pulse wave the same as the rapidity of the blood stream in the artery?

No; the main current passes along the vessel at a given rate of speed, while the force of each systole is transmitted along the blood stream as if it were a solid piece of metal or wood, which, having been struck at one end, transmits a wave of force to the other end. The blood being enclosed in partially rigid walls carries the impulse chiefly forward, not laterally. The pulse wave is twenty or thirty times as rapid as the blood current itself.

Does the pulse cause simply a lateral dilatation of the bloodvessel?

No; the bloodvessel is not only widened, but lengthened, so that a straight artery may be seen not only to dilate, but also to become curved to make up for its elongation.

Is the pulse wave equally strong in all portions of the body?

No; it diminishes in force and in speed as it travels onward, due to the force expended in distending successive parts of the bloodvessel, friction, and other causes. As a consequence of this, the pulse in certain portions of the body occurs an appreciable length of time after the cardiac contraction which has produced it. This

is noticed particularly in the radial artery, or markedly in the dorsalis pedis artery. The delay, however, even at the most distant point amounts to not more than one-sixth to one-eighth of a second.

At what speed does the blood circulate?

About ten metres or thirty-five feet per second, and takes but one-third of a second to pass a given point. The length of each pulse wave is, therefore, about three metres ($9\frac{1}{2}$ feet), or twice the length of the longest artery. When the last part of the pulse wave has passed the arch of the aorta the first part has just reached the arterioles.

RESPIRATION.

The respiratory apparatus is divided into the larynx, trachea, bronchial tubes, bronchioles, and vesicles in the lung. Surrounding each lung are the pleuræ, one layer of which is attached to the lung (visceral layer), the other to the chest wall (parietal layer).

What is the object of respiration?

In order to bring the oxygen of the air in close relationship with the hæmoglobin in the blood, and to permit of the elimination of CO_2 from the body, as well as other effete products in very minute amount. The enlargement of the chest occurs with *inspiration*, the contraction of the chest with *expiration*.

How many varieties of blood-supply exist in the lung?

Two; the *pulmonary artery* supply, and the *bronchial artery* supply.

What is the function of these two varieties?

The pulmonary artery supplies the blood for aëration, the bronchial artery that for the nourishment of the lung-tissue itself.

In what manner is the blood brought to the vesicles and exposed to the air?

The smaller branches of the pulmonary artery split up more and more, and have the *peculiarity that they do not anastomose* with one another. The fine capillaries run between the air vesicles, the

thin wall of the vessel and vesicle permitting the free interchange of gases to take place.

What difference do we have in the distribution of the bronchial and pulmonary veins from that of the arteries?

The pulmonary and bronchial veins anastomose with one another.

Is the circulation more or less rapid in the lung capillaries than elsewhere?

More rapid, since their area is not so great.

Why are the pulmonary veins slightly smaller than the artery?

On account of the lessening of fluid due to exhalation of moisture in respiration.

Are the movements of the lung passive or active?

They are passive, merely following the movements of the chest walls.

What are the movements of inspiration?

In inspiration all the diameters of the thorax are increased. The lateral or transverse diameter is increased by the raising of the ribs; the shape of the ribs and their relation to the vertebral column are such as to carry them outward at the same time that they are raised. This same movement carries the sternum forward, thus increasing the antero-posterior diameter. The increase in the vertical diameter is due to descent of the diaphragm, the dome-shaped surface of which becomes less arched. For this reason *the diaphragm is the most important respiratory muscle.*

The other muscles concerned in the inspiratory act are the quadrati lumborum, serrati postici inferiores, scaleni, serrati postici superiores, levatores costarum longi et breves, and intercostales externi et intercartilaginei.

In forced inspiration the following muscles supplement them: sterno-cleido-mastoidei, trapezii, pectorales minores, pectorales majores (costal portion), thromboidei, and erectores spinæ.

What are the movements of expiration?

Ordinary expiration is a passive act, brought about by the elastic tension of the lungs, costal cartilages, abdominal viscera, and abdominal walls, aided by the weight of the thorax. Contraction of the intercostales interni interossei may assist. In forced expiration

these muscles are active, as are also the triangulares sterni, musculi abdominales, and levatores ani.

What effect has sex on respiration?

In men respiration is largely abdominal or diaphragmatic; in women chiefly costal or thoracic. These differences are not due to sex, but to dress and heredity. In young children respiration is chiefly diaphragmatic.

Which is longer, inspiration or expiration?

The mean ratio of inspiration to expiration is as 5 : 6.

What sounds do we hear on listening to the chest?

The respiratory murmurs, which are produced by the passage of the air in and out of the respiratory apparatus.

What do you mean by "tidal air"?

The ordinary volume of air respired, amounting to about thirty cubic inches in the adult.

What do you mean by "reserve air"?

The air which can be voluntarily emitted after ordinary expiration. It amounts to about one hundred cubic inches.

What do you mean by "complemental air"?

The amount which can be taken in after an ordinary inspiration.

What do you mean by "residual air"?

It is the amount which remains after forced expiration, equalling about one hundred and twenty cubic inches.

What does the term "vital capacity" mean?

The greatest amount of air which can be emitted after forced inspiration, and is therefore the sum total of reserve, tidal, and complemental air. It varies with age, sex, size, posture, and occupation. The total quantity in an adult, passing in and out in twenty-four hours, is 686,000 cubic inches; in hard-working laborers, 1,568,390 cubic inches. For every inch of height above five feet one inch the capacity should increase eight cubic inches.

What influence has sex on capacity?

Females have less capacity than males where the chest has the same circumference.

How many respirations a minute?

Fourteen to twenty, but the number is influenced by sex, the age, and position, also by exertion. The size of the animal governs rapidity. The mouse breathes very rapidly; the elephant only eight times per minute.

What effect has the law of the diffusion of gases on respiration?

In the vessels we have a large amount of CO_2, while in the air we breathe we have an excess of O. According to this law, therefore, the O attempts to get in as the CO_2 attempts to get out. This law also prevents the reserve and residual air from becoming laden with CO_2. The change is assisted, too, by the different temperatures of the air within and without.

What amount of work is performed by the respiratory muscles?

The work done by the respiratory muscles is estimated by Haughton at 21 foot-tons in twenty-four hours.

What changes have we produced in the atmospheric air by respiration?

1. Increase in its temperature.
2. Increase in CO_2.
3. Increase in organic matter and free ammonia.
4. Increase in watery vapor.
5. Diminished amount of O.

The expired air is hotter than the inspired as a general rule, but on a hot day, with the atmosphere above 98.8° F., it is cooler.

The temperature varies from 97°–99½° F., according to the length of time the air remains in the lungs.

Is the amount of CO_2 exhaled constant?

It varies at all hours of the day, and is influenced by many conditions. The CO_2 given off by a normal man in an hour equals 1346 cubic inches, or 636 grains. Accordingly we have 173 grains of carbon given off in an hour, or 8 ounces in twenty-four hours.

Time of day, varieties of food, and exercise, greatly influence the amount of CO_2.

Does age affect the amount of CO_2?

Yes; CO_2 increases in amount from 8 to 32 years, while from 35 to 50 it remains stationary, or slightly falls. After 50 years it constantly diminishes. At 80 years it scarcely exceeds that of a child of 10 years.

How much O is abstracted from every volume of air?

About 4½ per cent.

What effect has quickening of the respiratory movements on the amount of CO_2?

The quicker the respirations the less CO_2 in each respiration, but the aggregate amount is increased.

What portion of the expired air contains the most CO_2?

That of the last half of expiration.

What effect has the condition of the atmosphere on the amount of CO_2?

More CO_2 is given off when air is moist than when it is dry.

What influence has the time of day on the relative amounts of CO_2 and O?

During the day more CO_2 is exhaled than O is taken in; while at night the reverse is the case. In other words, there is a reserve fund of O stored up at night to meet the exigencies of the day.

Is a very large amount of watery vapor given off by the lungs?

Yes; almost enough to saturate the expired air. The amount equals 6 to 27 ounces in twenty-four hours. The average amount is from 9 to 10 ounces.

Does ammonia exist as a physiological constituent of all expired air?

No; it does not. It is chiefly derived from decomposition products in the mouth.

The Nervous Mechanism of Respiration.

Is respiration purely an involuntary act?

No, it is not; since we can "hold the breath," or breathe rapidly or slowly, superficially or deeply, as we choose. That it is involuntary to a great extent is proved by the fact that one does not stop breathing when asleep or unconscious.

Respiration is governed by a centre, the respiratory centre, in the medulla oblongata near the calamus scriptorius.

What keeps this centre active?

It is kept active by the condition of the blood. If the amount of O is too small the centre sends out impulses and increases respiration.

Describe this centre more fully.

There is a respiratory centre on each side of the medulla oblongata, and these may in turn be divided into two centres, namely, the greater one for inspiration and lesser for expiration.

Does the expiratory centre constantly send out impulses?

No; it is only active on rare occasions, as when there is some obstruction to respiration.

Are there any centres for respiration higher up in the nervous system than the medulla oblongata?

No. All phenomena which have suggested such a centre can easily be explained as centripetal stimulations of the medulla oblongata, which by reflex action act on the respiratory centre in the fourth ventricle.

Are there any respiratory centres in the cervical part of the cord?

No. Only the tracts which carry the impulses.

What do you mean by eupnœa, apnœa, and dyspnœa?

Eupnœa is normal breathing; apnœa is a condition in which too much O is absorbed into the blood, and is readily produced by forced artificial respiration. *Remember*, that the use of the word apnœa to indicate a condition in which breathing has ceased from the ordinary causes, is incorrect. Breathing in apnœa ceases from

the excess, not the lack, of oxygen. Dyspnœa is labored or difficult breathing.

What effect has the pneumogastric apparatus on respiration?

If both vagi are cut the respirations become somewhat deep and full. If these nerves are stimulated the respirations become very rapid and violent.

Is this change due to a direct transmission of the stimulus along the nerves to the lungs, or to a reflex wave to the respiratory centre?

It is due to a reflex wave to the respiratory centre. *Remember*, that the vagus nerves are made up of both efferent and afferent fibres. Also *remember*, that not only do we have an efferent and afferent set of fibres, but that the afferent fibres are made up themselves of two sets of fibres, one of which, the central end of the superior laryngeal branch, after it has been cut, when stimulated slows the respirations, while stimulation of the central end of the vagus itself quickens the respirations. When the nerve is stimulated the impulse goes upward to the centre, and from there is irradiated down to the organs.

Sighing is a long inspiration. When great attention is being paid we speak of "shallow breathing." In other words, we almost forget to breathe. Sighing always follows this condition, and makes up for the shallow breathing before it.

Hiccough is a sudden inspiration due to descent of the diaphragm.

Coughing is expiratory.

Sneezing is expiratory, but is preceded by a full inspiration.

In speaking we expire.

Sobbing consists of a series of short inspirations, after each of which the glottis is closed.

Laughing is a series of short and rapid expirations.

DIGESTION.

What three forms of digestion have we?

Salivary, gastric, and intestinal.

What is the function of salivary digestion?

To convert starch into maltose.

On what does the gastric digestion act?

On the proteids, converting them into peptones.

What part of digestion is carried on in the small intestine?

The fats are prepared for absorption by being emulsified, the proteids converted into peptones, and starch is changed to maltose and dextrose.

The salivary secretion is derived from what three glands?

The submaxillary, sublingual, and parotid. The mucous glands present in the mouth are solely for the purpose of lubrication.

Describe the characteristics of the saliva.

It is a mixture of the secretion of the three glands named, and is a slightly turbid, tasteless fluid of a distinctly alkaline reaction. The specific gravity is 1003. It contains five-tenths per cent. of solids, the greater part of which are organic, such as mucin, which produces the viscidity, traces of albumin, and a peculiar ferment, *ptyalin*. The inorganic constituents are salts, the chief one of which is potassium sulphocyanide, which may be readily perceived by its odor when saliva is kept for a short time in a test tube. The other portions of the saliva are made up of salivary corpuscles which contain nuclei, and are probably altered leucocytes, epithelial cells, and various microörganisms.

How much saliva is secreted in twenty-four hours?

From 7 to 70 ounces.

What is the difference between parotid saliva and that of the other glands?

It contains more ptyalin, a smaller amount of urea, traces of a volatile acid, and some inorganic constituents, as salts of soda and potash; it contains no mucin, and is much thinner than is the secretion of the submaxillary or sublingual glands.

Describe the submaxillary saliva.

Submaxillary saliva is markedly alkaline, tenacious, and contains mucin; it contains much less ptyalin than does parotid saliva.

Describe the sublingual saliva.

Sublingual saliva is more sticky and cohesive than either of the others, and contains much mucin, salivary corpuscles, and potassium sulphocyanide.

What is the nerve supply of the salivary glands?

The *submaxillary* glands are supplied by the chorda tympani, which is derived from the facial nerve. It also receives filaments from the superior cervical ganglion of the sympathetic, and from the submaxillary ganglion.

Remember, that the chorda tympani contains two sets of fibres: 1st, true *secretory* fibres; 2d, *vaso-dilator* fibres.

The sympathetic also contains two sets of fibres: 1st, true secretory; 2d, vaso-constrictor fibres.

The *sublingual* glands are supplied by the same nerves as supply the submaxillary. The *parotid* glands are supplied by branches of the facial which join the auriculo-temporal branches of the fifth pair of cranial nerves.

What is the effect of section of the chorda tympani?

The flow of saliva is very greatly decreased.

What is the effect of stimulation?

Increased salivary flow and increased glandular vascularity.

What is the effect of stimulation of the facial nerve at its origin in the floor of the fourth ventricle?

It increases the salivary flow from the submaxillary gland.

What is the effect of stimulation of the sympathetic?

It causes a decrease in the salivary flow, with contraction of the bloodvessels and consequent decrease in vascularity.

Does the increase in salivary flow depend upon increased vascularity?

No; since if all the bloodvessels going to the gland be tied, secretion is still increased either when the chorda tympani is stimulated or when the sympathetic is paralyzed; under these circumstances the extra liquid required is obtained from the lymph vessels and spaces. Atropine and daturine are drugs which decrease salivary secretion by depressing the chorda tympani peripherally.

Remember, that mere increase in vascularity in the salivary glands does not of necessity increase the flow of saliva. The only influence which increased vascularity exerts is a greater supply of liquid which escapes from the gland rather by leakage than by secretion.

Is the pressure in the excretory ducts of the salivary glands very great?

Yes; Ludwig has found that the pressure in these ducts may be twice as great as the blood-pressure in the carotid itself. The pressure in Wharton's duct may equal 200 millimetres of mercury.

What is the cause of the great pressure in the salivary ducts?

It is due to the secreting power of the cells in the gland.

What change in temperature occurs in the gland?

During secretion the temperature of the gland rises, so that it is often warmer than the arterial blood.

How do you produce increased salivary flow from the parotid?

By stimulation of the facial nerve after it has joined the auriculo-temporal branch of the fifth or trifacial nerve, or reflexly by stimulation of the glosso-pharyngeal nerve.

In what way is secretion brought about when food enters the mouth?

Reflexly through the lingual branch of the glosso-pharyngeal and the inferior maxillary branch of the trifacial or fifth nerve, which carry the impulses up to the centre in the medulla.

What effect has section of the chorda tympani on this reflex?

If the chorda tympani be cut previous to the introduction of a substance into the mouth no increase of flow comes from the glands which it supplies; but if the sympathetic be cut the reflex, although partially interfered with, is not prevented.

Is the rate of secretion always the same?

No; it varies according to the condition of the mouth and the food *in it*.

What effect have the movements of mastication on the salivary flow?

They increase it.

In what condition is an increased flow of saliva produced?

When nausea is present, profuse salivary secretion occurs by a reflex through the vagus nerve.

What is the physiological action of saliva?

Its most important action is its *diastatic* or *amylolytic* action, or, in other words, the transformation of starch into dextrins, and of dextrins into maltose.

What do you mean by the term diastatic?

The power which certain substances have of acting on starch and converting it into sugar.

Upon what does the diastatic power of saliva depend?

Upon *ptyalin*.

Is the ptyalin destroyed when it acts?

Scarcely at all, for it acts by catalysis, or its mere presence.

What effect have high and low temperatures on the action of ptyalin?

High and low temperatures prevent its action, and boiling and freezing stop it absolutely.

What is the sugar called which is formed by the action of the saliva?

The sugar formed by the action of saliva on starch is called maltose, which is converted into dextrose by an inverting enzyme in the small intestine. It is in the form of dextrose, or dextrose and levulose, that the carbo-hydrates are absorbed.

What is the object of boiling starchy foods?

In order to break up the cellulose coverings of the starch granules, and enable the diastatic ferment to attack the starch.

What is the first change in the starch as it is digested?

It becomes liquefied.

What are the mechanical uses of saliva?

It keeps the mouth moist, facilitates speaking and the mastication of food, also the movements of the tongue. It dissolves certain substances, and renders them capable of being tasted; by

mixing with food it forms a soft bolus which is easily swallowed and digested.

What are movements of mastication?

1. The elevation of the jaw is accomplished by the combined action of the temporal, masseter, and internal pterygoid muscles.

2. The depression of the jaw by its own weight, aided by the action of the anterior bellies of the digastrics, mylo-hyoids and genio-hyoids, and the platysmas.

3. The displacement of the articular surfaces backward or forward is produced, when forward, by the external pterygoid muscles which pull the jaw down and forward. As one external pterygoid acts it pulls the jaw sideways and we have a grinding movement. When the movement is backward the digastric and hyoid muscles act.

What is the function of mastication?

We divide, by this means, the food into small pieces, biting it off by the incisors, tearing it off by the canines, and grinding it up by the molars. Soft food is broken up by the tongue pressing it against the roof of the mouth. By this means the digestive fluids may attack the food more readily.

What is the function of the tongue in mastication?

To keep the food between the teeth, in which it is assisted by the muscles of the lips and the buccinator muscles.

In what way is deglutition accomplished?

1. The aperture of the mouth is closed by the orbicularis oris.

2. The jaws are pressed together by the muscles of mastication.

3. The tip, middle, and root of the tongue, one after the other, are pressed against the hard palate, thereby propelling the food backward. Just at this time the levator palati draws the soft palate upward and backward, completely closes the posterior openings of the nasal cavities, and the intrinsic muscles of the larynx firmly close the rima glottidis.

4. After the anterior palatine arch is passed, it is prevented from returning to the mouth by the palato-glossi muscles, lying in the anterior pillars of the fauces.

5. The bolus is now urged on, first, by the action of the superior constrictors of the pharynx, next the middle, and third the inferior constrictors.

6. Having reached the œsophagus, it is urged on by the outer longitudinal and the inner circular non-striped muscular fibres, which contract peristaltically. Recent experiments show that this peristalsis only occurs on forced deglutition, the food ordinarily being projected into the œsophagus by the voluntary muscles.

What is the nervous mechanism of deglutition?

The centre for swallowing is in the medulla oblongata. The efferent nerves which govern deglutition are: the hypo-glossal, which supplies the hyoid or tongue muscles; the glosso-pharyngeal and vagus nerves to the pharyngeal plexus, which supply the constrictor muscles; and the facial and fifth, which supply the fauces and palate. The movements of the œsophagus are governed both afferently and efferently by the vagus, which also acts with the superior maxillary branch of the trifacial. The afferent vagus filaments for the first part of deglutition are the pharyngeal branches of the anterior laryngeal branches.

The Stomach.

What varieties of cells do we find in the stomach?

In the cardiac end of the stomach we have two distinct kinds of cells. One kind, the most numerous, consists of small, pale, spheroidal cells which line the interior of the glands. The other cells are much fewer as well as larger, and are scattered over the fundus of the glands.

What two sets of glands have we in the stomach?

The mucous, which are chiefly situated at the pyloric end of the stomach, and those which secrete gastric juice.

What are the movements of the stomach?

When the stomach is empty it lies with its greater curvature downward and its lesser upward; when it is full the greater curvature swings forward against the abdominal wall, while the lesser curvature approximates itself to the spinal column.

What other gastric movements have we?

We have two distinct varieties of gastric movement different from the two mentioned: the first is a *rotatory* or *churning* movement whereby the walls glide over the food, these movements occur periodically and last for several minutes, their function is to moisten the food by the gastric juice and break it up; the other is

Fig. 4.

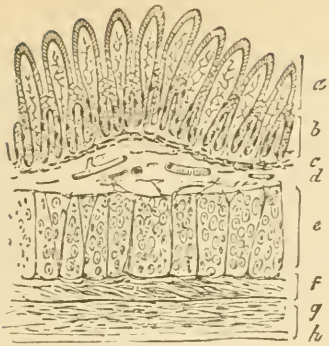


Diagram of a section of the wall of stomach. *a*, orifices of glands, with cylindrical epithelium. *b*, fundus of glands, with spherical and oval epithelium. *c*, muscularis mucosæ. *d*, submucous tissue, containing bloodvessels, etc. *e*, circular; *f*, oblique, and *g*, longitudinal muscle coats. *h*, serous membrane. (Yeo.)

Fig 5.

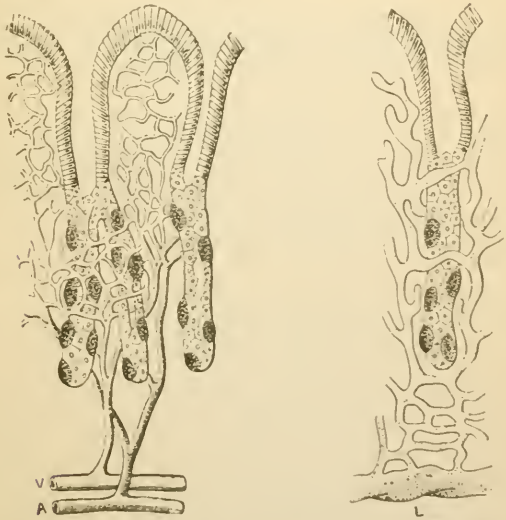


Diagram showing the relation of the ultimate twigs of the bloodvessels (V and A) and of the absorbent radicals (L) to the glands of the stomach, and the different kinds of epithelium, viz.: above cylindrical cells; small, pale cells in the lumen; outside of which are the dark ovoid cells. (Yeo.)

the *peristaltic* movement whereby the food is pushed out into the duodenum through the pylorus.

What are the intrinsic and extrinsic nerves of the stomach?

Auerbach's plexus is the motor portion of the apparatus. The left vagus supplies the anterior surface of the stomach, the right vagus supplies the posterior surface.

Describe the gastric juice.

It is a tolerably clear, colorless fluid (straw-colored), of acid reaction, sour taste, and peculiar characteristic odor; it is not rendered turbid by boiling and resists putrefaction for a long time; its specific gravity is 1002.5. The quantity secreted in twenty-four hours amounts to from eight to fourteen pints.

What does the gastric juice contain?

First, *pepsin*, the characteristic nitrogenous hydrolytic ferment, which dissolves proteids; second, *hydrochloric acid*, the chief acid present; also small amounts of lactic acid. The latter, however, is not secreted, but is due to decomposition of carbo-hydrates in the stomach.

Which cells secrete the greatest amount of pepsin?

Those at the cardiac end of the stomach.

Does pepsin exist in the glands ready formed?

According to most physiologists it is due to the presence of a compound known as pepsinogen, which forms pepsin as soon as it comes in contact with hydrochloric acid in the stomach.

What is the function of lactic acid?

It digests the proteids in much the same manner as does hydrochloric acid.

Does secretion go on constantly in the stomach?

No. Only on the entrance of stimuli, such as food, etc.

What change takes place in the gastric mucous membrane on the entrance of food?

It becomes red and the circulation more active.

What happens to the gastric juice when the food passes out of the stomach into the alkaline intestine?

It is neutralized and part of the pepsin reabsorbed.

What is chyme?

The mixture of food and gastric juice.

What effect has gastric juice upon proteids?

