Redlich, E.: Senile Gehirnatrophie. Monatschr. f. Psychol. u. Neurol., Berl., Bd. v., H. 3, S. 228.
Sander, M.: Untersuchungen über die Altersveränderungen im Rückenmark. Deutsche Ztschr. f. Nervenh., Leipz., Bd. xvii., SS. 369–396.
Pugnat, C. A.: De la destruction des cellules nerveuses par les leucocytes chez les animaux agés. Compt. rend. Soc. de biol., Par., vol. iv. (1898), 242.

Degenerations of the Neurone.

Under this heading will be considered (*a*) Primary Degenerations of the Neurone, including (1) cloudy swelling, (2) fatty degeneration, (3) vacuolar degeneration, (4) pigmentary degeneration, (5) albuminous degeneration; and (*b*) Secondary Degenerations of the Neurone.

(*a*) Primary Degenerations of the Neurone.—(1) *Cloudy Swelling.*—In view of the fact that parenchymatous degeneration or cloudy swelling has been described in connection with the acute infections and intoxications in most of the organs of the body, it is rather surprising that we find so few references in the bibliography to this form of degeneration in the nerve cells. The changes which accompany infection and intoxication are so characteristic and constant in the various secreting cells that it seems probable that a similar degeneration has been frequently met with in the nervous system, but has been described under a different name. Doubtless the presence of the peculiar tigroid masses in the protoplasm of nerve cells has been responsible for the difficulty in studying this change. If one reads Benario's careful review of the whole subject of cloudy swelling and then examines the articles by Ewing, Marinesco, and others on the pathological changes in the nerve cells in acute infections, he cannot but feel that the preliminary swelling of the nucleus and protoplasm and swelling of the tigroid masses followed by their breaking up into fine granules, described by these writers, correspond more or less closely to the cloudy swelling which affects gland cells. The alterations described by Franca in the nerve cells in plague, and by Camia in the nerve cells in influenza, are very suggestive in this connection.

References Bearing on Cloudy Swelling.

Benario: Die Lehre von der trüben Schwellung in ihrer Entwickelung und Bedeutung, Würzburg, 1891.
Ewing, J.: Studies on Ganglion Cells. Arch. Neurol. and Psychopathol., New York, vol. i., pp. 263–440.
Marinesco, G.: Recherches sur quelques lésions peu connues des cellules nerveuses corticales. Roumanie med., Bucarest, vol. vii., 1899, p. 913.
Franca: Contribution à l'étude des altérations des centres nerveux dans la peste bubonique humaine. Le Névraxe, Louvain, 1900.
Camia, M.: Due casi di psicosi consecutiva ad influenza, con autopsia. Riv. d. patol. nerv. e ment., Firenze, vol. v., 1900, p. 100.

(2) *Fatty Degeneration.*—Fat droplets of smaller or larger size are frequently met with in nerve cells in the most different pathological processes, but especially in infections and intoxications. These are usually met with in the protoplasm of the perikaryon and are visible as yellow, glistening droplets in frozen sections, or as black spherules in Marchi preparations. I have often seen black droplets in the nuclei of nerve cells in Marchi specimens; in some instances they appear to be coincident with the nucleolus.

(3) *Vacuolar Degeneration.*—The study of vacuolar degeneration of the nerve cell has had an interesting history. In the older publications, where the studies were nearly all made upon Müller's fluid preparations, nothing was more common than to read of extensive vacuolar degenerations in the cells of the brain and spinal cord. We know now that the majority at least of these were nothing more nor less than artefacts due to the action of the hardening reagent (work of Kreyssig and of Trezebinski). In some of the more recent studies, however, true vacuolization of both protoplasm and nucleus of the nerve cells has been described. Nerlich has investigated the origin of vacuoles in a case of cerebral tetanus in which the nucleus nervi hypoglossi, the nucleus nervi facialis, and the nucleus motorius nervi trigemini contained vacuolated ganglion cells. He found occasionally as many as twenty vacuoles in a single cell. The cell body was swollen, though often surrounded by a large pericellular space. The nuclei were not altered, though they were sometimes displaced from the normal position by the vacuoles.

Besides in tetanus, vacuolization of the nerve cells has been described in various infectious diseases, in acute poisoning with mineral acids (ganglion cells of the heart), and in fasting. Sometimes the nucleus, as well as the cell protoplasm, is vacuolar (Kazowsky).

The study of vacuole formation in cells generally has been approached recently from the experimental side. Two kinds of vacuoles may be distinguished according to their origin: (1) solution vacuoles, which increase in size with the diffusion and endosmosis of the agent producing them; (2) expulsion vacuoles which are formed suddenly as a result of coagulation and do not usually increase in size.