It changes the proteids first into a substance known as syntonin or acid-albumin, which is immediately changed again into propeptone or hemi-albuminose or para-peptone. The para-peptone is now converted into peptone, which is absorbed into the blood from the small intestine and immediately converted back again into proteids, and so deposited in the tissues.

Does pepsin suffer any change when acting?

It acts chiefly by catalysis, but is partially destroyed.

(For properties of peptones and para-peptones, see page 19.)

Is any albumin absorbed unchanged?

According to Yeo, a considerable quantity of albumin is absorbed unchanged, both from the stomach and intestines.

What other special ferment have we in the stomach?

The milk-curdling ferment.

What is the action of the gastric juice on carbo-hydrates?

It has no effect on starch, inulin, or the gums. Cane-sugar is slowly changed by it into dextrose and levulose.

Why does not the stomach digest itself?

There is much discussion in regard to this point. No satisfactory explanation has been given. Some physiologists teach that the protection which the coats of the stomach, during life, seem to have is due to the constantly circulating alkaline blood through them.

This explanation is unsatisfactory, as it does not explain why the small intestine is not digested by its alkaline fluids. All that can be said in either case is that living tissue is protected from self-digestion by the properties of its living structure.

What gases have we in the stomach?

Those which are derived from the air which is swallowed with the saliva and those which regurgitate from the duodenum. Besides these we have gases which arise in cases of dyspepsia from fermentative and putrefactive changes in the food.

What is the mechanism of vomiting ?

It is caused by contraction of the walls of the stomach, whereby the pyloric sphincters are closed. It occurs most easily when the stomach is distended, and in infants, owing to the peculiarity of the position of their stomachs, the regurgitations of milk are due to scarcely more than reversed peristalsis. In children, therefore, the abdominal muscles do not always aid in the expulsion of food. In adults they always do.

In what way is vomiting produced ?

Vomiting is produced either by an action on the peripheral ends of the nerves of the stomach or by direct action on the vomiting centre in the medulla.

What effect has section of the vagi on vomiting ?

It prevents it.

Do we ever have bile in vomit ?

Frequently when the vomiting is so severe as to cause the bile to flow out of the duodenum into the stomach.

What is the movement called by which food is passed along through the intestines ?

Peristalsis.

In what portion of the intestinal tract is peristalsis most marked ?

In the small intestine.

What is peristalsis ?

Peristalsis is the constantly moving onward of a contractile wave along the wall of the gut, or, in other words, is the progressive narrowing of the tube from above downward.

Do the movements of the stomach and intestine continue during sleep ?

Some physiologists believe that they do; others that they do not. The matter is largely one of opinion, but it is probable that the first opinion is the correct one.

What do you mean by reversed peristalsis?

A condition in which the peristaltic wave travels from below upward, the cause of which has been supposed by some to be due to the fact that one band of the muscular fibres in the gut misses a contraction.

What are the functions of the muscular coat of the intestine?

To carry on peristalsis.

What nervous influence is exercised over intestinal movements?

Auerbach's plexus is the automatic motor centre which lies between the muscular coats and produces peristaltic movements in sections of the gut removed from the body. Meissner's plexus is much less important, supplying only a few motor fibres to the muscular coats, and a few motor and sensory fibres to the muscularis, mucosæ, and intestinal glands.

What do you mean by aperistalsis?

An absolute abolition of peristaltic movement. Normal peristalsis is known as *euperistalsis*. When peristalsis becomes very violent it is known as *dysperistalsis*.

What influence has the circulation of the blood on peristalsis?

Violent peristaltic movement is produced by interrupting the circulation of blood in the wall of the gut, whether the stoppage is due to congestion or anæmia of the parts. This is the cause of the marked peristalsis preceding death.

What are the inhibitory nerves of the gut?

The splanchnics, which, however, also contain motor filaments.

What effect has stimulation of the splanchnics on peristalsis?

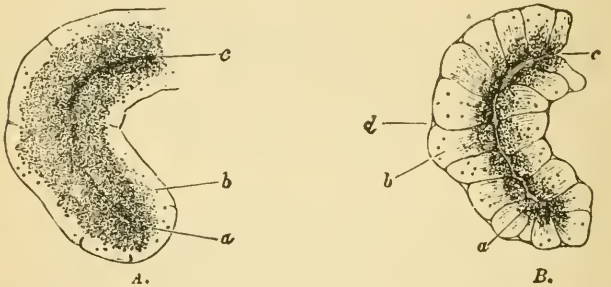
If the blood supply is normal it slows or prevents them. If abnormal, it increases them. The reason of this is that the inhibitory fibres of the splanchnics are paralyzed by venous blood in the gut, but the motor fibres are not.

Pancreatic Digestion.

Describe the pancreas.

The pancreas is a large racemose gland attached by its lateral branchlets to its main central duct. The cells making up the gland may be divided into two zones, an external homogeneous zone and an internal granular zone. Each zone corresponds to one-half of the cells, the clear half being next the boundary, and the granular half being next the lumen of the saccule.

FIG. 6.



One saccule of the pancreas of the rabbit in different states of activity. *A*. After a period of rest, in which case the outlines of the cells are indistinct, and the inner zone — *i. e.*, the part of the cells (*a*) next the lumen (*c*)—is broad and filled with fine granules *B*. After the gland has poured out its secretion, when the cell outlines (*d*) are clearer, the granular zone (*a*) is smaller, and the clear outer zone is wider. (KUHNE AND LEA.)

Describe the pancreatic juice.

Pancreatic juice is thick, transparent, odorless, and saltish in taste. The saltish taste is due to the presence of sodium carbonate; if acid be added CO_2 is liberated. It acts powerfully as a digestive agent.

What is the appearance of the pancreas when at rest and at work?

During digestion it is red and turbid, and at other times pale and anæmic.

What is the function of the pancreatic juice?

It contains at least four hydrolytic ferments, and is, therefore, a most important digestive fluid.

What are these four pancreatic ferments?

(1) The *diastatic action* is caused by a ferment known as *amylopsin*, a substance which seems to be identical with the ptyalin of the saliva.

What is the difference between the action of this ferment and ptyalin on starch?

It is much more powerful than ptyalin.

(2) The *tryptic action*, which is caused by the presence of a substance known as trypsin, or pancreatin, which acts on proteids converting them into peptones, or, as they are sometimes called, tryptones. The intermediary product between a proteid and a tryptone is alkali-albumin, corresponding to the acid-albumin of gastric digestion.

What are leucin and tyrosin?

Substances normally found in the small intestine produced by a too prolonged action of trypsin on its self-formed peptone. They are crystallizable nitrogenous bodies.

What are skatol and indol?

Strong, stinking decomposition products resulting from the continuation, pathologically, of this action of trypsin on peptone.

What is the difference in the manner in which trypsin acts on albuminous matters from that of the gastric juice?

In gastric digestion fibres of meat swell up before they are dissolved. In pancreatic digestion they do not swell up but become eroded.

What reaction is necessarily present for the pancreatic action to take place?

An alkaline reaction.

What is the alkali commonly present?

Sodium carbonate, the presence of which is as necessary to the pancreatic action as hydrochloric acid is to the peptic action.

What two forms of tryptones have we?

One known as anti-peptone, the other as hemi-peptone.

What is the action of the pancreatic juice on fats?

It first forms them into a fine emulsion, and secondly causes them to take up a molecule of water and split up into glycerine and fatty acids. This action of the pancreatic juice is due to the *third ferment*, known as *steapsin*.

According to Kühne and Roberts the pancreas contains, fourth, a *milk-curdling ferment*. The four are, therefore, as follows: amylopsin, trypsin, steapsin, and the milk-curdling ferment.

At what time is the pancreatic juice poured out?

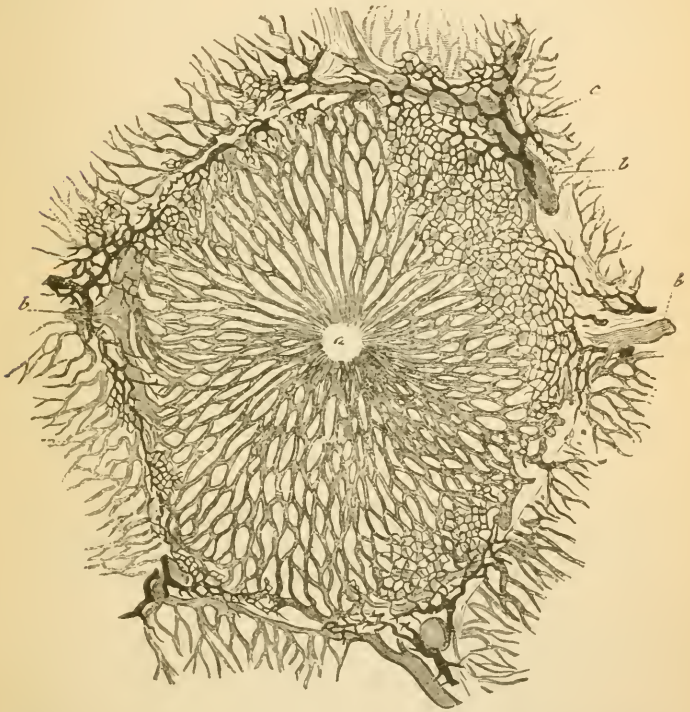
On the entrance of food into the small intestine coming from the stomach.

THE LIVER.

The anatomy of the liver is so closely concerned in its physiological functions that an outline seems unnecessary at this point. It will be remembered that the liver is made up of many little livers known as lobes and lobules, each lobule being a perfect gland in itself. The bloodvessels are derived from two sources, *first*, the *venous*, which enter by means of the *vena porta;* and which, branch-

ing, give off numerous *interlobular vessels* or *veins* forming dense plexuses around the lobules. Branching off from these interlobular vessels are the capillaries which converge to the centre of the lobule, forming elongated meshes, between which are rows of cells.

FIG. 7.

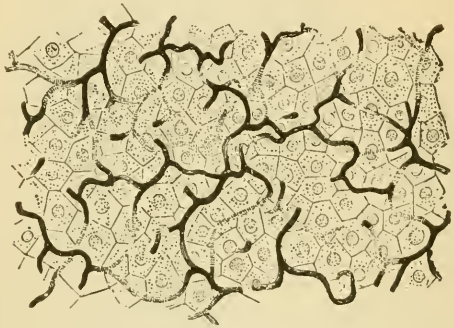


Section of lobule of liver of rabbit in which the blood and bile capillaries have been injected (after CADIAT). *a*. Intralobular vein. *b*. Interlobular veins. *c*. Biliary canals beginning in fine capillaries.

These capillaries on reaching the centre of the lobule form the intralobular vessel or central vein, which again joins together with

others and forms the radicles of the hepatic veins. The *second* set of bloodvessels are branches of the *hepatic artery* which dip down between the lobules to nourish the whole gland tissue whatever it may be. The *third* set of vessels which are present are known as the bile-ducts, which, arising from the centre of the lobule join one another and form the interlobular bile ducts, which anastomose and finally form the common biliary duct.

FIG. 8.



Section of the liver of the newt, in which the bile ducts have been injected, and can be seen to form a network of fine capillaries around the liver cells, the outlines and nuclei of which can be seen.

What is the chemical composition of the liver cells?

First, proteids or albuminous matters. *Second*, glycogen, or animal starch, which is a true carbo-hydrate, and is changed into sugar by a diastatic ferment.

What conditions influence the quantity of glycogen?

The eating of large quantities of starch, milk, fruit, or cane-sugar increases it greatly, while purely albuminous or fatty diets decrease it greatly.

What are the sources of glycogen?

It is probably derived from the carbo-hydrates of the food.

What are the functions of the liver?

The functions of the liver are three—the secretion of bile, the formation of glycogen, and the destruction of worn-out blood cells.

What is the use of glycogen in the body?

It is not really known.

Describe the bile.

Bile is a yellowish-brown or dark green transparent fluid with a neutral reaction and a bitter taste. Its specific gravity is from 1010 to 1050.

What does bile contain?

First, mucus, which makes it viscid, and which comes from the walls of the gall-bladder. Second, the bile acids, glyco-cholic and tauro-cholic acids, which unite with soda, forming cholates.

Which of the bile acids occur in human bile?

Both are usually present, though tauro-cholic may be absent.

What is Pettenkofer's test for bile?

Add concentrated H_2SO_4 drop by drop, then add a ten per cent. solution of cane-sugar when a reddish purple color is struck.

What is Heintz's test?

Heintz's test consists in adding nitric acid, when a play of colors results.

What are the bile pigments?

Bilirubin, which is yellowish-brown; *biliverdin*, which is green; *bilifuscin*, *biliprasin*, and *hydro-bilirubin*, the last being the normal coloring matter of the feces.

What is cholestrin?

Cholesterin is an univalent alcohol which occurs in the yolk of eggs, and in solution in the bile.

Is the secretion of bile a mere filtration of substances already in the blood?

No; it is a true secretion, being produced by the cells of the glands.

What is the quantity of bile secreted per day?

About seventeen ounces.

What is the difference between the contents of the blood-stream in the hepatic vein and the portal vein?

The hepatic vein contains more sugar (?), cholesterin, and blood-corpuscles, and less albumin, fibrin, free hæmoglobin, fats, water, and salts.

In what way is the coloring matter of the bile obtained?

By destruction of worn-out blood corpuscles.

What are the functions of the bile?

The emulsification of the fats, the lubrication of the walls of the intestine, and to increase the osmotic power of the wall of the gut in order to facilitate the absorption of fats. It also prevents to a very considerable extent decomposition and stimulates peristaltic action.

What is the fate of bile in the intestine?

Some of it passes out with the feces, and part is absorbed and eliminated as urobilin. The cholesterin is given off with the feces, and the bile salts are for the most part reabsorbed by the gut.

Have the other juices of the small intestine any digestive power?

They probably have some power in the solution of the proteids, and perhaps a diastatic action.

What is the fate of the salivary, gastric, and pancreatic ferments?

Ptyalin is destroyed in the stomach by the acid pepsin, and the milk-curdling ferment by the alkaline salts of the pancreatic and intestinal juices and by trypsin, the diastatic ferment of the pancreas by acid fermentation in the large intestine.

What is the function of the large intestine?

It absorbs the liquids from the fecal matter coming from the small intestine.

What is the amount of feces in twenty-four hours?

Six to twenty ounces according to the character of the food.

ABSORPTION.

FIG. 9.

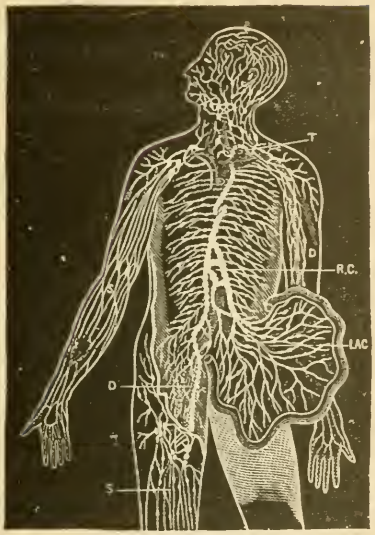


Diagram showing the course of the main trunks of the absorbent system. The lymphatics of lower extremities, etc., meeting the lacteals of intestines at the receptaculum chyli (R. C), which opens into the thoracic duct. The superficial vessels are shown in the diagram on the left arm and leg (S), and the deeper ones on the arm to the right (D). The glands are here and there shown in groups. The small right duct opens into the veins on the right side. The thoracic duct discharges into the union of the great veins of the left side of the neck. (YEO.)

The mucous membrane of the whole alimentary canal is capable of absorption, some portions more so than others.

Describe the intestinal mucous membrane.

In the mucous membrane are found small glands of two kinds—the first are Brunner's glands, and are localized in the duodenum, the others are those of Lieberkühn, which are distributed over the entire intestinal tract in great numbers.

What is a villus?

A small process from the wall of the intestine, containing blood-vessels and a lacteal.

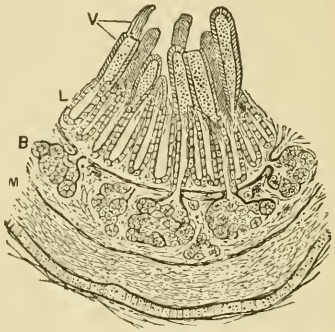
In what two ways does absorption occur?

By means of the blood-capillaries and the lacteals.

What substances are absorbed by the capillaries and what by the lacteals?

The first absorbs sugars and proteids, the lacteals the fats.

FIG. 10.



Drawing of transverse section of duodenum, showing Brunner's glands (B) opening into Lieberkühn's follicles (L); V, villi; M, muscular coats. (YEO.)

What portion of the gastro-intestinal tract carries on the greatest amount of absorption?

The upper half of the small intestine.

What is the position of the lacteal?

It lies in the axis of the villus, and is surrounded by a blood-vessel and a vein. The lacteals anastomose in the sub-adenoid tissue of the gut, and finally form lymphatic networks which end in the receptaculum chyli, the beginning of the thoracic duct which opens into the subclavian vein on the left side near the junction of the jugular. The villi are possessed of unstriped muscular fibres, which aid in emptying the lacteal, and the nerves which supply them are derived from Meissner's plexus.

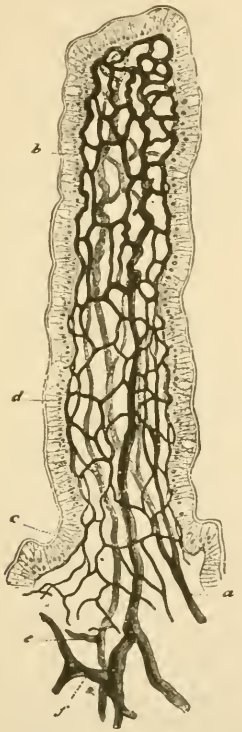
What three forces are at work in the absorption of digested food?

Endosmosis, diffusion, and filtration.

What do you mean by endosmosis and diffusion?

Endosmosis is the change which occurs between two fluids which are capable of forming an intimate mixture with each other through an animal membrane, but never between two fluids which do not

FIG. 11.



Villus, with capillaries injected, showing their close relation to epithelium, some of the cells of which are distended with mucus. (CADIAT.)

form a perfect mixture, such as oil and water. Diffusion is the mixing of two liquids placed one over the other in a vessel without the presence of a septum.

What is the law in regard to the diffusion of crystalloids and colloids?

Crystalloids will diffuse into colloids, but colloids will not diffuse

into crystalloids. Filtration occurs in the small intestine simply by the pressure which is exerted upon the fluid by the contraction of the walls, and also by a negative pressure or suction produced by the villi.

What is the influence of the nervous system on absorption?

Our knowledge is limited, but it has been found that after extirpation of the semilunar ganglion of Budge, or section of the mesenteric nerves, the intestinal contents became very fluid, which may be due to diminished absorption.

ANIMAL HEAT.

What do you mean by the term animal heat?

The temperature at which the body of a warm-blooded animal is maintained.

What is the normal temperature of man?

$98\frac{5}{8}^{\circ}$ F.

Is it constant in all persons?

It varies but a fraction of a degree.

Do all animals have the same temperature as man?

No; birds have as high as 107° F., and dogs as high a temperature as 103° F. In the lower animals the bodily temperature of members of the same species often varies.

Upon what does the temperature of cold-blooded animals depend?

Upon the temperature of the surrounding medium.

What conditions influence bodily temperature?

Age, sex, period of day, exercise, climate and season; food and drink also influence it.

What is the effect of age?

The temperature of a newborn child is one degree above that proper to the adult. In full adult life the temperature is lower than at any other time since it rises again in old age.

What effect has the period of day?

The variation may equal one to one and a half degrees, the minimum late at night or early in the morning; the maximum late in the afternoon.

What is the effect of exercise?

It raises the temperature; but physiologists differ as to the actual amount of increase thus, some state that the rise of temperature produced by exercise never raises the general bodily temperature more than about 1° F., while others believe that it raises it much more. Those who think the actual general rise is slight, believe that the great rise occurring in tetanus, where all the muscles contract, is due to some other concomitant pathological condition. Students must be governed in regard to this point by the opinion of their instructor. Climate and season have very slight influence over the bodily temperature.

What variations in bodily temperature may we have in disease?

In fever we may have a temperature as high as 106° and 110°, or even 115° F. In Asiatic cholera it sometimes falls to 77° or 79°.

What difference is there in the temperature of different portions of the body?

The surfaces of the hands and feet are cooler than any other portion of the body, while the liver often is as high as 105° F.

From what source is animal heat derived?

The ultimate source is contained in the potential energy taken into the body with food and with the oxygen during respiration, but the amount of heat formed depends upon the amount of kinetic energy liberated. The energy of the food stuffs may be called "latent heat." (For definitions of these terms, see Bodily Metabolism.)

What are the direct sources of heat?

The blood during digestion becomes laden with more carbon, hydrogen, and oxygen than is needful for the repair of the tissues, and these gases uniting with the sulphates develop heat by chemi-

cal means very rapidly, while the rest of the heat of the body i more slowly developed by a slower combustion. The brain, the muscles, and the glands manufacture heat, so that venous blood leaving one of these parts is warmer than arterial blood.

Is there any difference in the heat-producing properties of different food stuffs?

Fat are particularly heating, giving more kinetic energy.

What is the nervous mechanism of animal heat?

In the brain is seated a heat centre whose function it is to direct the rapidity of combustion or the development of heat in the body. Governing this centre are two others, the inhibitory heat centre (Wood), whose function it is to prevent a too rapid production of heat, and the accelerator heat centres (Sachs and Aronsohn), whose function it is to increase the production of heat.

What two functions govern the temperature of the body?

Heat production and heat dissipation. Heat production consists in the manufacture of a certain number of heat units or calories in a given space of time in the body, while heat dissipation is the function by which a certain number of heat units are given off from the body to the surrounding atmosphere or medium.

What is the effect of increased heat production and decreased dissipation?

Increase in temperature, or, in other words, fever.

What is the effect of a decrease in heat production or an increase in heat dissipation?

A fall of temperature. *Remember* that these two functions balance one another and that disorder of either of them either raises or lowers bodily temperature.

Under what circumstances is the dissipation of heat increased?

By cold surroundings, by conditions which bring large quantities of heat to the surface of the body, and by contact of the body with substances which readily conduct the heat away.

What keeps the temperature of the body uniform?

The circulation of the blood, which distributes the heat very evenly.

What conditions of the vasomotor system influence the distribution of heat?

Local dilatations of the bloodvessels produce increased temperature of the part and increased heat dissipation, and, indirectly, increased local heat production.

What is the function of the perspiration in regard to bodily heat?

By its evaporation it aids enormously in the dissipation of heat when heat is formed in or added to the body too rapidly.

Why can a person stand a high heat in a dry atmosphere better than in a moist atmosphere?

Because in a dry atmosphere the perspiration is evaporated so rapidly that the heat is readily dissipated.

How high a temperature may the human being stand in an absolutely dry atmosphere?

According to Blagden, a temperature of 198° to 211° F. was supported in dry air for several moments, and on one occasion he stood 260° F. for eight minutes, having trained his skin to excessive secretion. Workmen in English iron furnaces sometimes stand on a furnace floor which is red hot and the air of which stands at 350° F. Chabert, the so-called "fire-king," is said to have stood from 400° to 600° F., according to Morrant Baker.

Which one of the animal tissues is the best protector against cold?

The fatty layer, which nearly always occurs in varying amounts under the skin in all warm-blooded animals, and forms a protective covering whereby the conduction of internal heat is almost impossible.

Fibrous tissues conduct heat more readily in the direction of their fibres than at right angles. The bones are the next best conductors of heat, and are followed by blood-clots. The spleen, liver,

cartilage, tendon, muscle and elastic tissue, and nails follow as conductors of heat. The skin is a poor conductor of heat.

What influence has starvation on the bodily temperature?

It lowers it greatly.

What effect has sleep and hemorrhage on temperature?

In those persons who sleep during the day and work at night the typical course of the temperature is inverted from that which has been already stated as normal. Hemorrhage causes at first a slight fall in temperature, and after that a rise of several tenths of a degree, which is curiously usually associated with a chill or slight rigor. Several days after this the temperature falls again.

What is the cause of the fall of temperature after hemorrhage?

The interference with oxidation.

What effect has the artificial cooling of animals?

It produces great depression, but voluntary and reflex movements are not abolished. The pulse falls from 100 to 150 to 20 beats per minute, the blood pressure falls, the respirations become shallow, and death occurs with spasms and signs of asphyxia.

What is the asphyxia due to?

Failure of respiration: for if artificial respiration be employed at this time the temperature rises fifteen to twenty degrees. Landois asserted that if in addition to artificial respiration external warmth be applied, animals apparently dead for forty minutes can be resuscitated.

What is hibernation?

A condition in which an animal has all its vital processes temporarily in abeyance. Respiratory and intestinal movements cease completely and the cardio-pneumatic movements alone sustain the slight exchange of oxygen in the lungs. If a warm-blooded animal be cooled to 30° F., it wakes before freezing. Varnishing the skin of an animal increases heat dissipation so enormously that death occurs, which is put aside if external heat be applied.

THE KIDNEYS.

What are the kidneys?

Compound tubular glands.

What is the function of the kidneys?

Their function is the secretion of urine.

What is the purpose of the large amount of fat around these organs?

It acts as a protective.

What is the size of the adult kidney?

About four and four-tenths of an inch long, three inches thick, and two inches wide. In the male it weighs from four to six ounces, in the female from four to five and a half ounces.

Of what two portions is the kidney made up?

The parenchyma, consisting of the outer or cortical layer, and the inner or medullary layer. The medullary layer is also sometimes called the pyramidal portion.

Into what two divisions is the medullary portion divided?

It is subdivided into the boundary layer of Ludwig and the papillary portion.

What appearance has the cortical portion of the kidney when torn?

It presents a granular aspect, due to the presence of the Malpighian corpuscles. Striæ are also seen, due to the medullary rays.

What is the difference between the boundary zone or layer of Ludwig, and the papillary portion of the kidney?

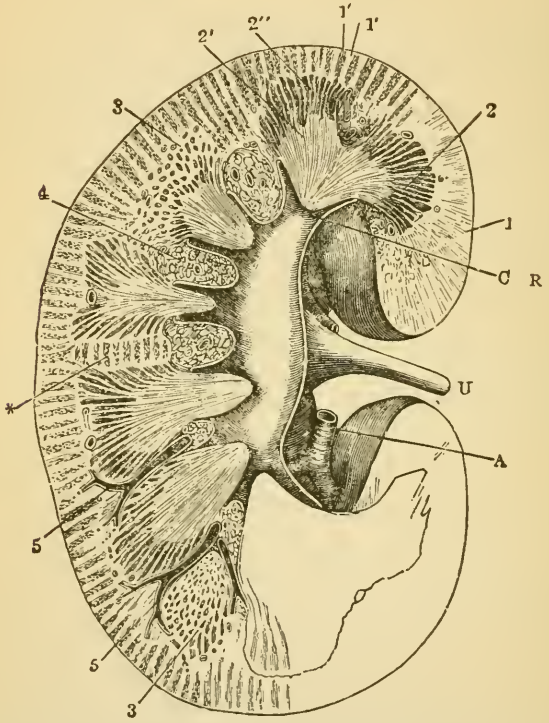
The boundary zone is darker, and often purplish in color, while the papillary zone is nearly white, and uniformly striated. The striæ merge into the apex of the pyramid.

Which is the least pliable, the cortex or medullary portion?

The medulla of the kidney is less pliable than the cortex. This

is due to the greater amount of connective tissue, and the bundles of straight tubes which may be traced at regular intervals, running upward, and becoming smaller and smaller as they pass toward the periphery.

FIG. 12.



Longitudinal section through the kidney (after TYSON and HENLE). 1. Cortex. 1'. Medullary rays. 1''. Labyrinth. 2. Medulla. 2'. Papillary portion of medulla. 2''. Boundary layer of medulla. 3. Transverse section of tubules in the boundary layer. 4. Fat of renal sinus. 5. Artery. * Transverse medullary rays. A. Branch of renal artery. C. Renal calyx. U Ureter.

In what portion of the kidney is the labyrinth?

That portion of the cortex which occurs between the medullary rays is called the labyrinth, owing to the arrangement of its tubules.

How many pyramids have we in each kidney?

Usually about eight or twelve. The pyramids are sometimes called those of Malpighi or Ferrein. The apices of the pyramids are directed toward the pelvis of the kidney, while their bases are directed toward the cortex, and each one of them opens into a small saccule or calyx, which in turn forms with others a dilated pouch, situated at the pelvis of the kidney, forming the beginning of the ureter.

How many times do we have the pelvis of the kidney divided?

First, into two or three divisions, and then again into eight or twelve smaller ones, which are called calyces.

What is the function of a calyx?

It receives the point of one pyramid, generally, but sometimes two pyramids empty into one calyx.

What do you mean by the tubuli uriniferi?

Fine, very elongated tubes, composed of a nearly homogeneous membrane, and lined by epithelium possessing the power of secretion. These tubes are, on the average, one six-hundredth of an inch in diameter. They begin at the Malpighian corpuscle in the cortical portion of the kidney, and, after passing through many convolutions, finally end in the pyramidal bodies, from the papilla-like point of which the urine drops into the saccules already mentioned.

In what portion of the kidney do we find the tubuli uriniferi?

Both in the medullary and cortical portions.

Into how many divisions are they divided?

Fifteen.

Is there any difference in the function of each division?

Certain sections are supposed to secrete certain substances.

What is the glomerulus or Malpighian body?

It is composed of a small tuft of bloodvessels covered with a

layer of cells and surrounded by a membranous covering, known as Bowman's capsule, which is the beginning or dilated extremity

FIG. 13.

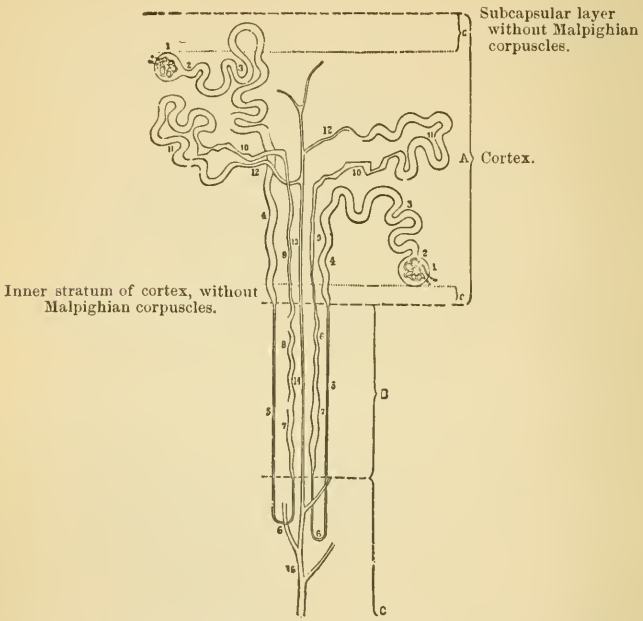


Diagram of two uriniferous tubules. (TYSON and BRUNTON, after KLEIN and NOBLE SMITH.) 1. Malpighian tuft surrounded by Bowman's capsule. 2. Constriction, or neck. 3. Proximal convoluted tubule. 4. Spinal tubule. 5. Descending limb of Henle's loop. 6. Henle's loop. 7 and 8. Ascending limb of Henle's loop. 9. Wavy part of ascending limb of Henle's loop. 10. Irregular tubule. 11. Distal convoluted tubule. 12. First part of collecting tube. 13 and 14. Straight part of collecting tube. 15. Excretory ducts of Bellini.

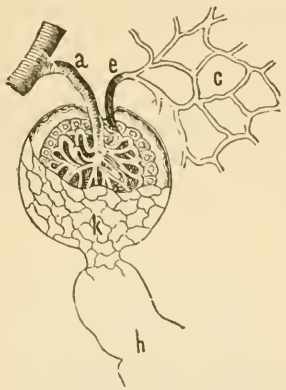
of the uriniferous tubule. They are apparent to the naked eye, in the cortical portion of the kidney, as little red points. Their average diameter is $\frac{1}{120}$th of an inch.

What is the function of the glomerulus or Malpighian tuft or corpuscles?

According to most physiologists, the Malpighian tuft secretes the

liquids and salts of the urine, while the epithelial lining of the uriniferous tubules secretes urea and uric acid, or any substance which taken into the body is eliminated by the kidneys.

Fig. 14.



Bowman's capsule and glomerulus (after Landois). a. Vas afferens. e. Vas efferens. c. Capillary network of the cortex. k. Endothelial structure of the capsule. h. Origin of convoluted tubule.

What peculiar arrangement have we in the blood supply of the Malpighian tuft?

The blood passes, by means of the afferent vessel or artery, to the Malpighian tuft and enters it, giving off immediately a capillary network. At the other side of this capillary network a vessel goes off, which, as a general rule, does not leave the Malpighian body on the opposite side from the entrance of the artery, but finds its exit from the same opening as that by which the artery entered. The uriniferous tubule, however, is given off from the Malpighian body on the opposite side from that at which the artery enters and the efferent vessel leaves.

The capsule of Bowman, or the beginning of the uriniferous tubule, may be considered as a sac, into which is secreted the liquid by the Malpighian tuft.

Is the efferent vessel called a vein?

The efferent vessel after leaving the Malpighian body forms a

second capillary network, twisting around the uriniferous tubules. Not until these capillaries come together do they form one vessel, known as the *vein*.

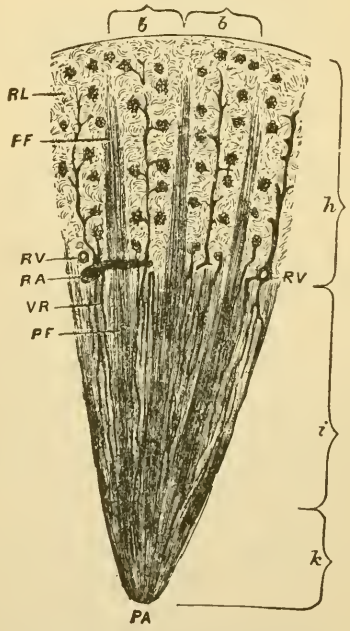
Why is the efferent vessel smaller than the artery?

It is somewhat smaller for the reason that it loses some of its liquid in the Malpighian body.

What other vessels have we?

Besides the efferent and afferent vessels, we have those known as the vasa recta, which, instead of being concerned in any way with the Malpighian tufts, pass directly out of the kidney, through the medullary portion.

FIG. 15.



Longitudinal section of kidney (after LUDWIG and TYSON). PF. Pyramids of Ferrein. RA. Rranch of renal artery. RV. Lumen of renal vein receiving an interlobular vein. VR. Vasa recta. PA. Apex of a renal papilla. *b*, *b*, embrace the bases of the renal lobules.

What is their function?

Their function is to afford a side stream for the blood in cases of congestion, so that all of it will not of necessity pass to the parenchyma of the organ.

What other vessels carry on a side stream?

Another side stream, which is less important, but for the same purpose, is produced by the fine interlobular arteries which, as they approach the surface of the kidney, communicate with the capillaries of the external capsule.

In what way is the kidney nourished?

By bloodvessels which dip down from the capsule, and from the vasa recta.

What are the nerves of the kidney?

They are derived from the renal plexus and the lesser splanchnics.

Do these nerves govern secretion, or only the blood supply?

We know that they govern blood supply, but it is not proven that they influence secretion.

What effect has increased blood pressure on the urinary secretion?

According to most of the text-books, increased blood pressure increases urinary flow, and vice versa; but recent investigations have seemed to prove that blood pressure has no very great influence over the kidney. The urine which is increased by pressure, contains less solids, proportionately, than urine formed by stimulation. "Pressure" urine is scarcely more than a leakage, and not a true secretion.

What is the function of the ureters?

To carry the urine from the pelvis of each kidney to the bladder.

Do the ureters possess any power of urging on the flow?

Yes; they have a slight peristaltic movement, and are supplied by motor and sensory nerves, the sensory nerves showing their presence in the human being when a calculus is being passed.

How long does it take the wave of contraction to travel along the ureters from the kidney to the bladder?

About one-tenth of a second.

In what way do the ureters enter the bladder?

Obliquely. They enter the external wall of the bladder at one point, pass between its coats for a short distance, and then open on its inner surface.

In what way is this opening arranged?

A small papilla with a valve-like action, permits the urine to flow out but not to return, and the oblique manner in which the ureter enters the bladder forms a sharp bend in that tube which acts as a valve, particularly when the bladder is distended.

What mechanical arrangement have we to prevent leakage from the bladder?

At the neck of the bladder the circular muscular fibres are strongly developed, and act as a sphincter, and in addition to this is the muscle known as the sphincter of the urethra, which also acts in very much the same way. *Remember!* Both these muscles must relax before urination can take place.

What is the function of the bladder?

To retain the urine until a sufficient quantity has been collected to pass, in order that a constant dribble may not take place.

What is its capacity?

About one pint.

In what condition is the mucous membrane of the bladder when the bladder is empty?

It is thrown into rugous folds.

What is the cause of the movement of the urine?

First, it is formed under high pressure in the kidney; second, gravity, when the person is erect, aids its passage; and, third, the muscles of the ureter contract rhythmically, and so aid its onward flow. This movement of the ureter is reflex, and is due to the presence of the urine in it.

Do both kidneys act constantly?

No; they act alternately.

What influence has the ingestion of small or large quantities of water on the urinary flow?

During thirst it amounts to but two or three drops every minute, when drinking it often runs in a steady stream.

In what way is the urine discharged from the bladder?

By contraction of its muscular coats, which, it will be remembered, run in all directions.

What muscles aid in the voluntary act of urination?

The respiratory muscles and abdominal muscles. The diaphragm is fixed, and the act is completed by the accelerator urinæ muscle, which quickens the stream.

In what portion of the spinal cord is the centre for the bladder?

In the lumbar region.

What other muscle aids in the expulsion of the last drops of urine, other than the accelerator urinæ?

The bulbo-cavernosus.

What is the nervous mechanism of urination?

The sphincter vesicæ is kept in a state of contraction by the motor centre governing it in the cord.

When the urine collects in the bladder a sensory impulse travels to the cord and brain, and the brain and cord in turn send down motor impulses which contract the muscular walls of the bladder, while a second impulse relaxes the sphincters.

Where is the spinal centre for urination situated?

About the point of origin of the third, fourth, and fifth sacral nerves.

THE URINE.

How much urine is secreted in twenty-four hours?

About three pints in the normal adult.

At what time of the day does the minimum secretion take place?

Between 2 and 4 A. M.

At what time of the day does the maximum secretion take place?

Between 2 and 4 P. M.

What are some of the causes that diminish the quantity of urine?

It is diminished by increase in the sweat, diarrhœa, thirst, non-nitrogenous food, diminution of blood-pressure, and certain diseases.

What are the causes which increase its quantity?

It is increased by increased blood-pressure, by copious drinking, by exposure to cold, by the use of nitrogenous food, and various conditions of the nervous system. Various drugs also influence the quantity.

What is the specific gravity of the urine?

It varies from 1.005 to 1.015 to 1.025. The minimum specific gravity occurs after copious drinking and may be 1.002; the maximum after profuse sweating, and may be 1.040. The mean specific gravity is 1.020.

What ready, but not strictly accurate, method have we for determining the amount of solids in a given specimen of urine?

By the use of Christison's formula, which consists in multiplying the last two figures of the specific gravity by 2.33, which will give the amount of solids in one thousand cubic centimetres.

What is the color of the urine due to?

The color depends on the matters present in it, chiefly urochrome and urobilin, a derivative of hematin. The color varies greatly, but the difference in intensity is chiefly governed by the quantity of water which is present.

What is the cause of the slight cloudiness which appears in the bottom of a vessel in which urine is placed for a length of time?

It is due to mucus, which is chiefly derived from the bladder.

What is the taste and odor of urine?

Its taste is slightly alkaline or bitter; its odor characteristic and aromatic. The odor, however, is altered by various causes, particularly by the administration of drugs.

What is the reaction of the urine?

It is acid, owing to the presence of acid phosphate of soda. After standing for a while the acidity is increased, due to fermentation of the mucus and other similar products, and, at the same time, with this increase in acidity, urates and free uric acid are deposited.

Under what circumstances outside the body does the reaction become alkaline?

After it has become acid it changes to an alkaline reaction, owing to the presence of ammonium carbonate derived from alterations of the urea. At the same time, a strong ammoniacal odor is noticeable, and fetor, with deposits of triple phosphates and alkaline urates, appears.

Does the reaction of the urine vary in different animals?

In most herbivora it is alkaline and turbid, but this difference depends not upon a different mode of secretion, but upon the variety of diet.

Into what three forms is the urine passed at different times divided?

Urina potus, urina cibi, and urina sanguinis.

What is the difference between each one of these?

Urina potus is secreted immediately after drinking, urina cibi after a solid meal, and urina sanguinis is that which is secreted early in the morning when neither food nor drink has been ingested.

What is the chief solid of the urine?

Urea is the chief solid constituent, and it is the most important ingredient since it is the substance by which the nitrogen of decomposed tissue is given off.

What is the result when this urea is not freely eliminated from the body?

It produces the condition known as uræmia, in which the patient has convulsions and low muttering delirium ending in death.

Does urea exist in a state of solution, or in a solid form in the urine?

In a state of solution.

What is its appearance in the solid state?

It forms delicate, silvery acicular crystals.

What is the quantity of urea excreted in twenty-four hours?

About five hundred grains.

Is the quantity of urea per day influenced by diet?

Yes. Nitrogenous or animal foods increase the urea, while a purely vegetable diet decreases it.

Is there any difference in the amount secreted by males and females?

Males secrete more than females, while middle-aged persons secrete more of it than the very young or old. *Remember*, however, that children secrete more in proportion to their weight than do grown persons.

What is the origin of urea?

It is derived from two sources: first, portions of unassimilated elements of nitrogenous food; second, from the breaking down of tissue, or tissue waste.

Does urea exist, to a certain extent, preformed in the blood, or do the kidneys manufacture it from the blood?

Some of it certainly exists ready formed, the kidneys merely extracting it.

What is uric acid?

An acid which appears, as a general rule, in small quantities in the urine of the human being, and which is entirely absent in the cat tribe. The quantity of it varies greatly in different animals. In birds and serpents its amount greatly exceeds that of the urea.

In what way is the quantity of uric acid increased?

By nitrogenous food, but decreased by vegetable food. In gout it is deposited around the joints as the urate of soda.

From what does uric acid arise?

From the destruction of albuminous matters. The relation between urea and uric acid is not well understood.

What is hippuric acid?

It is found in man and is allied to benzoic acid. Benzoic acid is eliminated as hippuric acid.

What are extractives of the urine?

They consist of kreatin and kreatiniu, two crystallizable substances derived from muscle metamorphosis.

What are the saline matters of the urine?

H_2SO_4 in the urine forms a compound chiefly or entirely with soda or potash, thereby forming salts. The phosphoric acid also combines and forms salts.

The breaking down of what tissues increases the amount of phosphates in the urine?

The nervous tissues.

How are the chlorides formed?

The chlorine combines with ammonia and potash to form chlorides.

Do gases exist in large quantities in normal urine?

No; in very small quantities. They are chiefly CO_2 and nitrogen.

What pathological conditions of the urine occur?

Albuminuria is a condition in which a certain amount of albumen is allowed to escape from the system by the kidneys. At one time the presence of albumen in the urine was considered to be pathognomonic of Bright's disease, but it has been proved that it may exist physiologically for a short time after the ingestion of large quantities of albumen. Hematuria is a condition in which there is blood in the urine, the blood coming from the kidney or any portion of the urinary apparatus.

What is hæmoglobinuria?

A condition in which free hæmoglobin occurs in the urine. Remember, that hæmoglobinuria is not hæmaturia.

What is choluria?

The presence of bile in the urine. It occurs in certain conditions in which the circulation of the portal vein is disordered, or after the ingestion of certain poisons, as, for example, phosphorus.

What is glycosuria?

Glycosuria is the presence of sugar in the urine. It is termed diabetes mellitus.

What is the cause of diabetes mellitus?

It is either produced by a lesion occurring in the diabetic centre in the floor of the fourth ventricle, or is due to disorder of the circulation of the liver whereby the sugars ingested and manufactured in this organ are improperly distributed.

What is chyluria?

It is a condition in which the chyle from the digestive tract is passed out in the urine.

What is diabetes insipidus?

A condition in which a very large quantity of liquid, of a low specific gravity and containing no sugar, is passed.

THE SKIN.

What are the chief functions of the skin?

It acts as an external integument for the protection of the deeper tissues, as a sensitive organ in the exercise of touch, as an important excretory and absorbing organ, and plays a highly important part in the regulation of the bodily temperature.

Of what does the skin consist?

The skin consists of a layer of vascular tissue named the *corium*, *derma*, or *cutis vera*, covered by a layer known as the *cuticle* or *epidermis*. Underneath and within the corium are embedded several organs with special functions, as follows: the *sudoriferous* glands, the *sebaceous* glands, and the hair follicles, while on its surface are sensitive papillæ.

Are the appendages of the skin, known as the hair and nails, formed from the corium or the epidermis?

They are modifications of the epidermis.

What layer of the epidermis contains the pigment in colored races?

The layer known as the rete mucosum.

From what portion of the skin does the papillæ arise?

They are conical elevations of the corium or true skin.

What is the function of the papillæ?

Nearly every one of them contains a nerve ending, thereby increasing the peripheral sensibility. (For the corpuscles of touch, etc., see the Special Senses, "Touch.")

What is the function of the cuticle?

It protects the papillæ from injury and forms a check on undue evaporation from the skin. The manner in which it protects sensibility is made evident when we remember the tenderness of those areas, where, by constant rubbing, the epidermis is rubbed off.

What is the function of the sudoriferous glands?

They pour out the sweat on the surface of the body through ducts which at first are spiral but which, as they approach the surface, become straight.

Are the sudoriferous glands the glands which secrete the familiar odors in the axilla and elsewhere?

No; the glands which are odoriferous are like them save that they are larger and have very short, straight ducts.

What is the difference between sweat and perspiration?

Sweat is applied to the liquid which is secreted so fast that it collects in drops; perspiration, to the moisture which is continuously and unconsciously given off by the skin.

What is the function of sweat and perspiration?

They aid in the dissipation of heat by their evaporation and thereby reduce the bodily temperature.

How much watery vapor is excreted by the skin in twenty-four hours?

From one and one-half to two pints.

How much CO_2 is lost in this manner per day?

An amount which is almost $\frac{1}{150}$ to $\frac{1}{250}$ of the amount exhaled by the lungs, and which differs enormously according to the conditions surrounding the individual, and exercise, food, and drink.

What other impurities are given off by the skin other than CO_2?

Urea and inorganic salts.

Is the excretory function of the skin important?

Exceedingly so, if interfered with it may produce death by throwing too great a strain on the kidneys, for *remember* that the skin is a supplementary organ to the kidneys.

In what ways may the flow of perspiration be increased other than by exercise or exposure to heat?

If a localized vaso-motor palsy occurs sweating sometimes takes

place; section of the cervical sympathetic produces copious sweating of that side of the head.

What are the objects of the sebaceous glands?

They secrete a lubricating fluid or oily matter which keeps the skin soft and pliable.

What is the vernix caseosa?

That sebaceous matter which covers the skin during intra-uterine life.

What is the function of hair?

It acts as a protection from cold, as when on the head, and protects the skin from friction in the axilla or on the pubis. Besides protecting the head from changes in temperature, it wards off blows which might otherwise be serious in their results to the more vital tissues.

What is the function of the nails?

To protect the ends of the fingers from injury or the sensory papillæ of the finger tips from contact with harsh, rough objects, which, if it occurred constantly, might deprive them of their delicacy of touch.

Can absorption of certain substances take place rapidly through the skin?

Very rapidly. A familiar example of this is the ptyalism produced by mercurial inunctions.

SECRETION.

What is secretion?

The separation from the blood of some product, directly or indirectly, by the vital process peculiar to a gland or membrane. This product is called an *excretion* when it is passed out of the body as waste, or a *secretion* when it carries out some function in the animal economy.

Give a good example of an excreting gland?

The kidney.

Give an example of a secreting gland.

The pancreas or mammary gland?

(For the manner in which secretion is carried on in each gland, see questions on each subject.)

THE MAMMARY GLANDS.

What changes take place in the mammary gland during gestation?

It becomes much larger, the areola around the nipple increases in width and deepens in color, the veins become more prominent, while the lobules can be plainly felt.

How many lobes has the mammary gland?

From fifteen to twenty, each one of which is divided into several lobules made up of acini.

What is the function of the lactiferous ducts?

They carry the secretion to the nipple, on which they open by a number of orifices. Just before they enter the nipple they dilate, forming little sacs which collect the milk.

In what way are the fat globules of milk formed?

They are supposed to be the results of a physiological fatty degeneration of the cells lining the acini and ducts.

(For Milk, see Articles used as Foods.)

THE BODILY METABOLISM.

What do you mean by the term Bodily Metabolism?

Those phenomena by which all living organisms are capable of taking substances derived from their food into their tissues, and making them an integral part of their own bodies; further than this, metabolism includes the breaking down of these tissues, and the removal of the results of their destruction; the first half of the process is termed *assimilation*, the second half *excretion*.

Does the body merely assimilate sufficient food to replace exactly those particles which are destroyed, or does it do more than this, and act as a storehouse, from which, on a sudden strain, energy may be derived?

It acts as a storehouse of potential energy, which, when necessity arises, it may transform into kinetic energy.

What do you mean by potential energy?

That energy which possesses the power to move, but is quiescent.

What do you mean by the term kinetic energy?

Potential energy, when exerting its influence, either by producing motion or preventing it, is called kinetic energy; in other words, potential energy is latent, kinetic energy is active. A coiled watch-spring held firmly represents potential energy, but if the pressure is removed, its force is transformed into kinetic energy.

GENERAL VIEW OF THE MOST IMPORTANT SUBSTANCES USED AS FOOD.

How much of the body is made up of water?

58.5 per cent. of the body consists of water, which is continually taken in and given off.

What is the purpose of water in the organism?

The processes of digestion and absorption require the presence of water for the solution of the food, and it is also used to carry off the effete products. So much water exists in the tissues of all animals that Hoppe-Seyler has put it that all organisms live in water.

Milk.

What is the use of milk and its preparations?

Milk forms a complete typical food, in which are all the constituents necessary for life and growth.

What are the constituents of milk?

In every ten parts of proteids we have ten parts of fats and twenty parts of sugar.

Describe some of the characters of milk.

It is an opaque, bluish-white liquid, with a sweetish taste and a characteristic odor.

What is this odor due to?

Probably to the peculiar volatile aromatic substances derived from the cutaneous secretion of the glands.

What is its specific gravity?

1.026 to 1.035.

What is the reaction of human milk?

It is always alkaline; cows' milk may be alkaline, sometimes acid, or even neutral. The milk of carnivora is always acid.

What are milk globules?

Small, highly refractive, oil globules floating in a clear fluid, the milk plasma. The white color of milk is due to their presence.

Of what do the globules consist?

Of fat or butter, surrounded by a coating of casein.

What is the effect of churning on these milk globules?

This coating of casein is broken, and the butter globules are allowed to run together.

What does the milk plasma contain aside from the globules?

It contains free casein, serum-albumin, and, to a less extent, a body resembling albumin, the lacto-protein of Millon and Liebermann.

What other substances have we in milk?

Galactin, albuminose, and globulin; very minute traces of peptone are also present. Milk sugar, a carbohydrate resembling dextrin, and urea and extractives complete the list of its constituents. *Remember*, that the casein is the albuminous portion

of milk while the butter globules make up the hydro-carbon portion.

When milk is boiled, what changes take place in it?

The serum-albumin coagulates, while the surface also becomes covered with a layer of casein which has become insoluble.

Is raw or boiled milk most digestible?

The raw milk; if nature had intended that boiled milk should be more digestible than raw milk, raw milk would have been formed with the same conditions present that exist in boiled milk.

Upon what does the coagulation of milk depend?

Upon the coagulation of its casein.

What salt in milk keeps the casein in solution?

Calcium phosphate; which is, of course, destroyed by the acid of the stomach. *Remember*, that milk coagulates in the stomach, not on account of the acid, but owing to the presence of a milk-curdling ferment. (See page 63, Digestion.)

What causes the spontaneous coagulation or souring of milk?

It is produced by the development of lactic acid, which is formed from the milk sugar by the action of the *bacterium lacticum*.

What is the difference between human milk and cow's milk?

It contains less albumin, and the albumin it does contain is more soluble than that in cow's milk. It also contains more sugar and fats than does cow's milk.

What is colostrum?

It is the substance which is secreted at the beginning of lactation, and contains much serum-albumin, and very little casein, while all the other substances, specially the fats, occur in large amount.

What is the purpose of colostrum?

Containing, as it does, a large amount of fat, it acts as a purgative, and sweeps out the meconium and other effete products from the alimentary canal of the infant.

Are gases found in ordinary milk?

Only in minute traces.

What salts are found in milk?

The potash salts are much more plentiful than the soda salts; there is also a large amount of calcium phosphate present.

What is the purpose of the calcium phosphate?

It is necessary in the formation of the bones of the infant.

What difference is there in the composition of milk at various times?

That drawn last is always richer in butter, while if the ducts are emptied frequently the butter decreases but the casein increases.

Are eggs a typically complete food?

They are not as complete a food as is milk, but are the most typical food next to milk.

What is the object attained by cooking flesh?

It breaks up to a certain extent the elastic coverings of the muscular fibre, softens the connective tissues, and renders it more tender and easy of digestion.

In the vegetable foods, what are the chief nitrogenous substances?

Gluten is the most abundant nitrogenous substance present, and occurs immediately under the husk.

How many groups of foods are necessary for the maintenance of health in man?

Five.

What substances make up these groups?

First, the *starches*, which are used for the purpose of adding heat to the body, and also fat; second, the *fats*, which are used for the purpose of maintaining the bodily heat and retaining it; third, *albuminous* foods, whose function is to add force to the system; fourth, *water*, which is necessary for the carrying out of the vital processes; and fifth, *salts*, which are also absolutely needful for the maintenance of health.

What is the absolute amount of the different food-stuffs required by an adult in twenty-four hours?

It varies enormously according to the surrounding conditions, but, as a general rule, it should contain 130 grammes of proteids, 84 grammes of fats, and 404 grammes of carbohydrates. *Remember*, that the carbohydrates should always be greatly in excess of the nitrogenous principles.

What effect has the withdrawal of all forms of food-stuffs, with the exception of one particular class, upon nutrition?

The animal wastes, and finally dies with very much the same symptoms as would follow starvation.

The manner in which effete products are taken up and excreted has already been considered (see Circulation, Respiration, and the Kidney and Urine).

What process goes on during starvation?

All food being taken away from the body the organism is required to abstract at first the unimportant tissues in order to keep up its vital processes. After this the wasting becomes marked, and the bodily weight falls. Weakness, the result of the breaking down of vital tissues, comes on, and finally death, after all substances capable of supplying force in the body have been used up, save those actually concerned in the vital processes.

How long will the average adult survive without food?

About twenty-one to twenty-four days, although cases are on record of survival for forty-one days.

How much bodily weight is lost before death?

Four-tenths of the bodily weight.

Are fats ever formed from proteids?

Yes; as an example of this, the cow does not consume as much fat in a day as she gives in butter.

THE MUSCLES.[1]

What is the function of the muscles?

To produce movements, which vary according to the rapidity and power of their contraction.

In what way do the voluntary muscles act upon the bones?

As levers. They are often attached to the short arm of the lever, and while this is apparently a disadvantage, since under these circumstances greater force is required to lift a given weight, it, in reality, is of the greatest service, since slight contractions of muscles cause very extensive and rapid movements of the part.

How many orders of levers are met with in the movements of the different bones of the skeleton by the muscles?

All three; and in some cases all three occur at the same joint.

Give an example of the first order of levers.

When the triceps is the power which draws upon the olecranon, thus moving the hand and forearm around the trochlea, which acts as the fulcrum.

Give an example of the second order.

This occurs when the hand, resting on a point of support, acts as the fulcrum, and the triceps pulling on the olecranon is the power which raises the humerus, upon which is fixed the body or weight.

Give an example of the third order.

This is exemplified by the action of the biceps in ordinary flexion of the elbow, in which the biceps is attached to the upper portion of the forearm.

What two varieties of muscular fibre have we?

Two; striped, or striated or voluntary; unstriped, unstriated or involuntary. The first group are moved entirely by the will-power, or by centres under the control of the will-power. The second group, solely by nervous centres over which the will-power has no direct influence.

[1] The anatomy of muscles is to be found in anatomical text-books.

What large mass of striped muscular fibre is an exception to this rule?

The heart, which, although it is made up of striped muscle, beats independently of the will. The arrangement of the heart muscle, however, is somewhat different from striped muscular fibres elsewhere.

What is the difference in the contraction of striped and unstriped muscular fibre?

The striped muscular fibre usually contracts more rapidly.

What is the consistency of muscle?

The contractile substance of muscle is so soft as to be almost fluid, being of the consistency of jelly.

What is the chemical composition of muscle?

As already pointed out elsewhere, it is impossible to determine this during life, since the analysis produces death. Muscle, however, contains the substances known as *muscle-serum* and *muscle-clot* or *myosin*, which are the result of certain chemical changes occurring after death.

What effect has coagulation of the myosin in muscle?

Its formation is followed by "rigor mortis," or post-mortem rigidity.

In what way can this coagulation be postponed?

By keeping the muscle at a temperature but a few degrees above freezing point. If a muscle be kept in this manner, pressure will cause the exudation from it of a yellow, opalescent, alkaline juice, which on still further cooling changes into a jelly.

What effect has warming of this jelly?

It passes through the stages of coagulation seen in ordinary muscle after death, producing the same fluid serum and muscle-clot or myosin.

What is this muscle juice sometimes called?

Muscle plasma, which is supposed to be the contractile matter in living muscle.

What does the coagulation of muscle plasma very closely resemble?

The coagulation of blood plasma, with the difference that the muscle clot is gelatinous and not in threads, as is fibrin. It is a globulin, and is soluble in a two per cent. solution of common salt. *Remember*, that this globulin forms the greater portion of albuminous matter in muscle.

What is the difference between the reaction of muscles before and after death?

Before death they are alkaline; after death, acid.

Of what does the serum of the muscle consist beside the albuminous principles?

1st, kreatin, kreatinin, and xanthin; 2d, hæmoglobin; 3d, grape sugar, muscle sugar or inosit, and glycogen; 4th, sarcolactic acid, made from the inosit by fermentation; 5th, carbonic acid; 6th, potassium salts; and, 7th, 75 per cent. of water.

What do you mean by the elasticity of muscle?

The degree to which the muscle can be stretched and still return to its normal length. If a given weight be applied to the end of a muscle, it is stretched a certain distance; but an additional weight or weights do not produce by any means an elongation equal to the first. The elongation, on additional strain, is constantly decreased in extent.

Is there any variation in the elasticity of muscles?

At first a strain on a muscle produces very rapid extension; but this is constantly decreased as time goes on, finally ceasing. Muscles which are fatigued are more readily stretched than fresh ones.

What difference is there between the elasticity of dead and living muscle?

Dead muscle possesses less elasticity and requires a greater weight to stretch it. It can be stretched further than living muscle, but does not return to its former length as completely as the normal muscle.

Are the muscles of the body always on the stretch, and if so, what is the object reached by this condition?

They are always on the stretch, even when passive, and act as ligaments which bind together, in a compact mass, the entire body. Muscles nearly always have opposing muscles whose function it is, when exercised, to produce opposite movements. The elasticity of these muscles, in a passive state, also opposes active contraction in the opposite muscle, which is, however, easily overcome. After the active contraction has taken place, the elasticity of the passive muscle acts as a weak spring, thereby keeping up the tonicity of the limb and preventing sudden jerkings of the body, as would occur if a muscle should contract suddenly and "take up the slack" in the opposite muscle.

What electrical phenomena have we in muscle?

In the normal living muscle we have invariably present an electric current known as the *natural muscle current.*

What circumstances influence this current?

It is greatly reduced by fatigue and loss of vital power, and is generally supposed to be absent in perfectly normal *passive* muscle lying *in situ.* As soon as the muscle is moved or disturbed by partial removal from the body the current develops.

What do you mean by "negative variation" in muscle?

If a muscle be connected with a galvanometer so as to measure its natural current and then be stimulated to a contraction by means of the nerve trunks, a marked decrease occurs in the current. The galvanometric needle swings toward the zero point, showing that the current is weakened and destroyed. This is called the *negative variation,* and precedes the change to an active condition of the muscle.

What do you mean by the irritability of the muscle?

The capability with which a muscle passes into contraction.

What are the usual causes of contraction of the voluntary muscles?

They contract ordinarily in response to impulses communicated

to them by nerves, the impulse originating in the brain or spinal cord. The will power is the most common cause of contraction of the skeletal muscles.

What other conditions may produce contractions of the muscles?

Contraction of the muscles may be produced either by the application to them directly of some irritating or stimulating substance, or by the application of stimulation to their supplying nerves.

Is it possible to cause contraction in muscular fibre which is devoid of terminal nerve filaments, or, in other words, does the contraction of a muscle necessarily depend upon the presence of peripheral motor nerves?

That muscles may be stimulated to contraction without the intervention of nerve fibres, is proved by the fact that some parts of muscles, as the lower end of the sartorius, respond energetically to all forms of muscle stimuli, though they possess no nerve endings; there are some substances, too, which produce contraction of muscles on direct application, which will not produce that contraction when applied to the nerve trunk, as, for example, ammonia. Again, the muscles will generally respond to various stimuli long after the nerve supplying them has been killed by exposure, and curare, which paralyzes the peripheral ends of the motor nerves in the muscles, in no way prevents the contraction of the muscle itself when it is directly stimulated.

What forms of muscle stimuli have we?

First, *mechanical* stimulation, as by a sudden blow or pinch, resulting in momentary transient contraction. Second, *thermic* stimulation. Contraction of the muscle takes place if the temperature be raised or lowered. This contraction, however, is scarcely identical with ordinary muscular contractions, since it is a prolonged spastic contraction of an abnormal type. Third, *chemical* stimulation, which may produce contractions by irritating mineral and organic acids, various metallic and neutral salts. Fourth, *electrical* stimulation, which is the most common form employed, and gives the most satisfactory results.

At what time during the application of an electrical current to a muscle does the contraction take place?

Remember that it takes place not while the current is passing through the muscle, but at the moment the current is turned on or turned off, or is suddenly increased or decreased in strength. A constant current of exactly even intensity may be made to pass through a muscle without exciting contraction.

Is the stimulus necessary to produce contraction in a muscle when applied to its nerve trunk, sufficient to produce the same degree of contraction in the muscle when applied to the muscle itself?

No, it is not.

What are the chemical changes resulting in a muscle during its contraction?

Its neutral or faintly alkaline reaction becomes for the moment acid, owing to the formation of sarco-lactic acid. More oxygen is taken up from the blood than when the muscle is at rest. A greater amount of carbon dioxide is given off, but the change in the quantity of CO_2 has no exact relation to the quantity of oxygen used. A diminution is said to occur in the glycogen of muscle, and a peculiar muscle sugar makes its appearance.

What changes occur in the elasticity of the muscle during contraction?

The elasticity is less than when it is in a passive state—that is, a given weight will stretch a contracted muscle more than a passive muscle, but the return to the normal length of the muscle is not so complete, or, in other words, extensibility is increased, elasticity is decreased.

What effect, therefore, has stimulation of a muscle which is overloaded by a weight greater than it can lift?

When stimulation is applied to such a muscle we get elongation instead of contraction, because of the rule just now given, namely, that the active state lessens the elastic power of the muscle.

What effect has stimulation of one part of a muscle upon the rest of the muscle?

A contraction wave passes from the part stimulated over the whole mass.

What effect has the activity of muscle fibre upon its temperature?

It raises it very markedly, the production of heat being in direct proportion to the tension of the muscle. If the muscle be kept in a state of constant activity, so that fatigue is produced, the temperature falls.

What change in shape takes place in the muscle on contraction?

It shortens, and in direct ratio with its shortening its thickness increases. There is, therefore, but little change in bulk, but considerable change in shape.

What do you mean by the "latent period"?

The short space of time which elapses between the moment of stimulation of a muscle and the beginning of its contraction. In the voluntary muscle of the frog this lasts only about one-tenth of a second.

What do you mean by the period of "rising energy"?

The space of time during which contraction occurs first slowly, then more quickly, then more slowly.

What do you mean by the term "falling energy"?

The period at which relaxation of the muscle takes place. At first slowly, then more quickly, finally, more slowly.

Is there any pause at the height of contraction before relaxation begins?

No, none at all.

Is there any variation in the rapidity of contraction of different muscles?

Yes, an enormous difference exists not only in various animals, but in the same muscles of a single individual. As an example

of the difference in rapidity of contraction in the muscles of different animals, may be mentioned the fact that while the unstriped muscular tissue of a mollusc occupies several minutes for its contraction, the muscle of the wing of a horse-fly contracts 330 times a second. The variation and rapidity of contraction differ very largely with the needs and habits of the animal.

What do you mean by the "maximum contraction" of a muscle?

The greatest shortening which can be produced by a single instantaneous impulse or stimulus.

What do you mean by the term "over-maximal contraction"?

If the current be increased after the maximum contraction is reached, a second and still further contraction occurs. This is called the over-maximal contraction.

What do you mean by the term "summation"?

If a muscle be caused to contract by a shock of medium strength, it contracts to its maximum; but if a second shock be given while the muscle is contracting from the first shock, a new maximum contraction is added to that already under way. This is called the *summation* of effect.

What do you mean by the "tetanus"?

A condition of a muscle in which it apparently remains in a constant state of contraction—or, in other words, a *summation* of contractions exists. To produce artificial tetanus, impulse after impulse must be transmitted to the muscle with great rapidity, otherwise between each stimulus the muscle will partially relax or attempt to pass into the condition known as *falling energy*.

Upon what does the irritability and fatigue of a muscle depend?

Upon the amount of labor required and the nourishment supplied by the blood. Fatigue means lessened irritability.

THE NERVOUS SYSTEM.

What is the nerve trunk made up of?

First, the primitive fibril, which is the simplest form of nerve filament, and is visible only with a very high power of the microscope.

Is the primitive fibril the same thing as the axis cylinder?

No; the axis cylinder is made up of bundles of the primitive fibrils held together by a slightly granular element.

Give a description of a complete nerve.

It is made up of: 1st. The primitive fibril. 2d. The naked axial cylinder. 3d. The clothed axis cylinder, covered by the white substance of Schwann, or the medullary sheath, or the myelin. 4th. The clothed axis cylinder covered by the sheath of Schwann, or the neurilemma. 5th. The clothed axis cylinder with both these coverings, or the complete nerve.

What is the difference between the fibres of the cerebro-spinal system and those of the sympathetic system?

Those of the first are formed as the nerves of the 5th group just given, while the sympathetic are made up of axis cylinders covered by the sheath of Schwann, or neurilemma, as in the 4th group.

What is the function of Ranvier's nodes?

They are supposed to permit the diffusion of plasma from outside into the axis cylinder, and thereby to aid the nutrition of the nerve.

What are the nervi-nervorum?

They are small nerves which accompany the nerve sheaths, thereby endowing them with sensibility.

Give some facts in regard to the chemistry of the nervous substance.

Albumin occurs chiefly in the axis cylinder and in the substance of the ganglionic cells. Potash, albumin, and a globulin-like substance are also present. Another substance of the same character is nuclein, which occurs especially in the gray matter, and neuro-keratin, a body resembling keratin and which contains much sulphur. The connective tissue of nerves yields gelatin, but the sheath of Schwann only yields elastin. In addition to these we have cerebrin, lecithin, and protagon.

What is the chemical reaction of nervous matter?

When passive it is neutral or feebly alkaline; while active and after death it is acid.

What difference is there between the reaction of the nervous matter in general and the reaction of the brain?

The gray matter of the brain is supposed to be always acid, while the other is not.

Have nerves great or slight tensile strength?

They possess great strength, for it is a well-known fact that in cases where by accident the arm is torn off, the nerve is the only part not ruptured. Tillaux has found that the sciatic nerve will hold a strain of as much as 120 pounds.

What is the function of the nervous system?

It is the apparatus by which distant parts of the body are kept in constant relationship with one another so that a change of condition in any one spot is communicated to, and may set up corresponding changes in, remote parts.

What two divisions have we of nerve fibres?

The afferent or *centripetal*, and the efferent or *centrifugal;* most nerves contain both sets of fibres.

Do nerve fibres possess the power of generating force in themselves?

They do not. Neither are they capable of originating impulses. They are functionally inactive until they receive impulses from higher nerve centres.

What is the distinction between the white and the gray nerves?

The white nerves contain the white substance of Schwann, the gray nerves do not.

Which of these two varieties is the most common?

The white by far, since the gray are contained chiefly in the sympathetic system and parts of the organs of special sense.

What is the function of an afferent or centripetal nerve?

To carry impulses from the periphery to the centre which may receive them.

What is the function of an efferent or centrifugal nerve?

To carry impulses from the centre to the periphery, which impulses may arise of themselves in the central nervous system or be excited reflexly through a sensory nerve.

Are impulses travelling along one nerve trunk ever transferred to another nerve trunk running near by?

No, never, under any circumstances, if both nerves are intact.

How many divisions have we of efferent nerves?

First, *motor*, or nerves going to muscles causing them to contract; second, *secretory*, which call forth the activity of glands; third, *inhibitory*, which check or prevent some activity; fourth, *vaso-motor* nerves, which regulate the contraction of the muscular coat of the bloodvessels, and trophic, thermic, and electric nerves, all of which are doubtfully in existence, save the electric, which occur in animals capable of emitting electrical discharges.

What do you mean by inter-central nerves?

Inter-central nerves are those which act as bonds of union between the cells of nerve centres.

What is the velocity of nerve force?

It is about at the rate of thirty metres per second, or the speed of a fast express train, so that impulses can only travel from one portion of a man's body to another at about the same rate as an express, or about twice as fast as the fastest horse can gallop.

What do you mean by "negative variation"?

The natural current of a nerve, like that of a muscle, undergoes a diminution at the moment the nerve is stimulated; this is termed the negative variation. The negative variation travels along the nerve at just the same velocity as the impulse does from the point of stimulation; as a consequence of this the negative variation and nerve impulse are believed to be identical.

What do you mean by electrotonus?

Electrotonus may be defined as the electrical condition of a nerve, which undergoes constant variation according to the circumstances affecting it. This will be more clear after the question on anelectrotonus and katelectrotonus has been read.

What do you mean by the terms anelectrotonus and katelectrotonus?

Anelectrotonus is the term applied to the condition of the nerve near the anode, or positive pole, during the passage of a constant electrical current, the irritability of the nerve being *de*creased in this region. Katelectrotonus is applied to the part of the nerve near the cathode, or negative pole, the irritability being here *in*creased.

What do you mean by the irritability of nerves?

The condition which permits of the transmission of impulses from more or less powerful stimuli.

What conditions are necessary for this irritability?

A perfect supply of blood, to bring nourishment and carry away effete matters, an uninjured connection with the nerve centres, and a normal temperature.

What is the result if the blood supply of a nerve is cut off?

The nerve rapidly loses its excitability, and finally becomes paralyzed.

Supposing a nerve is exhausted by fatigue or lack of blood supply, how does recovery occur?

When a nerve recovers it does so slowly, then more rapidly, and afterward more slowly.

At what portion of the nerve trunk would you apply the stimulus to produce the greatest contraction in the tributary muscle, or, in other words, at what point would you find the greatest irritability of the nerve?

At some part of the nerve distant from the muscle. The further from the muscle the more powerful is the contraction produced. The impulse seems to gather force as it goes along the nerve.

What do you mean by the "indifferent point" of a nerve?

As already stated, when a constant current is applied to a nerve its irritability is greater in the neighborhood of the cathode, but is diminished in the neighborhood of the anode. Near the middle of the nerve, or rather a point about half way between each pole, we have an area known as the *indifferent point*, since at this portion the increased irritability of the cathode no longer exists, nor does the diminished irritability of the anode occur. This *indifferent point* is not *always* midway betweeen the two poles, since variations in the strength of the current influence its position.

What are the laws of contraction?

1. In all muscles, when the current is broken, the disappearance of anelectrotonus is the cause of the stimulation. 2. When the current is made it is the appearance of katelectrotonus which causes the stimulation. 3. With the same current the contraction produced with the *making* of the current is more than the contraction which occurs on the *breaking* of the current. 4. Anelectrotonus causes *reduction* of irritability and conductivity. 5. Katelectrotonus causes *increase* of irritability. 6. With ascending currents, the portion of the nerve next to the muscle is in a state of reduced functional activity or anelectrotonus. 7. With descending currents the part of the nerve next the muscle is in a state of exalted activity—katelectrotonus. 8. These changes are much weaker with weak currents than with strong ones.

What do you mean by the term nerve corpuscles or terminals?

Those small nerve bodies or corpuscles in which nerve fibres end and through which efferent nerve fibres give off their impulses and afferent nerve fibres receive their impulses. Those which are attached to the endings of sensory or afferent nerves of the skin are known as tactile corpuscles.

PHYSIOLOGY OF THE SPINAL NERVES.

It will be remembered that thirty-one pairs of *spinal* nerves leave the vertebral canal between the vertebræ, in contradistinction to the *cranial* nerves, which come out from the base of the skull, and that each pair of nerves is attached to the spinal cord by two roots, known as the anterior and posterior, which becoming united pass through the intervertebral canal, forming one trunk. Just before the junction of the two roots it will also be remembered that the posterior root is enlarged by a ganglionic swelling. The spinal nerves are, therefore, sometimes called mixed nerves, for the reason that they contain both efferent and afferent fibres. Those going from the anterior portion of the spinal cord carry the motor or efferent impulses, those coming to the posterior part of the spinal cord carry the afferent impulses.

What do you mean by recurrent sensibility?

If after division of a motor root the peripheral portion of it be stimulated some pain is felt. This is due to what is known as *recurrent sensibility*, and depends on the fact that some of the fibres of the sensory root, after having joined the motor root, instead of going as usual to the periphery, revert and supply the motor root.

What is the function of the ganglia which occur on the posterior roots of the spinal nerves?

Their function is not clearly understood. There is no evidence of their being centres of reflex action, nor can they be shown to possess any marked automatic activity, but it is supposed that they preside over the nutrition of the nerve itself, for if the roots be cut off, that part of the posterior root attached to the cord degenerates, while the piece attached to the ganglion remains intact. This is not the case where the anterior or motor root is cut, since under these circumstances that portion of the nerve next the cord remains intact, while the divided portion undergoes degeneration. From this it would appear that the nutrition of the sensory nerves is governed by the ganglia, while that of the motor nerves is governed by centres in the cord itself.

What is the Ritti-Valli law?

If a nerve be separated from its centre, or if the centre dies, the excitability of the nerve is *increased;* the increase begins at the central end and travels toward the periphery—the excitability then falls rapidly until it disappears entirely.

Do these changes take place more rapidly in the central or peripheral end?

They take place more rapidly in the central end. In other words, the peripheral end remains excitable for a longer time than the central end.

THE PHYSIOLOGY OF THE CEREBRO-SPINAL NERVOUS SYSTEM.

The physiology of the cerebro-spinal nervous system includes that of the spinal cord and the medulla oblongata, the brain, and the nerves given off from each one of them, and the functions of the ganglia on those nerves.

What is the function of the membranes of the brain and spinal cord?

The dura mater is a tough membrane, and composed of bundles of connective tissue, whose function it is to enclose, and, to a certain extent, protect the nervous tissue beneath it. The arachnoid is a much more delicate membrane, similar in structure to the dura mater, the function of which is to secrete the cerebro-spinal fluid. The pia mater consists of immense numbers of bloodvessels, which dip down and nourish the surface of the brain.

What do you mean by the neuroglia?

A special form of connective tissue which supports the nerve-fibres and the cells of the brain and spinal cord.

Of what does the spinal cord consist?

It is a cylindriform column of nerve-substance connected with the brain through the medium of the medulla oblongata and pons Varolii, and terminating in the midst of the roots of the many nerves which form the cauda equina. It is composed of white and

gray nervous matter, of which the white is situated externally and constitutes the chief portion, while the gray occupies its central portion, and is so arranged that on the surface of a transverse section it appears like two somewhat crescentic masses, connected together by a narrow portion or isthmus.

Is the spinal cord of the same size throughout its whole length?

No; it varies greatly. It is very large in the middle and lower part of the cervical region and at the lowest part of the dorsal region, since at these two points a large number of nerve fibres are given off.

Of what does the white substance of the spinal cord consist?

Of nerve fibres with a medullary sheath.

What is the function of these nerve fibres?

The transference of impulses from cell to cell.

Of what does the gray matter consist?

Of a dense network of naked nerve fibrils with numerous ganglionic cells scattered between them. The nerve fibres in this substance also transmit impulses from cell to cell.

Does the white or the gray substance contain the ganglionic cells?

The gray substance.

What are these cells called?

Multipolar, bipolar, or unipolar cells, for the reason that they possess processes, one or more in number, which do not divide in the same way as do the interlaced nerve fibres.

What groups of nerve cells have we in the gray matter?

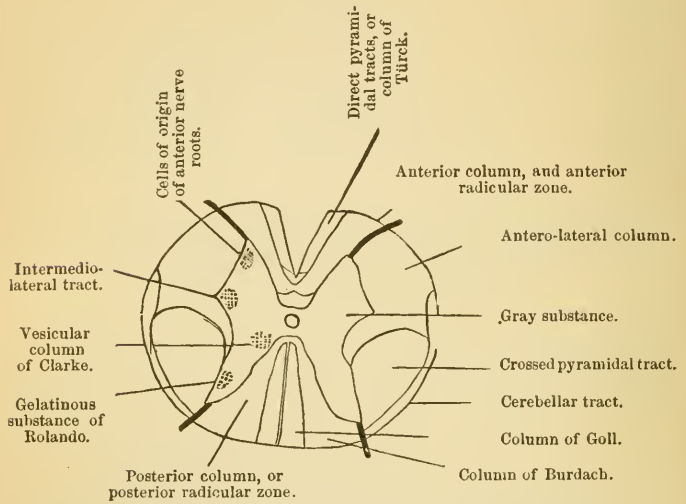
1. In the anterior cornua are cells which are the points of origin for the motor spinal nerves. (See Fig. 16.)

2. The tractus intermedio-lateralis, a group of nerve cells midway between the anterior and posterior cornua, near the external surface of the gray matter. (See Fig. 16.)

3. The posterior vesicular columns of Clarke and Stilling are found in the posterior cornua near the inner surface. (See Fig. 16.)

4. The substantia gelatinosa cinerea of Rolando is scattered throughout the gray matter, but is chiefly found in the posterior cornua. (See Fig. 16.)

FIG. 16.



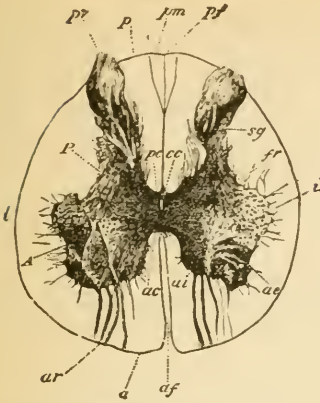
Transverse section of the spinal cord at level of the upper dorsal vertebræ. (See scheme below.)

Into how many columns is the spinal cord divided?

Three on each side. The following scheme will illustrate this more clearly than words, particularly if the figure is also examined.

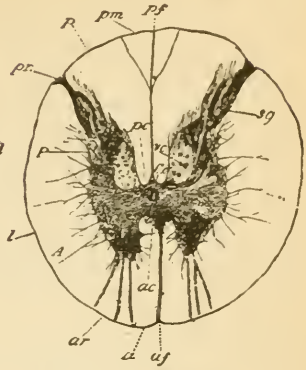
1. Anterior columns	The direct or uncrossed pyramidal tracts, or column of Türck, or antero-median column. The anterior ground bundles, or anterior radicular zones.
2. Posterior columns	Goll's column, or the postero-median column. Burdach's columns, or the posterior radicular zones, the posterior lateral columns or the funiculus cuneatus.
3. Lateral columns	The anterior and lateral mixed paths. The crossed pyramidal paths. The direct cerebellar paths.

FIG. 17.



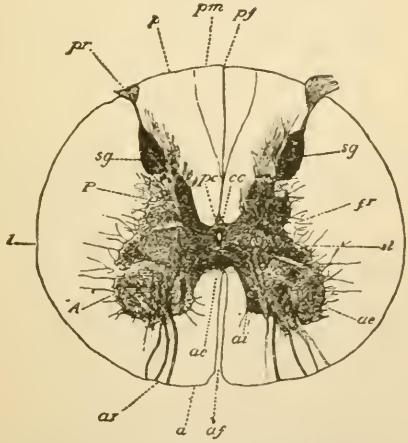
Transverse section of spinal cord of monkey; lumbar region. (After FERRIER.)

FIG. 18.



Same, but in dorsal region. (After FERRIER.)

FIG. 19.



Same, but in cervical region. (After FERRIER.)

A, Anterior cornu. *P*, Posterior cornu. *a*, Anterior column. *l*, Lateral column. *p*, Posterior column. *ac*, Anterior commissure. *ae*, External cell groups; and *ai*, internal cell groups, of anterior cornu. *af*, Anterior median fissure. *ar*, Anterior roots. *cc*, Central canal. *fr*, Formatio reticularis *il*, Cells of the tractus intermedio-lateralis. *cc*, Clarke's vesicular column. *pc*, Posterior commissure. *pf*, Posterior median fissure. *pm*, Posterior median column (column of Goll). *pr*, Posterior roots. *sg*, Substantic gelatinosa.

Give the boundaries of each column.

The anterior column is that tract which lies between the anterior median fissure and the point of emergence of the anterior nerve roots; the lateral column lies between the point of emergence of the anterior and posterior roots, and the posterior column between the posterior roots and the posterior fissure.

What are Goll's columns?

The posterior median columns, the functions of which are not as yet definitely known.

What are Türck's columns?

The anterior median columns, or the direct pyramidal tracts. They conduct impulses from the brain in the same manner as do the lateral columns.

The Functions of the Spinal Cord.

In what manner is conduction carried on by the spinal cord?

It carries the sensory impulses transmitted to it by the sensory nerves up to the perceptive centres in the brain, and the motor impulses from the brain down to the nerves which are distributed to the muscles.

Roughly speaking, what portion of the cord may be considered motor, and what portion sensory?

The anterior portion is motor; the posterior, sensory.

What difference is there in the function of the white and gray matter?

According to Schiff, and most physiologists, the gray matter transmits in all directions both sensory and motor impulses which are purely reflex in character, or, in other words, only intended to remain in the cord, while sensory impulses which are to go *to* the brain, or motor impulses which pass *from* the brain, must travel by the white matter.

It will be remembered that both the anterior motor and the posterior sensory nerve roots do not arise from the white matter, but from the horns of the gray.

The function of the gray matter in the posterior horns is, therefore, limited to the receipt and transmission of sensory impulses from the periphery to the white matter, which will conduct them to the brain, or across the cord to a motor cell to complete a reflex action.[1]

The function of the gray matter of the anterior horns is limited to the transmission of motor impulses from the white matter to the motor nerve trunks, or to the originating of a reflex movement.

What function is supposed to be possessed by the gray matter around the central canal of the spinal cord?

To transmit sensory impulses up to the brain without their having to pass through the white columns.

In what way can you prove, physiologically, that the anterior columns of the cord are motor and the posterior sensory?

If the posterior columns be destroyed, the foot may be burnt off but no signs of pain are elicited. If, upon the other hand, the anterior columns be destroyed, burning of the foot produces violent pain-cries, but the animal is unable to send the impulse from the brain to the leg and draw it away from the injury. Another method is to destroy a motor centre in the brain, and some time later, the animal being killed, tracts can be traced downward which have undergone sclerosis or atrophy. Similarly tracts may be traced from the periphery to the centres by destruction or inflammation of a sensory nerve. This has not yet been found in he lateral sensory fibres.

What is the function of the direct or uncrossed pyramidal tracts of the anterior columns and the crossed pyramidal tracts of the lateral columns?

They carry all the impulses from the central convolutions of the cerebrum, by which voluntary movements are executed.

Are the lateral columns solely efferent in function?

No; for after destruction of the posterior columns of the cord, burning of the foot causes signs of pain.

[1] For definition of a reflex movement, see page 125.

What is the function of the direct cerebellar paths of the lateral columns?

They connect with the cerebellum directly by ascending fibres, which proceed through the restiform bodies from Clarke's columns of nerve cells in the gray matter. They connect the posterior nerve roots of the trunk (not of the extremities) with the cerebellum.

What is the function of the anterior ground bundles of the anterior columns, and the anterior and lateral mixed paths of the lateral columns?

They connect the gray matter of the spinal cord with that of the medulla, and carry reflex impulses. They also contain those fibres which are the direct continuation of the anterior spinal nerve roots which have entered the gray matter. The anterior and lateral mixed paths of the lateral columns also contain some sensory paths. This explains how the afferent impulses just spoken of travel to the medulla.

What is the function of Goll's column?

It unites the posterior roots with the gray nuclei of the posterior pyramids, otherwise known as the funiculi gracili, and carries impulses *centripetally*.

By what is the nutrition of these various conducting paths governed?

By nutritive centres, in the case of the centripetal tracts, situated in the cerebrum. In the centrifugal, or motor, tracts these centres are situated in the anterior cornua of the cord.

What classification can we make in the function of the nervous centres in the cord?

Their functions can be divided into *conduction*, *transference*, *reflection*, and *automatism*, or the power of originating impulses in themselves.

Give an example of conduction through a nerve centre.

If an impulse travels from a peripheral sensory nerve to a single centre in the spinal cord reflexly it may produce contraction in the muscles which are tributary to the motor centre next to it.

This stimulation, if strong enough, may cause an impulse to travel to all the other centres in the cord, so that general muscular movements may take place.

Give an example of the transference of nerve force.

The pain in the knee or ankle occurring during hip disease is a good example of this condition, and is supposed to be due to the fact that the sensory nerves running from the hip carry impulses up to the sensory cells in the spinal cord, which again transfer the sensation they receive to sensory centres in direct communication with the area of the knee or ankle. Under these circumstances the brain receives the impulse from the two sets of fibres and misinterprets the real cause of the sensory impulse. The impulse, under these circumstances, may be divided into two portions, the first of which is the primary, and goes to the brain directly from the cells in communication with the hip, while the other is the secondary, and is due to the transference to other centres of the impulse before it reaches the brain. If the primary and secondary impulses reach the brain together the pain is referred to both the hip and knee.

What do you mean by the reflexion of nerve force, or reflex action?

Reflex action is due to the fact that an impulse travelling from the periphery to the body along the sensory nerve reaches the same point at which a sensory or receptive cell and a motor or expulsive cell exist side by side. Under these circumstances the sensory cell transfers an impulse to the motor cell, by conduction, which in turn starts an impulse down along its tributary motor nerve, with the result of contraction in the muscle which it supplies.

Give an example of this.

If the foot of a frog be pricked, the leg which is pricked, and to a certain extent the other leg, are immediately jerked away. That this jerking away of the leg is not due to the fact that the brain desires to remove the leg from the irritation, is proved by the fact that if the spinal cord be cut, thereby preventing any impulses from reaching the brain, reflex action is as marked as if the cord was intact.

What is Setschenow's reflex inhibitory centre?

A centre situated in the upper portion of the spinal cord whose function it is to prevent excessive reflex action. If it were not for this centre the pricking of a pin would cause but a slight reflex contraction of the leg, while a violent blow would send such an impulse to the reflex centres that a severe convulsion or tonic spasm might result. Under these circumstances, however, the reflex inhibitory centre controls the motor centres of the spinal cord and prevents their sending out impulses which would be too violent.

What is automatism?

The originating, entirely independent of any external cause, of an impulse in a nerve cell.

What special centres have we in the spinal cord?

Centres which govern the bladder and genital organs.

What effect has irritation applied directly to the anterior and lateral white columns?

It produces muscular movements but no pain, and they are consequently excitable but insensible.[1]

Are the posterior columns, when irritated, sensitive or insensitive?

They are very sensitive, particularly near the origin of the posterior roots.

Is this sensibility due to the presence of sensory nerve filaments belonging to these columns, or simply to the presence of the fibres of the posterior roots?

It is simply due to the fibres of the roots.

What effect has section of the antero-lateral columns?

It abolishes all power of voluntary movement in the lower extremities.

[1] This has been denied by Van Deen and Schiff, but has been proved correct by Fick, Mendelsohn, Ludwig and Woroschiloff, and Horsley.

What effect has section of the posterior column?

The power of muscular coördination is lost. It is these columns which are diseased in locomotor ataxia.

Is the transference of impulses stopped by this?

No; because of the sensory fibres in the lateral columns.

Does the gray matter respond in any way under the influence of direct stimulation?

No, it does not.

What is the result of a lesion of the spinal cord in the lower part of the sacral region?

There is paralysis of the sphincters of the rectum and bladder and of the accelerator urinæ and the compressor urethræ muscles.

What is the result of a lesion high up in the sacral region?

Paralysis of the muscles of the bladder, rectum, and anus; loss of sensation and motion in the muscles of the leg, except those supplied by the anterior crural aud obturator nerves.

What is the effect of a lesion of the upper part of the lumbar region?

Loss of motion and sensation in both legs; loss of power over rectum and bladder; paralysis of the muscles of the abdominal walls. As a result of this, there is some interference with respiration.

What effect has a lesion of the cervical part of the cord?

It produces palsy, as do the other lesions named, with, in addition, paralysis of all the intercostal muscles, and, as a result, great interference with respiration. There is paralysis of the muscles of the upper extremities except those of the shoulders. If a lesion occurs at the upper cervical region, death is instantaneous from respiratory failure.

The Medulla Oblongata.

The *points* to be *remembered* concerning this portion of the nervous system are as follows:

Its columns are continuous with those of the spinal cord, and each half of it may be considered to be divided into three columns or tracts of fibres, in the same manner as they occur in the spinal cord.

What difference exists between the columns here and in the cord?

They are more prominent, and separated from each other by deeper grooves.

What are these columns of the medulla called?

Pyramids; the anterior columns are called the *anterior pyramids,* those of the posterior columns *restiform bodies* and *posterior pyramids.*

FIG. 20.

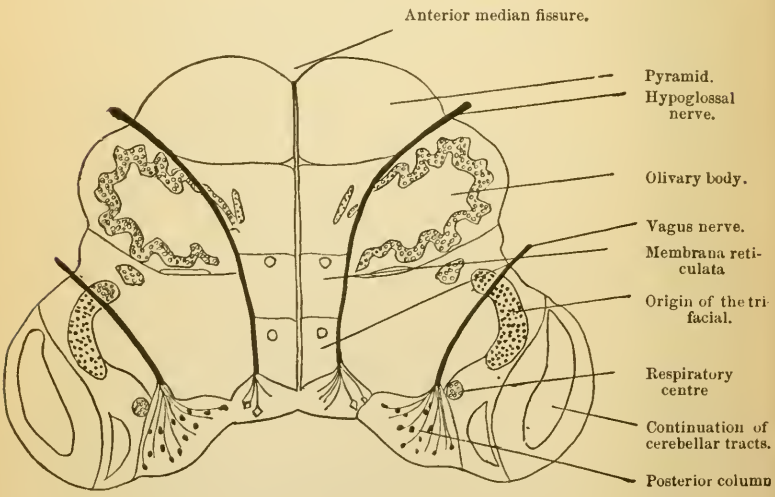


Diagram showing cross section at level of fourth ventricle.

What are the direct pyramidal tracts?

The anterior pyramids which pass directly upward to the cerebrum without crossing to the other side.

What are the crossed pyramidal tracts?

Those fibres of the lateral columns which cross to the opposite anterior pyramid.

What is the olivary body?

On the outer side of each anterior pyramid is a small oval mass of gray matter, the *olivary body*.

What is the posterior pyramid?

A small tract marked off from the posterior part of the restiform bodies on each side by a slight groove.

What forms the fourth ventricle?

The restiform bodies diverge, and by so doing lay open a space—the fourth ventricle.

What is the distribution of the fibres of the medulla oblongata?

The anterior pyramids receive fibres from the middle fibres of the lateral columns of the cord, *not only* from the same side but from opposite sides. In other words, some of the lateral fibres of the left side enter the anterior pyramid of the right side and *vice versâ*. These are the crossed pyramidal tracts already mentioned.

What is the crossing from one side to the other called?

Decussation.

After this occurs, what happens next?

The anterior pyramids with their new fibres pass on upward, the greater part going through the pons to the cerebrum, while a smaller part joins some fibres from the olivary body forming the *olivary fasciculus* or *fillet*. Still another small mass of fibres proceeds to the cerebellum.

What course do the fibres of the lateral columns pursue?

The *outer* fibres go with the restiform tract to the cerebellum, the *middle* decussate to the anterior pyramids as already stated,

and the *inner* pass on to the cerebrum along the floor of the fourth ventricle.

What is the direct cerebellar tract?

The outer fibres of the lateral columns first named.

Do the impulses of the will which arise in the brain pass down each side of the spinal cord directly and produce contractions in muscles of the same side?

No, they do not. The fibres carrying these impulses cross each other in such a way that impulses arising in the left side of the brain are made manifest on the right side of the body, while those arising in the right side of the brain are made manifest in the left side of the body.

Why is this so?

The decussation of part of the fibres of the anterior pyramids of the medulla transfer impulses across the cord.

Does this same transference of impulses take place in the sensory tract, or, in other words, is a sensation occurring in the left foot recognized in the right hemisphere of the brain?

Yes.

Does the transference take place in the medulla?

No, it does not. The posterior fibres do not decussate in the medulla, but Brown-Séquard has shown that the crossing takes place in the spinal cord.

What effect has section of a lateral half of the spinal cord?

It produces paralysis of motion on the injured side, but does not affect sensation in the least on that side. On the uninjured side motion is preserved but sensation lost.

Why is this so?

Because, as has already been stated, the motor impulses are not transferred in the cord but in the medulla, while sensory impulses are transferred in the cord.

What is the function of the medulla oblongata?

In many ways it is similar to that of the spinal cord for it carries on conduction, transference, reflexion, and *automatism*. It is in this portion of the nervous apparatus that the decussation of part of the fibres of the anterior cornua of the medulla takes place, explaining the phenomenon which has just been mentioned in regard to paralysis occurring on the opposite side from the lesion.

What special centres exist in the medulla oblongata?

First, the *respiratory centre*, whose function it is to send out those impulses which result in respiratory movements, and the interference with which causes great disorder of respiration or death; second, it contains the hypoglossal nuclei for *deglutition* which send out the impulses which produce the movements necessary to the acts of swallowing; third, a centre for the movements of *mastication*; fourth, the chief *vaso-motor* centre which governs the bloodvessels all over the body (see Circulation); fifth, the *cardio-inhibitory* centre for the regulation of the movements of the heart through the pneumogastrics; sixth, the superior cilio-spinal centres which govern the movements of the iris[1]; seventh, the inner and outer nuclei of the special sense of hearing; and eighth, the glosso-pharyngeal nuclei for the sense of taste; ninth, the centres for vomiting. The medulla oblongata also gives rise from its posterior surface and its continuation to the cranial nerves from the 12th to the 5th inclusive. (See Figs. 21 and 22.)

How do you know that the medulla contains all those centres which are necessary for the continuance of life?

Because the brain and cerebellum can be destroyed and yet the respiration and heart go on unimpaired.

[1] Remember that the inferior cilio-spinal centre acts thus also.

FIG. 21.

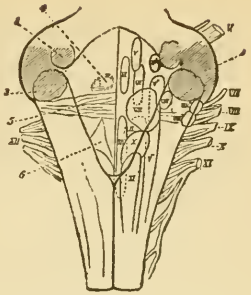
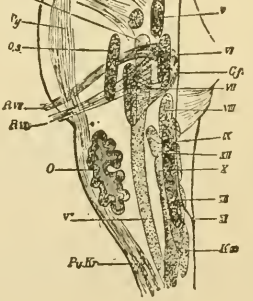


Diagram of posterior aspect of medulla oblongata showing positions of the nuclei of the cranial nerves. (After ERB and FERRIER.)

V, Motor nucleus; V′, middle; and V″, inferior sensory nucleus of the fifth nerve; VI, abducens nucleus; VII, facial nucleus; VIII, inner, and VIII′, outer auditory nucleus; VIII″ and VIII‴, divisions of the anterior auditory nucleus; IX, glosso-pharyngeal nucleus; X, vagus nucleus; XI, accessorius nucleus; XII, hypoglossal nucleus; 1, middle cerebellar peduncle; 2, superior cerebellar peduncle; 3, inferior cerebellar peduncle; 4, eminentia teres; 5, striæ acousticæ; 6, ala cinerea.

FIG. 22.



Diagrammatic representation of the nuclei of the cranial nerves as seen on section. The left half is supposed to be removed, and the nuclei near the median line are shaded darker than the others. (After ERB and FERRIER).

Py. Pyramidal tracts. *Py Kr.* Decussation of the pyramids. *O.* Olivary body. Os. Upper olivary body. Roman numbers have same meaning as in other cut. *Kz.* Clavate nucleus. *Rv.* Roots of fifth nerve. *Rvi.* Roots of sixth, or abducent nerve. *Rvii.* Roots of facial nerve.

What is the function of the pons Varolii?

It contains a large number of nerve fibres both transverse and longitudinal, and is a conductor of impressions from one part of the spinal axis to another. Concerning its functions as a nerve centre little or nothing is certainly known.

What are the functions of the crura cerebri?

They are formed of nerve fibres, of which the inferior or superficial are continuous with those of the anterior pyramidal tracts of the medulla, and the superior or deeper fibres with the lateral and posterior pyramidal tracts, and with the olivary fasciculus. Each crus cerebri contains among its fibres a mass of gray substance known as the *locus niger*. They act principally as conducting organs. As nerve centres they are probably connected with the functions of the oculo-motor nerves through which are directed the numerous movements of the eyeball. They are also connected with the coördination of other movements than those of the eye.

What is the result of injury to the crus cerebri?

Either rotatory or disorderly movements, with loss of coördination, result.

What is the function of the corpora quadrigemina or optic lobes?

Removal of those bodies produces total loss of vision; destruction of one of them produces blindness in the eye of the opposite side. It also produces rotatory movements of the body resembling those occurring after division of the crus cerebri, save that the movements are slower.

What is the effect of injury to these bodies?

They cannot be said to be the centres of vision, but seem to be the centres of correlation between retinal impressions and oculo-motor reactions.

What is the function of the corpora striata?

They are centres of innervation for the same movements as exist in the cerebral cortex, but of a lower grade of specialization.

Injury to the corpora striata on one side prevents the communication between the will and the muscles of the opposite half of the body, so that palsy results, or, in other words, hemiplegia. The corpus striatum may, therefore, be considered as the motor connection between the cerebrum and the crus cerebri.

FIG. 23.

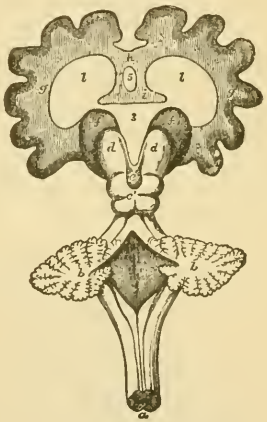


Diagram of brain and medulla oblongata. *a*, spinal cord; *b*, *b*, cerebellum divided, and above it the valve of Vieussens partially divided; *c*, corpora quadrigemina; *d*, *d*, optic thalami; *e*, pineal body; *f*, *f*, corpora striata; *g*, *g*, cerebral hemispheres in section; *h*, corpus callosum; *i*, fornix; *l*, *l*, lateral ventricles; 3, third ventricle; 4, fourth ventricle; 5, fifth ventricle, bounded on each side by septum lucidum. (CLELAND)

What is the function of the optic thalami?

If the optic thalamus is destroyed on one side sensation of the opposite side of the body is impaired or lost. It is, therefore, regarded as the sensory band between the cerebrum and the crus cerebri.

What are the functions of the cerebellum?

It is absolutely insensible to irritation and may be cut away without any signs of pain; its removal from the body or destruction by disease is generally unaccompanied by loss or disorder of sensibility. Animals from which it is removed can see, hear, and feel pain to all appearance as perfectly as before. It governs the coördination of movements, and while irritation of the cerebellum produces no movements at all, remarkable results are produced by removing part of its substance. As portion after portion of it is cut away the animal gradually loses the power of springing, walking, standing, or preserving its equilibrium. If laid upon its back it cannot recover its normal posture but struggles to get up, and if a blow is threatened tries to avoid it, but fails to do so. According to Gowers, the middle lobe of the cerebellum governs equilibrium by means of afferent fibres from the semicircular canals and the ocular muscles and also the muscles of the legs.

What other function has the cerebellum?

The middle lobe is also very closely associated with the vagus, and this is the reason that we are so apt to have vomiting with vertigo or in cerebellar disease.

What results do we gain, therefore, from these experiments?

We know that the cerebellum has no connection with volition, sensation, and memory, but merely has the faculty of combining the action of the muscles and producing thereby the movements intended by the higher nervous centres. *Remember*, that the influence of each half of the cerebellum is directed to the government of the opposite side of the body, and that both halves must act in unison, or, otherwise, strange disorders of motility result.

What is the mean weight of the brain?

The mean weight of the brain in man is 1358 grammes, in woman it is 1220 grammes.

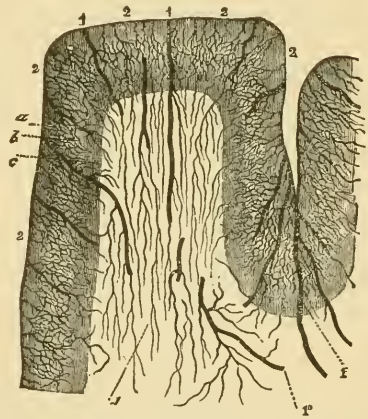
What position does the gray matter occupy in regard to the white?

The gray matter forms the cortex and is outside the white.

Which is the most vascular?

The gray matter is much more vascular than the white.

FIG. 24.



1, 1, Medullary arteries; and 1′, 1″, in groups between the convolutions; 2, 2, arteries of the cortex cerebri; *a*, large-meshed plexus in first layer; *b*, closed plexus in middle layer; *c*, more open plexus in the gray matter next the white substance, with its vessels (*d*). (LANDOIS.)

What two varieties of bloodvessels do we have in the brain?

The long medullary arteries which, as their name implies, pass from the pia mater to the white matter through the gray, and the cortical arteries which in great part enter the gray matter of the cortex only, although some pass down to the white matter.

What difference is there between these two sets of arteries?

The medullary arteries are terminal and do not anastomose, while the corticals do anastomose and are, therefore, not terminal arteries.

What is the physiological significance of this?

A thrombus or embolus in one of the medullary arteries produces a total starvation of the area supplied by it, but if such an accident occurs to one of the corticals then the collateral circulation prevents a total cutting off of blood; therefore, we find that the most important portion of the cerebrum is supplied in such a way that it is guarded against accident, while the white matter which is not nearly so important is unprotected. (See Fig. 24.)

What arrangement of bloodvessels have we for the nutrition of the rest of the brain and the portions of the nervous apparatus?

From trunks constituting the circle of Willis branches are given off which pass upward and enter the brain to supply it with blood.

Are these arteries terminal, or do they anastomose with each other?

They are terminals, and do not anastomose.

What is the function of the cerebrum?

The cerebral hemispheres are the organs by which perception is carried on and from which motor impulses are given out. They contain the organ of the will; they possess memory, or the means of retaining impressions of sensible influences; and they are the medium of all the higher emotions and feelings. They carry on intellection as is evidenced by imagination, understanding, reflection, and judgment.

How do we know that consciousness depends upon the action of the cerebral hemispheres?

If they are injured in any way, consciousness is lost—as, for example, during an apoplectic fit.

How do we know that it is in the cerebral hemispheres that the intellect is situated?

Because the higher the intellect is the greater development is possessed by the brain, and because destruction of the cerebrum stops intellection. Congenital and other morbid conditions of the hemispheres always produce disorders of the intellect.

What effect has the extirpation of the cerebrum?

After the removal of both cerebral hemispheres in animals, every voluntary impulse, every conscious impression, and every sensory perception ceases, but the maintenance of the equilibrium and all the mechanical movements of the body are preserved.

What example of this can you give?

A frog with its cerebrum removed retains its power of maintaining its equilibrium. It can sit, spring, or execute complicated movements which are coördinated, and when it is placed upon its back immediately turns right side up again.

What is the purpose of the convolutions?

In order to give a greater surface for the spreading of the cells in the cortex without making the brain so large that the skull would be out of proportion to the body.

What do you mean by cerebral localization?

The determination of the areas in the cerebral hemispheres governing various portions or functions in the body.

Where is the speech centre located in the cerebrum?

In the third frontal convolution and the Island of Reil.

On which side of the brain is the speech centre best developed?

The left side.

What are these areas?

The surface of the cerebrum may be divided into three sections —anterior, middle, and posterior. The anterior lobes contain the cells for intellection, the middle areas the cells for motion, and the posterior lobes those for sensation or perception.

As an example of some of the motor centres, give the area for the arm and leg.

Stimulation of the upper extremity of the ascending parietal and ascending frontal convolution causes movement of leg, while stimulation of these two areas lower down causes movements of the arm.

What is the relative position of the chief centres in the brain?

It is a fact that the centres which govern the more massive parts and which govern the lower regions of the body are high up in the brain, while the centres for the control of the face and arm, for example, are lower down on the surface of the cortex.

What portion of the brain perceives pain?

Horsley has shown that destruction of the gyrus fornicatus prevents the perception of pain.

In what two ways are these impulses carried to the lower portions of the nervous system?

From all this area radiating fibres converge to the base of the brain, where some of them pass through the corpora striata and its three nuclei (the caudate, lenticular, and taeniform), while others pass through the internal capsule.

What course do these fibres now take?

After leaving the internal capsule these fibres once more meet some of those fibres which passed through the nuclei of the corpora striata and form the crustæ of the crura cerebri, which continuing downward through the pons Varolii emerge from its posterior and lower border in the form of the anterior pyramids of the medulla oblongata.

What course do centripetal impulses take to get to this portion of the brain ?

When the sensory fibres of the spinal cord reach the medulla oblongata they pass up on either side of the motor nuclei to form

FIG. 25.

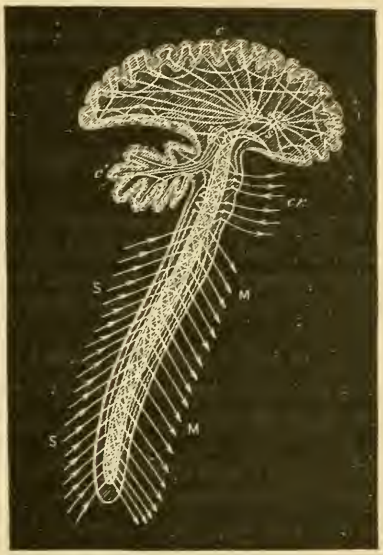


Diagram of some of the paths taken by nerve impulses in the brain and spinal cord. *c*. Gray substance of cerebral cortex. *c'*. Gray substance of cerebellum. *cr*. Cranial nerves, some afferent and some efferent. M. Motor (efferent) spinal nerves. S. Sensory (afferent) spinal nerves. (YEO.)

the tegmenta, and to become connected with the optic thalami, corpora geniculata, and corpora quadrigemina. From these ganglia radiating fibres pass to the receptive areas of the brain.

THE CRANIAL NERVES.

It will be remembered that, according to most anatomists, the cranial nerves are divided into twelve pairs.

1. What is the function of the olfactory nerve?

It is the nerve of special sense by which odors are distinguished; in other words, it is the nerve of smell. It is distributed to the mucous membrane of the nose, and arises superficially from the lower part of the frontal lobe in advance of the anterior perforated space, passing through the cribriform plate of the ethmoid bone.

2. What is the function of the optic nerve?

It is the nerve of sight, and is distributed to the retina of the eye. It arises superficially from the geniculate and quadrigeminal bodies and thalamus, and passes out through the optic foramen of the orbit. It conveys no other impulses than those of sight.

What is the effect of division of one of the optic nerves?

It produces complete blindness in the eye of the corresponding side.

What is the effect of division of the optic tract?

It produces loss of sight in the outer half of the eye of the same side, and of the inner half of the eye of the opposite side.

What is the effect of injury to the anterior part of the optic chiasm?

It causes blindness in the inner half of both eyes.

3. What is the function of the oculo-motor nerve?

It is the motor nerve of the levator palpebrarum, the superior, internal, and inferior rectus, and the inferior oblique muscle of the eye. Its superficial origin is the inner side of the cerebral crus, and it finds its exit from the sphenoidal foramen. It also supplies filaments to the ciliary ganglia from which the ciliary nerves arise, which enter the eyeball and are distributed to the circular fibres of the iris and the ciliary muscle. It governs the accommodation of the eye.

What effect has stimulation of the oculo-motor on the pupil?

It causes contraction of the pupil, internal strabismus, and muscular movements of the eye, but no pain. Section of the nerve is followed by ptosis, or drooping of the upper eyelid, internal strabismus, due to the supposed action of the external rectus muscle, and paralysis of the accommodation of the eye.

4. What is the function of the pathetic nerve?

It governs the movements of the eyeball so far as those are concerned which are produced by the action of the superior oblique muscle; it arises from the valve of Vieussens and passes through the sphenoidal foramen.

5 What is the function of the trifacial nerve?

It is a nerve of sensation, motion, and taste. It arises from the side of the pons by a smaller motor and a larger sensory root, and is divided into three divisions, the *first* of which supplies the conjunctiva, the lachrymal gland, the eyeball, the upper eyelid, the integument of the forehead, and the mucous membrane and integument of the nose. The *second* division supplies the lower lid and conjunctiva, the temple, upper lip, nose, cheeks, and teeth of the upper jaw. These two divisions are purely sensory. The *third* division supplies the muscles and skin of the lower part of the face, the muscles of mastication, the teeth in the lower jaw, the tongue, the parotid gland, and the auricle of the ear. This division contains motor, sensory, and other filaments which carry the sense of taste.

What is the effect of irritation of the larger root of the trifacial nerve?

It produces marked evidence of pain, which is always felt in the periphery of the nerve, since it will be remembered that pain arising at the origin of a sensory nerve is always referred to its peripheral filaments. Irritation of the small root produces movements of the muscles of mastication, whilst section of this root causes paralysis of these muscles. Section of the large root is

[1] For medullary origin of all the rest of the cranial nerves, see page 121.

followed by a complete abolition of sensibility in the head and face, but no disturbance of motion.

6. What is the function of the abducent or sixth pair of nerves?

Motion, which results in turning the eyeball outward. They arise from the anterior pyramids, and supply the external rectus muscle of the eye. Stimulation of this nerve causes outward rotation of the eyeball, while paralysis of it causes internal strabismus.

7. What is the function of the facial nerve?

It supplies the motor filaments of the muscles of the ear, scalp, and face—platysma, digastric, and stylohyoid muscles—and arises between the olivary and restiform bodies. It finds its exit through the internal auditory meatus, the facial canal, and the stylomastoid foramen.

What is the peculiarity of the facial nerve?

It is a motor nerve in its origin, but in its course receives sensory filaments from the fifth pair and the pneumogastric. Irritation of the facial produces muscular contractions, while division produces paralysis of the muscles of the face. *Remember*, that it is this nerve which gives off the chorda tympani, that branch which supplies the bloodvessels and secretion of the sublingual and submaxillary glands and the sense of taste in the anterior two-thirds of the tongue.

8. What is the function of the auditory nerve?

It governs the sense of hearing, conducting the impulses from the exterior to the brain. It rises in the floor of the fourth ventricle, and is distributed to the labyrinth of the ear. Destruction of this nerve produces deafness.

9. What is the function of the glosso-pharyngeal nerve?

It governs the sensibility of the pharynx, and therefore influences taste. It has also motor filaments which pass to the root of the tongue, the tonsils, the soft palate, the pharynx, and the tympanum.

10. What is the function of the pneumogastric or vagus nerve?

It is chiefly made up of sensory filaments which anastomose with motor filaments from other sources. It influences deglutition, the action of the heart, the circulatory and respiratory systems, the voice, and the stomach. It arises from the fore part of the restiform body and the vagal nucleus of the floor of the fourth ventricle. The functions of its branches have been considered when studying the circulation, respiration, etc.

11. What is the function of the spinal accessory nerve?

It is made up of motor filaments, some of which pass to the vagus nerve, while others supply the sterno-mastoid and trapezius muscles. It arises from the lateral columns of the spinal cord and the gray substance within. It will be remembered that it consists of two parts, a smaller accessory root whose deep origin is in a nucleus of gray matter at the back of the medulla below the origin of the vagus, and a large spinal root from the lateral columns of the cord.

What is the effect of destruction of its medullary root?

It produces paralysis of the laryngeal muscles, resulting in aphonia, and impairs the action of the muscles of deglutition. Irritation of the spinal root produces contractions of the trapezius and sterno-mastoid muscles, but section of this branch does not produce absolute palsy in these muscles, since they are supplied by motor filaments from elsewhere.

12. What is the function of the hypoglossal or sublingual nerve?

Its function is motor and it governs all the movements of the tongue, influences mastication, deglutition, and articulate language. It rises from the anterior pyramid, the olivary body, and the hypoglossal neucleus. Irritation of it produces convulsive movements of the tongue, while division of it abolishes all these movements and interferes considerably with deglutition; articulation is considerably impaired, and mastication is performed with difficulty from inability to retain the food between the teeth.

THE SPECIAL SENSES.

What do you mean by the term 'nerves of special sense"?

Those nerves which carry, as do sensory nerves, impulses from the periphery to those centres in the brain which may perceive and interpret them, and which differ from the ordinary sensory nerves in that, as a general rule, the impulses are not the result of ordinary stimulation by contact, but of one special form of irritation. As an example of this the optic nerve appreciates light, yet light can never be said to produce activity of the nervous protoplasm by contact; nor do the vibrations of air produced by sound cause any impulses to travel along any sensory nerves save the auditory; neither can we say that the olfactory nerves are stimulated mechanically by the presence of substances so small that they cannot be distinguished by spectrum analysis, but which, nevertheless, are perceived by the nostrils; this is the reason why each one of the nerves carrying the impressions of sight, smell, taste, or sound, are called *special*, since each one of them can transmit but one variety of impulse.

Do the nerves which carry these impulses of special sense differ from other nerves in their structure and ordinary capabilities?

No; they differ in no way at all from ordinary afferent nerves, with one or two exceptions.

Is the sensation recognized at the point at which the cause exists, or by the special centres in the brain?

It is recognized in the centre, but, as has been stated before, impulses in sensory nerves are always referred to the periphery, and, therefore, we are accustomed to say that we feel the burn or other injury at the spot where it occurs.

By what means is this peculiar condition in regard to sensation governed?

It is solely governed by the mind itself, which has been taught to do this as the result of education, experience, and habit, acquired by a long series of unconscious experiments in early youth.

What is necessarily present for a complete special sense apparatus?

First, a special nerve ending, only capable of being excited by special forms of stimuli; *second*, an afferent nerve to conduct the impulse from the special end organ to the nerve centre; *third*, nerve cells forming a centre, which is capable of translating the impulse received into a sensation and of referring that sensation to some local point; *fourth*, associated nerve centres capable of perceiving sensations, forming ideas, and drawing conclusions therefrom, with the object of determining the position, character, and intensity of the external influence.

The Sensibility of the Skin.

Those impulses which are received through the skin are obtained through the *sense of touch*.

Into how many divisions is this sense of touch subdivided?

First, tactile sensibility, by means of which we appreciate the slightest touch and recognize the exact point at which the skin receives the impulse. *Second*, the *sense of pressure*, by which we are enabled to judge of the compression which is being exerted on a certain area; this sense, however, is by no means so well developed as the tactile sense. *Third*, the *sense of temperature*, by which we are enabled to determine whether an object is hot or cold. This sense, also, is not perfectly developed, since for a moment we are unable to determine whether an object is hot or cold unless the eye or other special sense aids us.

What is the object of tactile sensibility?

In order that we may judge of the position, character, and shape of bodies.

Is tactile sensibility exceedingly important to the animal organism?

Very important, since without it nothing could be held firmly in the hand, and all the movements of the body would be seriously interfered with.

In what way are the nerves arranged for tactile sensibility?

The sensory nerves running to the skin are endowed with endings of various forms according to their function; these forms are divided into five varieties: *First*, the *touch corpuscles*, which are egg-shaped bodies situated in the papillæ of the true skin, directly under the epithelial cells of the rete mucosum; they vary in size considerably, according to the amount of work which they are forced to perform; in these the axis-cylinder of the nerve ends. *Second*, the *end bulbs*, which are smaller than the last and differ from them in that they are only distributed to localized areas; they are made up of a little vesicle containing fluid in which the axis-cylinder terminates, the wall of the vesicle joining the sheath of the nerve. *Third*, *touch cells*, which differ from the others in that they exist in the deeper layer of the epiderm. *Fourth*, *free nerve endings*, which occur on the surface of the epithelium of mucous membranes. *Fifth*, *Pacinian corpuscles*, which are ovoid bodies made up of concentric layers of varying consistence, with a collection of fluid in the centre, in which the axis-cylinder ends.

The Sense of Taste.

In what way is taste produced?

By the contact of sapid substances with the endings of the gustatory nerves of the tongue in the various papillæ.

What are these papillæ sometimes called?

"Taste buds" or "taste goblets."

Is it possible to taste a dry substance?

No; when a dry substance is placed on the tongue the moisture dissolves or moistens at least some of it.

What proof have we that this is so?

If the tongue be thoroughly dried no taste is perceived.

Where is the chief sense of taste situated?

In the tongue.

What other surfaces aid the tongue in tasting?

The soft palate and its arches, the uvula, tonsils, and upper pharynx. The hard palate has little taste power.

What is the nerve supply of the back part of the tongue?

The glosso-pharyngeal.

What is the nerve supply of the tip of the tongue?

The lingual branch of the trifacial nerve.

What portion of the tongue perceives taste the best?

The back portion. The tip and middle of the tongue are not so well endowed with nerves.[1] The sense of smell aids the sense of taste when eating. If the nostrils be closed and the eyes shut no distinction can be exercised between a piece of apple, potato, or onion on the tongue.

Do certain areas of the tongue taste certain bodies?

Yes. The sulphate of quinine is scarcely noticed at the tip, at the back it is very well perceived. Sugar, on the other hand, is best tasted on the tip of the tongue.

The Sense of Smell.

How is the sense of smell excited?

By fine bodies floating in the atmosphere.

What effect on smelling has drying of the nasal mucous membrane?

It impairs the power of perceiving odors very greatly.

What is the object of sniffing?

In order to draw over the nerve endings a current of air containing the odor.

In what way are the olfactory nerves arranged?

Most of these nerves are distributed to the mucous membrane of the middle and upper meatus of the nose. The mucous membrane

[1] For the muscular movements of the tongue, see Mastication.

in this area is not covered by motile cilia such as are found in the rest of the nasal cavity; it is less vascular and of a peculiar yellow hue. The extreme delicacy of smell can best be understood when we remember that Valentin has estimated that two-millionths of a milligram of musk is sufficient to excite the olfactory nerves of man. In other animals this sense is even more acute.

The Sense of Sight.

The Eye and its Coverings

What is the function of the eyelids?

To protect the eyeballs, and to distribute moisture over them constantly, thereby preventing drying.

How are they formed?

They are movable folds of skin, each of which is kept in shape by a thin plate of yellow elastic tissue.

What is the function of the eyelashes?

To prevent the entrance of foreign bodies, especially when the lids are half closed.

In what way do they differ from ordinary hairy growths?

They possess tactile sensibility, which causes, reflexly, the lids to close tightly when a foreign body touches them.

What is the purpose of the Meibomian glands along the edges of the lids?

To lubricate them, and prevent irritation from the tears.

In what portion of the orbit is the lachrymal gland placed?

In the upper and outer angle.

What is the use of the lachrymal gland?

To secrete liquid, which will lubricate and keep the eye moist. When an excessive secretion takes place it runs over the lower lids, in the form of tears.

On what side of the orbit does the lachrymal secretion escape?

On the inner side, through the puncta lachrymalia, one of which

exists in each lid; thence it passes into the lachrymal sac, and from there through the nasal ducts into the nose.

What function has the lower eyelid which is not possessed by the upper lid?

It acts as a gutter along which an excess of the tears may flow; when one cries the gutter overflows.

What is the function of the orbicularis palpebrarum muscle, and what is its nerve supply?

It closes the eye, and is supplied by the facial nerve.

What muscle opens the eye?

The upper lid is raised by the levator palpebrarum superior, which is supplied by the oculo-motor nerve.

In what way does the ending of the optic nerve differ from any other sensory nerve?

It is enclosed in a specially arranged organ, the *eyeball.*

What is the object of the eyeball?

For the purpose of so directing the rays of light that they strike in a certain way upon the peripheral optic filaments. It also protects the nerve filaments from all contact with external conditions, except light.

What is the only stimulus which ordinarily excites the optic nerve?

Light.

What is the purpose of the movements of the eyeball?

In order that objects may be brought within the range of vision without movements of the head.

If electrical, mechanical, or other stimuli be applied to the optic nerve, what sensations will they produce?

Light is the only thing appreciated.

What is the function of the sclerotic coat of the eye?

It gives shape and protection to the organ.

Is the sclerotic coat continuous all over the eyeball?

No, it is not; for at the anterior portion is a window-like opening, known as the *cornea,* through which the rays of light pass.

What is the function of the cornea?

It permits light to enter the eye in much the same manner as a window-pane lets light into a room, and it also effects very markedly refraction of the rays of light.

What peculiar bodies have we in the cornea which move about?

The corneal corpuscles, which resemble amœbæ in their movements.

Does the cornea possess nerves and bloodvessels?

Only nerves, which are partly sensory in function.

From what are these nerves derived?

From the long and short ciliary nerves.

What change takes place in these nerves as they enter the cornea?

They enter the cornea as medullated nerve fibres, but the myelin soon disappears and leaves the naked axis cylinder.

In what way, then, is it nourished?

By absorption from the bloodvessels at the corneal margin.

What is the function of the choroid coat?

Owing to its black, pigmented connective tissue cells, it prevents the transmission of all light from the exterior, save by the corneal opening, and prevents reflections from side to side. It is this coat which lacks pigment in albinoes and nocturnal animals, and its absence prevents good vision in the daytime.

What are the ciliary processes?

They are highly vascular folds of the choroid, occurring near the edge of the cornea.

What is the function of the ciliary muscle?

It attaches the choroid to the sclerotic coat, governs the diameter and shape of the crystalline lens, and governs accommodation.

What is the function of the iris?

It is a circular membranous diaphragm provided with a central aperture, the pupil, and regulates the amount of light entering the eye. It contains two sets of muscular fibres, circular and radiating.

What are the functions of these two sets of muscular fibres?

The radiating fibres dilate the pupil, the circular fibres contract it.

What is the object of this pupillary movement?

The regulation of the amount of light entering the eye.

Have the vessels of the choroid any intimate connection with the nutrition of the eye?

Yes.

Describe these bloodvessels.

The arteries are the short posterior ciliary arteries, which are about twenty in number and perforate the sclerotic near the optic nerve. They terminate in the vascular network of the chorio-capillaris, which reaches as far as the ora serrata. The long posterior ciliary arteries lie on the nasal and temporal side of the eye; they run to the ciliary part of the choroid and penetrate the iris, helping to form the circulus arteriosus iridis major. The anterior ciliary arteries, which arise from the muscular branches, perforate the sclerotic coat anteriorly and give branches to the choroid and iris.

What are the veins, and what is their function?

The anterior ciliary veins receive the blood from the anterior part of the eyeball and carry it outward; they do not receive any blood from the iris.

In what way does the blood from the iris pass out of the eye?

The venous plexus of the ciliary processes receives the blood from the iris and passes it backward to the choroidal veins.

What arrangement have we on the posterior surface of the iris to prevent the transmission of light through it?

A layer of dark pigment.

What is the nerve supply of the circular fibres of the iris?

The oculo-motor.

What is the nerve supply of radiating or dilating fibres?

The trifacial and sympathetic.

Why does the pupil contract when we are looking at near objects, but dilate for objects which are far away?

When an object is near, the rays of light are so near together that they enter through a small opening; when it is far off the pupil dilates, in order to let all the rays in that it can to make the image more distinct.

What is the function of the retina?

Lying next to the choroid coat the retina is formed by the expansion of the optic nerve, and it is this membrane which receives the impression of light.

What is the chemical reaction of the retina?

When fresh it is acid in light, but it is alkaline in darkness.

In what way do the nerve filaments end in the retina?

In the rods and cones.

Which of these is most highly developed in man?

The rods.

What do you mean by the blind spot?

A small point in the retina on which, when light falls, no impulse is produced; it is the point of entrance of the optic nerve.

What do you mean by the macula lutea?

The point at which rays of light produce the greatest visual impression. It is exactly in the centre of the retina.

Are the rods or the cones in greater number here?

The cones.

What is the visual purple?

A certain purple substance on the retina, which is destroyed by contact with light. It has been supposed that it aids vision, but this is apparently contradicted by the fact that it is absent from the cones and the macula lutea, where vision is best. It can only be seen by opening an eye in a dark room, and flashing a light upon it. If the operation be quickly done the image falling on the retinal pigment may be made permanent by dipping it quickly in a strong solution of alum.

Does every part of the retina receive all the rays of light?

No. Each portion receives different colored rays. The peripheral portion sees the red rays, etc.

What is the function of the aqueous humor of the eye?

It affords a medium in which the iris can move. It also supports the posterior surface of the cornea, and influences the refraction of light.

What is the function of the vitreous humor?

It fills out the eyeball and keeps it tense, and aids very largely in the refraction of the rays of light transmitted to it through the crystalline lens.

What is the function of the crystalline lens?

It acts like a strong, magnifying glass, and is biconvex. It is the most important refracting portion of the eye, and, aided by other portions of the optical apparatus, directs the rays of light in such a manner that they fall properly on the retina. It also separates the aqueous from the vitreous humor.

In what way are images thrown on the retina?

They are inverted by the lens, which is biconvex.

Why do we not see objects, therefore, upside down?

Because the brain interprets the inverted image for one in the proper position.

What variation is there in the power of refraction of the various parts of the lens?

It increases in density, and consequently in power of refraction, from without inward.

Give the essential portions of the eye for the carrying out of its functions, namely, sight.

1. A retina or nervous mass to receive and transmit impulses.

2. Certain refracting media so arranged as to throw the rays of light in proper form.

3. A contractile diaphragm, the iris, which governs quantity of light admitted.

4. A contractile muscle, the ciliary muscle, to regulate the shape of the lens and to "accommodate" the eye to distances.

What would be the effect if the retina was exposed to the light with no refracting media in front of it?

The perception of light from darkness, but no objects could be seen.

What do you mean by the terms "refraction and accommodation of the eye?"

By *refraction* we understand that optical adjustment of the eye which depends upon its anatomical structure; the *accommodation* includes those changes of the optical adjustment which are effected by the ciliary muscle.

When the eye is at rest is it accommodated to near or far objects?

It is accommodated for the greatest distance.

What do you mean by the "near point?"

The "near point" is the nearest point at which the eye can clearly perceive an object held before it, as, for example, printed matter held close to the face.

The "far point" is the same thing reversed, save that the far point in the human eye is an infinite distance.

By what means do we judge of distance?

This is largely a matter of education and is unconsciously ob-

tained, in the same way as the judgment of size, a mere matter of practice.

What is chromatic aberration?

It is the breaking up of ordinary white light into colored rays, owing to the different colored lights of which ordinary light is made up. It is due to a defect in the optical apparatus, but in the normal eye it is diminished by the iris, which cuts off the marginal rays.

What is spherical aberration?

It depends upon the fact that luminous rays passing through a convex lens strike the various parts of the surface at different angles, and, hence, are differently refracted, the rays striking the margin of the lens being more bent than those passing through the centre. Spherical aberration does not, however, cause inconvenience, since the iris allows only the central rays to pass.

What is astigmatism?

It consists in an inability to see clearly lines running at certain angles.

It depends either upon some irregularity in the shape of the cornea, or in the shape of the lens.

What are entopic images?

Those which depend on the presence of some opacity in the transparent media of the eye itself. They occur in all eyes to a a certain extent, and are frequently noticed when one uses the microscope.

What is the cause of color-blindness?

The inability of certain areas of the retina to perceive those rays of light which normally fall on them, owing to the imperfect development of these areas. The common forms of blindness are for the red, green, and yellow rays.

What is diplopia?

Double vision, due to the fact that each eye receives the impulse at a different time from the other.

What is hemianopsia?

Blindness of one-half of the eye so that objects are split down the middle and only half of the body perceived. Since the rays of light cross in the eye, the part of the retina which is blind is always opposite the object, which cannot be seen. Thus, when the eye sees no objects to the left of it, it is the right side of the eye which is blind.

What is myopia?

"Short sightedness." A condition of the eye in which objects are focussed at a point in front of the retina.

What is hypermetropia?

"Far sightedness." A condition of the eye in which objects are focussed behind the retina.

What do you mean by presbyopia?

A state common to old age, due to loss of the power of accommodation.

What is an emmetropic eye?

A normal eye.

Does such an eye as an absolutely normal eye exist?

Probably not, or in very rare instances.

By what form of glass would you remedy myopia?

By a concave glass.

By what form of glass would you relieve hypermetropia?

By a convex glass.

Why do you do this?

Because in the myopic eye the lens is too convex, while in the hypermetropic eye it is not convex enough. While this is often the case, the fault generally depends on a misshapen eyeball.

What do you mean by dioptric media?

Transparent bodies which so refract the light that images come to a focus on the retina.

What do you mean by intraocular pressure?

The tension to which the coats of the eyeball are put by the varying quantity of the humors of the eye. When the tension is increased abnormally it is called glaucoma.

What do you mean by the Argyll Robinson pupil?

An abnormal condition of the pupil in which it does not contract to light, but does contract when accommodation is carried on.

What is nystagmus?

Gowers think that it is due to faulty fixation of the eyeball by the reflexes which generally keep it steady. Either the stimulation of the reflexes is insufficient or too great. In albinoes we often have it because of too much stimulation from light. In children blind soon after birth it also comes on before the steadying centres can be developed.

Hearing.

In the same way that all impulses travelling along the optic nerve are interpreted as light, so are all the impulses travelling along the auditory nerve interpreted as sound.

Through how many divisions of the ear does the sound pass?

Three; the external ear and auditory canal, the middle ear, which is shut off from the auditory canal by the tympanic membrane, and the labyrinth.

What is the purpose of the external ear?

To collect sound.

What is the function of the auditory canal?

By circumscribing the air it increases its vibrations.

What is the function of the cerumen of the external ear?

To catch foreign bodies which might otherwise enter.

What is the function of the tympanic membrane?

It receives the vibrations of the air in the auditory canal, transmitting them to the bones of the middle ear.

For what purpose is the tympanic membrane sloped from outward inward?

By this means it more readily responds to sounds of varying character and can be of greater dimensions.

By what means are the vibrations of sound transmitted after leaving the tympanic membrane?

Three small bones known as the malleus, incus, and stapes join together, and reach from the membrane to a secondary membrane which covers the oval window leading into the vestibule of the internal ear; the malleus is attached to the tympanic membrane, while the stapes is in contact with the oval window.

What is the function of the stapedius muscle?

It is attached to the stapes, and when it contracts pulls that bone away from the oval window, otherwise a loud sound might jam the bone into the oval window and produce deafness.

What is the function of the tensor tympani muscle?

By drawing the handle of the malleus internally it increases the tenseness of the tympanic membrane and prevents it from vibrating too much to sounds of great intensity.

What is the function of the laxator tympani muscle?

It draws the handle of the malleus outward, and relaxes the tympanic membrane.

What is the function of the Eustachian tube?

It communicates with the pharynx and opens into the middle ear back of the tympanic membrane, affording vent by which, when the drum is driven in, some of the air may escape. It equalizes the pressure within and without.

Is the Eustachian tube constantly open?

No, it is not; if it were, the various sounds in the mouth would produce sounds in the ear.

In what way is sound transmitted, after passing through the ossicles, to the terminal filaments of the auditory nerve?

Through the semicircular canals and the spiral staircase.

What fills the semicircular canals?

A liquid known as the endolymph.

In what manner does the endolymph receive impulses from the exterior?

The endolymph is in direct contact with the membrane which covers the oval window, and when the stapes strikes against this membrane it produces vibrations which are taken up by the endolymph.

In what way do the nerves end in the semicircular canals?

In peculiar epithelioid cells, to which are attached fine hair-like processes.

What are the functions of the otoliths?

These small calcareous masses are set in motion by the vibra-

tions of the endolymph and come in contact with the endings of the nerves, producing impulses. The function of those nerve fibres which run to the cochlea is not clearly understood.

What function have the semicircular canals other than hearing?

They appear to govern equilibrium, for if injured the animal immediately loses its balance. When the horizontal canal is divided the animal rolls its head from side to side. When one of the vertical canals is cut the head moves up and down.

Does section of the semicircular canals destroy the power of hearing?

No; it influences it very slightly.

What is the function of the organ of Corti?

It is not distinctly known, but it was supposed to be especially developed in persons with musical tendencies, till it was found that the pig possessed them in a highly developed state. As nerve filaments end in these rods, it has been supposed that each set of rods responds to a certain set of notes.

What differences in sound can the ear distinguish?

Loudness, pitch, and quality. The judging of the distance from which a sound is transmitted is purely a matter of training.

The Voice and Speech.

With scarcely any exception all air-breathing vertebrates possess some arrangement for the production of sound in some part of the respiratory apparatus. In some animals various modifications of this sound are produced. In man its modifications are so great as to permit of speech.

In what way is the voice or sound produced?

By an expiratory blast of air being forced through the narrow opening at the top of the windpipe, called the glottis. The glottis, it will be remembered, lies in the lower part of the larynx and is bounded on each side by thin membranous bands, which, extending from side to side, vibrate as the air rushes over them. For this reason, opening of the trachea prevents speech, since all the air rushes out of the opening rather than over the cords.

What are the chief organs of the voice?

The vocal cords. These are governed by the muscles of the larynx.[1]

What is the function of the larynx?

It acts as a cavity in which the vocal cords may produce the voice.

What is the function of the thyroid and cricoid cartilages?

The function of these two cartilages is chiefly for the purpose of affording stiff walls around the vocal apparatus for the sake of protection and attachment. The thyroid cartilage forms an incomplete ring around the larynx, and covers only the front portion and sides. The cricoid cartilage, on the other hand, is a complete ring, the back part of the ring being broader than the front.

What is the function of the arytenoid cartilages?

They are situated on the top of the back portion of the cricoid cartilage and are movable upon it, forming a place for the insertion of certain muscles concerned in speech.

What are the intrinsic muscles of the larynx?

They are those which have a direct action on the vocal cord, and are nine in number—four pairs and a single muscle: two crico-thyroids, two thyro-arytenoids, two posterior crico-arytenoids, two lateral crico-arytenoids, and one arytenoid muscle.

What are the functions of these muscles?

When the crico-thyroids contract they rotate the cricoid on the thyroid cartilage in such a manner that the upper and back part of the former, and of necessity the arytenoid cartilages on the top of the cricoid cartilage, are tipped backward, while the thyroid is inclined forward. The result of this is that the vocal cords being attached in front to the thyroid cartilage and posteriorly to the cricoid cartilage are put on the stretch. The thyro-arytenoid muscles have an opposite action, for they pull the thyroid backward and the arytenoid and the upper and back part of the cricoid

[1] For the anatomy of the larynx and those portions of the body concerned in speech, see an anatomical text-book.

cartilages forward, thus relaxing the vocal cords. The posterior crico-arytenoids dilate the glottis and separate the vocal cords by an action on the arytenoid cartilage. When they contract they pull together the outer angles of the arytenoid cartilages in such a manner as to rotate the latter at their joint with the cricoid, and to throw asunder their anterior angles to which the vocal cords are attached.

What muscles oppose these posterior crico-arytenoid muscles?

The lateral crico-arytenoids, which, pulling in the opposite direction from the other side of the axis of rotation, have, of course, exactly the opposite effect, and enclose the glottis. The arytenoid muscle may also close the glottis almost completely, by pulling together the upper parts of the arytenoid cartilages, between which it extends.

What is the nervous mechanism of the voice?

The sensory filaments in the pneumogastric give the glottis that acute sensibility which prevents the ingress of foreign bodies or noxious gases into the air-passages. The superior laryngeal branch of the vagus and the inferior laryngeal branch, or the recurrent nerve, coöperate not only with the pneumogastric in the closure of the glottis which excludes foreign bodies, but also in the protection and regulation of the voice. The inferior laryngeal nerve governs the contraction of the muscles that vary the tension of the vocal cords, while the superior laryngeal conveys to the mind the sensations of the state of these muscles, which is absolutely necessary for their intelligent guidance.

What three properties are possessed by the human voice?

Quality, pitch, and intensity.

Over how wide a musical range does the human voice extend?

Including all forms of voice, about three and one-half octaves; but of this wide range a single individual can rarely sing more than two octaves.

What difference exists between the notes of the female voice and those of the male?

The lowest note of the female voice is about an octave higher than the lowest note of the male voice. The highest note of the female voice is about an octave higher than the highest note of the male.

In what portion of the vocal apparatus is the variation in sound produced which results in speech?

Not in the larynx, but in the mouth and nose, by means of the teeth, tongue, and lips.

What sound do we have when speech is not accompanied by the action of the vocal cords?

Only a whisper.

What effect upon sound has approximation of the vocal cords?

The sound emitted is high pitched in character, while non-approximation of the cords produces sound of greater volume, but of lower pitch. The pitch does not depend, however, absolutely on the approximation or non-approximation of the cords, but more upon the tensity of the cords themselves.

What is the function of the epiglottis in regard to sound?

When pressed down so as to cover the cavity of the larynx it serves to render the notes deeper in tone, and, at the same time, somewhat fuller in quality.

What is aphasia?

The partial or complete loss of the power of articulate speech from causes arising in the cerebrum.

What is the difference between aphasia and aphonia?

Aphasia is the derangement of the mental functions immediately connected with word-thought, while aphonia is the term applied to the voicelessness of laryngeal disease.

What is the term aphæmia applied to?

It is usually used to signify a condition of speechlessness due to inability to execute the normal movements of the mouth and tongue. This condition is sometimes called ataxic aphasia.

Does a patient who is aphasic still have the power to think, and does he still remember words?

Yes; and he, therefore, can express himself in writing.

What do you mean by the term amnesic aphasia?

It is the condition in which the idea is present but the word is wanting, although articulation is "at the service of the word." The movements in this condition are correct, so far as speech is concerned, but the patient cannot think of the word to speak it. This condition is often seen in old persons to a slight extent, and is called amnesia senilis.

What is paraphasia?

The inability to connect rightly ideas with the proper words to express them, so that instead of giving expression to the ideas the sense may be inverted.

What is agrammatism?

The inability to form the words grammatically and arrange them in sentences.

What is bradyphasia?

A pathological slowness of speech.

The Sympathetic Nerve.

It will be remembered that the sympathetic system contains a very large number of non-medullated nerve fibres, and consists of a double gangliated prevertebral cord, one on each side of the vertebral column.

What are the rami communicantes?

The nerves given off by the spinal nerves to the sympathetic cord. Each spinal nerve does this.

What do you mean by the cephalic, dorsal, and abdominal portions of the sympathetic?

Those portions which govern these areas. In the head the cephalic portion anastomoses with the cranial nerves to a great extent. The abdominal portion supplies the abdominal organs.

What are the functions of the sympathetic?

First, the *independent* functions as represented by the automatic cardiac ganglia, the mesenteric plexus of the intestine, and the plexuses of the uterus, Fallopian tubes, ureters, and lymph and bloodvessels. They are independent in that they are capable of acting without any impulses from higher centres, but they may also be governed by the spinal centres under some circumstances. *Second*, the *dependent* functions which are governed by centres, as, for example, the sensory fibres of the splanchnics.

What is the function of the cervical sympathetic?

It contains (1) pupil-dilating fibres which, according to Budge, arise from the spinal cord and run through the upper two dorsal and lowest cervical nerves into the cervical sympathetic, which conveys them to the head.

What does the cervical sympathetic also supply?

(2) *Motor* fibres for Müller's smooth muscle of the orbit, and *partly* for the external rectus muscle of the eye. It also supplies (3) *vaso-motor* branches for the outer ear and the side of the face, tympanum, iris, choroid, retina in part, the œsophagus, larynx, thyroid gland, and fibres for the vessels of the brain and its membranes; (4) *secretory* and vaso-motor fibres for the salivary glands. (5) Sweat secretory fibres are given off, as are also secretory fibres to the (6) *lachrymal* glands, according to Wolferz and Demtschenko.

What are the functions of the thoracic and abdominal sympathetic?

(1) The sympathetic portion of the cardiac plexus, which receives *accelerating* fibres for the heart from the lower cervical and first thoracic ganglion. (2) The cervical sympathetic and the splanchnics contain fibres which, when their central ends are stimulated, excite the cardio-inhibitory centre in the medulla.

Give an example of this.

If an animal be struck sharply on the belly, over the solar plexus, death may result from cardiac stoppage due to reflex inhibition.

What is the splanchnic?

The splanchnic is a division of the sympathetic, and contains vaso-motor filaments. All the vaso-motor nerves do not run through the cord, but some of them leave the cord high up and pass into the sympathetic. These nerve filaments in the splanchnics govern the bloodvessels of the abdomen very largely. The splanchnic also contains vaso-motor fibres which supply the kidneys.

What effect has section of the cervical sympathetic, or its rami communicantes, on the pupil?

It causes contraction of the pupil.

What other effect has section of the cervical sympathetic?

It causes increased fulness of the bloodvessels on that side, the eyelids are not held well apart, while the eyeball is sunken and retracted. Sometimes unilateral atrophy of the face comes on. If this section be performed in young growing animals, hypertrophy of that ear and side of face occurs, owing to the increased blood supply and other trophic changes.

What is the effect of stimulation of the cervical sympathetic?

It causes dilatation of the pupil, and occasionally hyperidrosis or profuse sweating of that side of the head. There is also protrusion of the eyeball, and the eyelids are held wide open. The eyeball, instead of being sunken, as after section, is in a condition of exophthalmos.

GENERATION AND DEVELOPMENT.

What do you mean by generation and development?

The first term signifies the original cause of growth, while the second term signifies the manner of growth after it is once begun.

Generative Organs of the Female.

They consist of two ovaries, two Fallopian tubes or oviducts, the uterus, and a canal known as the vagina.

What is the function of the ovaries?

The formation of the ova or eggs.

What is the function of the Fallopian tubes or oviducts?

The conduction of the ova from the ovaries to the uterus.

What is the function of the uterus?

It is a cavity in which, if impregnated, the ovum is retained until it is fully developed and capable of maintaining its life independent of the parent.

What is the function of the vagina?

It is the canal which receives the male generative organ, the penis, in the act of copulation, and is the passage through which the fœtus is discharged.

Describe the ovaries.

They are two oval bodies situated in the cavity of the pelvis, one on each side, inclosed in the folds of the broad ligaments. Each ovary measures about an inch and a half in length and three-quarters of an inch in width. They are about half an inch in thickness, and are attached to the uterus by a narrow fibrous cord, the ligament of the ovary, and more slightly to one of the fimbriæ of the Fallopian tubes. They are enveloped by a dense fibrous tissue. They are covered on the exterior by the *germ epithelium.* The inner substance, or stroma, is a soft fibrous tissue containing, imbedded in it, a number of vesicles in various stages of development.

What are these vesicles called?

Graafian vesicles.

In what way do the Fallopian tubes grasp the ovule when it is expelled from the ovary?

By means of their fimbriated extremities, which are in constant ciliary movement.

Describe the formation of the ovule in the ovary.

The vesicles in the stroma gradually approach the surface until they project above it. Each follicle or vesicle is covered by an external membranous envelope lined with a layer of nucleated cells, the *membrana granulosa*. This follicle contains liquid full of small microscopic bodies, with the ovule nearly in its centre, unless the follicle is fully matured when it comes in contact with the *membrana granulosa*.

What is the discus proligerus?

A granular zone of the nucleated cells of the membrana granulosa, which is heaped around about the ovule.

What is the size of the human ovule?

About $\frac{1}{120}$th of an inch.

What is the zona pellucida or vitelline membrane?

The investment of the ovule, and it adheres closely to the discus proligerus.

What lies within the zona pellucida?

The yelk or vitellus, which is composed of granules and globules of various sizes.

What arrangement have these globules?

The largest are at the periphery, the smallest are at the centre.

What does the yelk or vitellus contain?

The *germinal vesicle* or the vesicula germinativa.

What does this germinal vesicle contain?

At its periphery, at the point nearest the yelk, it contains the *germinal spot* or the *macula germinativa*.

These are all the parts of the *Graafian* follicle.

Does the formation of Graafian follicles go on constantly during the child-bearing part of life?

Yes.

What do you mean by the discharge of the ovule?

When the follicle is ripe and has reached the surface of the ovary, the follicular wall becomes thinner and finally bursts. The ovule and its fluid surroundings escape on the surface of the ovary, which is grasped by the Fallopian tube, down which the ovule travels.

Is there any difference in the periodicity of the maturity of the ovule in the different varieties of animals?

Yes; in human beings it is once in every twenty-eight days, while in the common fowl it is constant.

What is the difference between the ovule and the ovum?

The term ovule is ordinarily applied to the egg previous to impregnation, while the ovum is the fecundated ovule.

What is menstruation?

It is regarded by most physiologists as the flow of blood accompanying the discharge of a ripened ovule. The rupture of a follicle is not necessarily accompanied by menstruation, neither is menstruation necessarily followed by ovulation.

Does rupture of the follicle take place before or after the flow?

In most cases before or at the beginning; more rarely at the middle or end of menstruation.

Describe the menstrual discharge.

It is a thin, sanguinolent fluid having a peculiar odor, and consists of blood, epithelium, the mucus of the uterus and vagina, and the remains of the mucous membrane lining the uterus.

What is this mucous membrane called?

The *decidua menstrualis*, which is developed to perfection just before the menstrual flow and then thrown off.

Can menstruation be regarded as a hemorrhage?

No; it can not. It is merely a destructive process whereby the membrane which was prepared for receiving a fecundated ovule is thrown off.

At what time of life does menstruation begin and end in the temperate zone?

It begins at twelve or fourteen years of age, and ceases at a period between forty and fifty.

Does menstruation ever occur during pregnancy, or in nursing women?

Rarely; but such cases are on record.

What is the corpus luteum?

At the time of rupture of the Graafian vesicle, a yellowish mass, the *corpus luteum*, develops itself. It is a round, solid body whose walls, after the rupture, become covered by small buds of flesh-like matter, resembling a granulating wound, and these granulations extend above the ovarian surface. Ultimately they become covered, but still go on growing inside the ovary. As pregnancy goes on, the red granulations change to yellow and its consistence becomes firmer.

Does the corpus luteum depend for its formation on the effusion of blood which takes place when the follicle ruptures?

Not in the least. *Remember this.* The corpus luteum is, in reality, a growth of cells from the *membrana granulosa.*

What difference is there in the growth of the corpus luteum of pregnancy and in that of ordinary menstruation?

In pregnancy it remains till gestation is nearly ended. When impregnation does not occur it shortly disappears.

The Male Sexual Organs.

What is the function of the testicles?

They are the organs which secrete portions of the semen.

What other tissues aid in this secretion?

The vesiculæ seminales, the prostate gland, and Cowper's glands.

What does the semen consist of?

Of the secretion of all these tissues.

In what way is the secreting portion of the testicle arranged?

Into two parts, one of which is the body of the testicle inclosed within a tough, fibrous membrane, the *tunica albuginea*, which is covered externally by a serous membrane, the *tunica vaginalis*. The second part is the *epididymis* and *vas deferens*.

What is the vas deferens, and what is its function?

It is the duct of the testicle, about two feet in length. It passes to the lower part of the epididymis, with which it is continuous, where it becomes exceedingly tortuous in its course.

Of what does the epididymis consist?

Of a single tube about twenty feet long.

What are the tubuli seminiferi?

They make up the parenchyma of the organ.

In what way, and from what are the spermatozoids formed?

The seminal tubule is limited by an elastic membrane, the *membrana propria*, inside of which are several layers of cells, known as the *seminal cells*.

How many kinds of seminal cells have we?

Two. Those resting quietly, others in a state of active division. The active cells are called the mother cells; and the smaller cells, resulting from their division, the daughter cells or *spermatoblasts*. The spermatozoids are formed from the spermatoblasts.

What is the appearance of the spermatozoid?

It consists of a small body or head, to which is attached a cilium, or rapidly moving tail.

What is the function of the spermatozoids?

They are absolutely needful for impregnation, and it is the spermatozoids which fecundate the ovule.

How does the semen reach the exterior of the body?

It is secreted in the tubules of the testicles, then passes along the vasa deferentia into the vesiculæ seminales, and from there into the urethra.

What is the function of the seminal vesicles other than the carrying off of the semen?

They secrete some of the liquid in which the spermatozoids float or swim. This is probably their chief function, at least in some animals.

What is the function of the prostate and Cowper's glands?

To add the proper liquid to the semen.

Of what, therefore, does semen consist?

The liquor seminis and the spermatozoids, with detached epithelial cells.

Development.

In what part of the female genital organs does the ovule become fecundated?

Most commonly in the upper part of the Fallopian tube.

What changes take place in the ovum or the fecundated ovule?

The visible change is a slight amœboid movement of the protoplasm of the ovum, which is shortly followed by segmentation, which consists in the repeated subdivision of the cells present.

How long does this segmentation last?

It is finished by the time the ovum reaches the uterus.

What is seen in the centre of each segment?

A central vesicle, which is the result of the repeated division of another central vesicle, just as the segments themselves are the result of the division of the yelk itself.

What appearance has the ovum as it enters the uterus?

Owing to the many segmentations, it is granular, and resembles a mulberry.

How long a time does the passage of the ovum from the ovary to the uterus take?

Probably eight or ten days.

What is the germinal or blastodermic membrane?

It is a membrane which is formed by the accumulation at the periphery of the yelk of a number of the segments or cells. Owing to their number they are pressed against one another, and become polyhedral in shape.

What are the layers of the blastoderm?

The epiblast, mesoblast, and hypoblast.

What is the function of the epiblast?

From the epiblast are eventually developed the epidermis and its various appendages, the cerebro-spinal *nerve centres*, the sensory epithelium of the mouth, and the salivary glands.

What are developed from the hypoblast?

The epithelum of the whole digestive canal, and the lining of all the ducts which open into it; the parenchyma of the liver and pancreas, and the epithelium of the respiratory tract.

What are developed from the mesoblast?

All the organs not so far mentioned, all the connective tissues, the muscles, the vascular and genito-urinary apparatus, and the entire digestive tract, save its lining epithelium.

What is the germinal area?

The position at which the embryo is about to appear. It is at first circular, then pyriform.

What is the area pellucida?

A clear, transparent spot, which develops in the centre of the germinal area.

What is the area opaca?

That portion of the germinal area surrounding the area pellucida.

What is the primitive groove?

A shallow longitudinal groove which is the first trace of the embryo. It appears near the back part of the area pellucida.

What is the medullary groove?

A more permanent groove which soon replaces the primitive groove. It begins at the anterior part of the area pellucida, and gradually displaces the primitive groove.

What are the laminæ dorsales?

Two longitudinal elevations which bound the medullary canal. They are folds of the epiblast which grow up and extend over and join each other over the medullary canal, forming it into a closed canal or tube.

What is this tube now called?

The primitive cerebro-spinal axis.

At what portion of the embryo do the laminæ dorsales first unite?

About the neck, then the head, and down to the lower extremity.

What is the notochord or chorda dosalis?

It is an aggregation of cells from the mesoblast immediately underneath or back of the medullary canal. It extends nearly the whole length of the canal, and occupies the future position of the vertebræ.

What are the protovertebræ?

Square segments composed of cells from the mesoblast which appear on each side of the medullary canal along its whole length.

What is the "splitting of the mesoblast"?

Outside of the protovertebræ the mesoblastic cells are split up into two laminæ, known as the *parietal* and *visceral*. These laminæ form the origin for the walls of the trunk. The parietal lamina is closely connected with the epiblast which adheres closely to the

hypoblast, and forms the serous and muscular walls of the alimentary canal and other parts.

What is the somatopleure?

The united parietal lamina and the epiblast.

What is the splanchnopleure?

The united visceral layer and the hypoblast.

What eventually becomes of the space between the somatopleure and the splanchnopleure?

It forms the pericardium, pleuræ, and peritoneum.

What are the head and tail folds?

Those folds of the blastoderm which limit the embryo at the head and caudal extremities. Similar folds or depressions mark off the lateral margins of the embryo, which now finds itself entirely separate from the yelk and surrounded by a clear space.

What is the last portion of the embryo to become completely separated from the yelk?

The head and caudal extremity are first separated, but the anterior wall of the belly is not closed by the folds till later. Indeed it is never closed in fœtal life, for the *umbilicus* is the remains of this connection with the yelk.

What is the neural cavity?

That cavity formed by the upward growth of the laminæ dorsales.

What is the body cavity?

That cavity formed by the downwardly folded blastoderm.

What are the visceral plates?

The downwardly folded portions of the blastoderm are known as the visceral plates.

What forms the rudiment of the alimentary canal?

The folding in of the splanchnopleure lined by hypoblast pinches off a portion of the yelk-sac inclosing it in the body cavity.

What is the condition of this rudimentary alimentary canal?

It is blind or closed at both ends at this time, while its centre communicates freely with the cavity of the yelk-sac.

What is the canal called which permits of this communication?

The vitelline or omphalo-mesenteric duct. This condition divides the yelk-sac into two portions.

What is the portion of the yelk-sac outside the body cavity called?

The *umbilical vesicle.*

What is the purpose of the umbilical vesicle?

It affords nutriment for the embryo.

In what way does the nutriment reach the embryo?

Through the omphalo-mesenteric vessels which ramify in the walls of the yelk-sac.

Does this yelk-sac or umbilical vesicle afford food all through pregnancy for the embryo?

In mammalia it lasts only for a short time, the nourishment being derived from the mother.

What is the amnion?

Beyond the head and tail folds the somatopleure, coated by epiblast, rises in folds which grow up and arch over the embryo, anteriorly, posteriorly, and laterally, all directed toward one point over the dorsal surface of the embryo.

What is the true amnion?

The inner of the two layers of the somatopleure forms the true amnion.

What is the false amnion?

The outer layer of the somatopleure.

What is the chorion?

It is formed by the coalescing of the inner surface of the original vitelline membrane with the false amnion.

How is the amniotic cavity formed?

The cavity between the true amnion and the external surface of the embryo becomes a closed space, which is called the amniotic cavity.

Does the amnion adhere closely to the embryo?

No, it gradually is distended with fluid which separates it from the embryo.

What is this fluid called, and what is its function?

The *liquor amnii*, which increases as pregnancy goes on. This forms a yielding cushion-like support for the embryo, protecting it from injury and gradually distends the neck of the uterus in parturition.

What is the allantois?

It is a highly vascular growth, arising from the hinder portion of the peritoneal cavity, which gradually pushes its way out through the amniotic folds, attaching itself to the outer layer of the amnion (false amnion). In other words, it becomes attached to the chorion, in mammals in one spot, in birds all over the chorion.

What is formed at this point?

By the interlacing of these vessels with those of the mother the *placenta* is developed.

Of what does the chorion now consist?

Three layers: 1st, the vitelline membrane; 2d, the outer layer of the amniotic fold; 3d, the allantois.

What are the villi of the chorion?

Small processes on its surface which soon become vascular, particularly so in the region of the future placenta, so as to dip between the maternal vessels.

What changes take place in the uterine mucous membrane during this time?

The follicles become tortuous and enlarged, while the epithelial layers increase in amount.

What is the result of this increase in the uterine mucous membrane?

It makes up the membrana decidua.

Into how many divisions are the portions of the membrana decidua divided?

Three: The *decidua vera, decidua reflexa,* and the *decidua serotina*

What is the function of these three divisions?

The *vera* lines the cavity of the uterus; the *reflexa* grows up around the ovum and forms an investment for it; while the *serotina* becomes especially developed in connection with the villi of the chorion. *Remember,* by the third month the *vera* and *reflexa* come in contact, and can no longer be distinguished one from the other.

What is the function of the placenta?

It is an organ by which the gaseous and nutritive changes take place between the maternal tissues and the embryo.

The placenta has, therefore, a fœtal part and a maternal part.

THE DEVELOPMENT OF ORGANS.

Vertebral Column and Cranium.

How are the vertebral column and cranium developed?

The notochord or chorda dorsalis consists primarily of soft cellular cartilage which is gradually inclosed in a membranous sheath, which after a time becomes fibrous and has transverse annular fibres. The protovertebræ (see page 154) send processes downward and inward to surround the notochord, and also upward between the medullary canal and the epiblast covering it. In the former situation the cartilaginous bodies of the vertebræ make their appearance, in the latter their arches which inclose the neural canal. The vertebræ do not exactly correspond in their position with the protovertebræ, but each permanent vertebra is developed from the contiguous halves of the protovertebræ.

The cranium is developed from a prolongation of the vertebral

column, and is formed long before the facial bones. It is formed of one mass, the cerebral capsule, the chorda dorsalis being continued into its base and ending there with a tapering point.

In what way is the dorsal portion of the body formed?

The muscles and integument of the back, with the exception of the epiderm, which is developed from the epiblast, are developed from the *musculo-cutaneous* plate which is formed by the dorsal portion of the protovertebræ.

What is developed from the ventral portion of the protovertebræ?

They give rise to the vertebræ and the heads of the ribs, but the outer part of each protovertebra gives rise to a spinal ganglion and nerve-root.

What is the condition at this time of the chorda?

It is inclosed in a case, formed by the bodies of the vertebræ, and gradually wastes and disappears.

How are the body cavities formed?

The *dorsal laminæ* coalesce at the back and complete, by their union, the spinal canal, and the visceral laminæ coalesce anteriorly and thus form the thoracic and abdominal cavities. An analogous process occurs in the facial and cervical regions, but the inclosing laminæ are cleft. When these clefts fail to unite in the median line cleft-palate or harelip results.

Extremities.

In what way are the extremities developed?

They appear in the form of leaf-like elevations from the parietes of the trunk at points where more or less of an arch will be produced for them within.

Heart and Bloodvessels.

How is the heart developed?

It makes its first appearance as a solid mass of cells of the splanchnopleure. A cavity is hollowed out of the centre, and

those detached cells float about in a liquid which soon begins to move about under the pulsations of the embryonic heart.

How are the bloodvessels developed?

In the formation of the large vessels masses of embryonic cells are arranged in longitudinal form and hollowed out in much the same manner as the heart, the cells of the heart cavity and blood-vessel cavities forming corpuscles. The capillaries seem to be formed of cells arranged end to end in single line and hollowed like a pipe-stem.

Nervous System.

How is the nervous system developed?

All the *spinal nerves* are derived from the mesoblast, as are also the cranial nerves, except the optic and olfactory, which are outgrowths of the anterior cerebral vesicles. The sympathetic system is also developed from the same mesoblastic layer.

Have the spinal cord and brain the same origin as the spinal nerves?

Yes. They arise from the epiblast for the gray matter and for the white matter.

From what is the spinal cord developed?

Out of the primitive medullary tube which results from the folding in of the dorsal laminæ.

How is the gray matter formed?

The tube is narrowed in one diameter so that the canal becomes narrow and oval in shape, and finally the two opposite sides unite in the centre of the slit, while the attachments of the two sides at the top and bottom of the canal decrease in thickness, and finally separate. The white matter is derived from the surrounding mesoblast and grows up around the gray columns. The fissures are formed by the separating at the top and bottom of the tube already described.

What do you mean by the cerebral vesicles?

A widening out of the medullary canal very early in embryonic life.

How many cerebral vesicles have we?

Three.

What is the purpose of each?

From the first anterior vesicle are budded off the two primary optic vesicles, and the rudiments of the hemispheres appear in the form of two outgrowths at a higher level. The middle vesicle gives off the rudiments of the corpora quadrigemina, the crura cerebri, and the aqueduct of Sylvius. The posterior vesicle gives off the rudiments of the cerebellum, pons Varolii, the medulla oblongata, and auditory nerve.

Eye.

From what is the eye developed?

The anterior cerebral vesicle, which sends out a smaller vesicle on each side, the primary optic vesicles, which are hollow. The stalks which attach the vesicles to the original vesicle form the optic nerves. After this the formation of the *lens* and *optic cups*, or secondary optic vesicles, begins.

How is the lens formed?

By a thickening of the epiblast, which indents the extremity of the primary optic vesicle and pushes it back till the front wall of the vesicle is in contact with the posterior wall, and the cavity of the vesicle is thereby obliterated.

What does this front wall, which has been pushed back, form?

The retina.

What does the back wall form?

The pigment layer of the choroid.

The margins of the cups grow up around the lens everywhere except at the lower part, by the optic nerve, where a fissure remains.

What is this fissure called?

The *choroidal fissure.*

What is its purpose?

Through it the mesoblast, which forms the connective tissue of the eye, finds an entrance into the cavity of the eye.

Ear.

How is the ear developed?

Early in embryonic life a depression occurs on each side of the surface of the head, which is covered by a membrane, the *primary otic vesicle.*

What is the purpose of this vesicle?

It develops the membranous labyrinth of the internal ear. The surrounding mesoblast gives rise to the various bony and cartilaginous parts inclosing the membranous labyrinth, the bony semicircular canals, etc. The mesoblast also develops the auditory nerve.

Nose.

How is the nose developed?

It originates, like the eyes and ears, in a depression of the superficial epiblast at each side of the fronto-nasal process, and these cavities gradually grow back till they reach the cavity of the mouth.

Alimentary Canal and Organs.

In what way is the alimentary canal developed?

It results from the folding in of the splanchnopleure, and is at first straight and parallel to the vertebral column. It is connected with the omphalo-mesaraic duct, a point which corresponds with the lower segment of the ileum, but the duct atrophies and usually disappears about the fourth month. The attachment is at first very broad, and only a thin stratum of mesoblast separates the hypoblast of the canal from the notochord and protovertebræ; but it subsequently attenuates and becomes the mesentery. In the fourth month the part connected with the umbilical vesicle loops forward. The part above the umbilical opening becomes the

small intestine, and the part below almost wholly the large intestine. The limit between the two is soon indicated by a projection, the cæcum. The intestine separates from the abdominal wall, the remains of the attachment appearing at the third month, and sometimes later, as a thread-like appendage to the lower part of the ileum. Convolutions then begin to form, and an enlargement in the region of the liver, which is the stomach.

In what way is the posterior opening in the intestine formed?

By the establishment of a communication between the cloaca, or tube common to the gut and allantois, and a depression outside of the body at about the sixth or seventh week. At the same time a septum, which is the future perineum, separates the intestine from the organs forming the allantois. The mouth is formed in the same manner.

In what way are the salivary glands, the pancreas, and the liver developed?

The liver commences as a projection formed by two primitive hepatic ducts, which divide and subdivide. At the periphery of the ducts are solid masses of cells which proceed from the hypoblast. The mass of the gland is developed from the mesoblast. The liver secretes as early as the third month. The pancreas is also formed from the mesoblast, as are also the salivary glands. The lining of their ducts is, however, derived from the hypoblast.

The Fœtal Circulation.

Describe the fœtal circulation?

The blood in the placenta, aërated and well nourished, passes up the umbilical vein to the navel, where it enters the body of the fœtus, and, after a short course, reaches the liver, where it is split up into two streams, one of which supplies the lobes of the liver, while the other passes through the *ductus venosus*, which lies in the longitudinal fissure of the liver, into the inferior vena cava and right auricle of the heart, but instead of passing into the right ventricle it is directed by the Eustachian valve along the back of the auricle

to the foramen ovale, and immediately enters the left auricle; the left auricle, contracting, propels it into the left ventricle, which drives it into the general circulation.

What is the difference in the circulation of blood in the inferior vena cava from that of the superior vena cava?

The blood returning from the head, or superior vena cava, passes into the right auricle and enters the right ventricle (which the blood from the inferior vena cava does not). When the right ventricle contracts the blood is driven into the pulmonary artery, but instead of being distributed through the lungs it is directed through a channel given off by the left pulmonary artery, known as the ductus arteriosus, into the aorta just beyond the point where the left subclavian is given off from that vessel. The right ventricle and the left ventricle may, therefore, be said to drive the blood through the general circulation in fœtal life. As the result of this, however, it will be seen that in the aorta we have blood, half of which is aërated and half of which is not.

In what way does the blood return to the placenta to be nourished and oxygenated?

It passes through the descending aorta, the common iliacs, and the umbilical artery, by which it reaches the placenta.

What changes take place in the circulation at birth?

Respiration is commenced, the lungs become expanded, and, in consequence of this, the pulmonary vessels permit the blood to traverse them freely. The ductus arteriosus being no longer required, contracts and shrivels up, but remains as a fibrous cord. At the same time the detachment of the placenta leads to the immediate arrest of the flow of blood from the umbilical arteries, and no flow passes along the umbilical vein. The ductus venosus contracts, the currents of the superior and inferior vena cava mix in the right side of the heart, and the Eustachian valve and the foramen ovale become useless.

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