References Bearing upon Vacuolar Degeneration of the Nerve Cell.

Schmaus, H., u. E. Albrecht: Vakuoläre-fettige Degenerationen. Ergebn. d. allg. path. Morphol. u. Physiol., Wiesb., 1895, SS. 151–161.
Nerlich: Ein Beitrag zur Lehre vom Kopftetanus. Arch. f. Psychiat., etc., Berl., Bd. xxiii. (1892), S. 672.
Popoff, N. M.: Pathologisch-anatomische Veränderungen des Centralnervensystems bei der asiatischen Cholera. Arch. f. path. Anat. [etc.], Berl., Bd. cxxxvi. (1894), S. 42.
Kazowsky, A. D.: Ueber die Veränderung in den Herzganglien bei akuten Mineralsäurevergiftungen. Centralbl. f. allg. Path. u. path. Anat., Jena, Bd. v. (1894), S. 1020.
Statkewitsch: Ueber Veränderungen des Muskel- und Drüsengewebes, sowie der Herzganglien beim Hungern. Arch. f. exper. Path. u. Pharmakol., Leipz., Bd. xxxiii. (1894), SS. 415.
Ströbe, H.: Experimentelle Untersuchungen über die degenerativen und reparationischen Vorgänge bei der Heilung von Verletzungen des Rückenmarks, etc. Beitr. z. path. Anat. u. Physiol., Jena, Bd. xv. (1894), S. 383.
For a list of diseases in which vacuolar degeneration has been described, see Barbacci: *loc. cit.*, p. 805.

(4) *Pigmentary Degeneration.*—In frozen sections and in Nissl preparations of adult nerve cells in various parts, a yellowish pigment can be made out. This is said to be entirely absent in the newly born. According to Pilcz, Obersteiner, and others it appears at different periods of life in different nerve cells, at the sixth year in the spinal ganglia; at the eighth year in the anterior horn cells. The amount of pigment increases as age advances (*vide supra*, Atrophy).

This pigment is not identical with that of the locus cœruleus, substantia nigra, or substantia ferruginea. It may be improper to speak of it as pigment at all. It stains black with osmic acid, and thus is easily visible in Marchi preparations. It seems to be related to the fats (Rosin). Ramón y Cajal regards it as a metabolic product of the cell, which the latter cannot rid itself of. Whether it arises from the stainable or from the unstainable substance of Nissl is not known. Obreja and Tatuses believe that this pigment is of a fatty or myelinic nature, probably related to lecithin. They therefore look upon it as a store of nutrient substance in the cell; according to their findings it is diminished in amount in the anterior horn cells in strychnine poisoning and in tetanus, while after prolonged rest it is increased. Against this view van Gehuchten urges that the substance is absent from the nerve cells in early life, and further that in a case of tetanus which he examined there was no diminution in the amount of pigment. The whole matter requires further investigation.

References Bearing upon So-Called Pigmentary Degeneration.

Rosin, H.: Ein Beitrag zur Lehre vom Bau der Ganglienzellen. Deutsche med. Wchnschr., Leipz. u. Berl., Bd. xxii., 1896, SS. 395–397.
Ramón y Cajal, S.: Textura del sistema nervioso del hombre y de los vertebrados, Madrid, 1899, t. i., pp. 129–130.
Obreja et Tatuses: Le pigment des cellules nerveuses. Compt. rend. Soc. Sc. Méd., Bucarest, November, 1898 (*cf.* Rev. Neurol., Par., 1899, p. 326).
Barker, L. F.: The Nervous System and Its Constituent Neurones, New York, 1899, pp. 107–108.

(5) *Albuminous Degenerations.*—Accepting the definition of Klebs, by albuminous degenerations are to be understood those disturbances of nutrition in which insoluble albuminous bodies are deposited in the tissues. In the nervous system we have to deal with two such albuminous deposits: (*a*) the so-called Russell's fuchsin bodies, and (*b*) the corpora amylacea.

Ad (*a*). Russell's fuchsin bodies described in cancer, in 1890, have since been proven non-specific as far as these tumors are concerned. They occur under normal conditions in various tissues of the body, including the nervous system, but are greatly increased in numbers under pathological conditions. They are usually extracellular in situation but may occur also inside of cells. As a rule, several of them exist together. They are small, round, homogeneous bodies, varying from 0.5 to 20 μ in diameter. Under the microscope they appear as glistening masses looking not unlike fat droplets, when examined in water. They stain intensely by Gram's method and in acid fuchsin. In Ehrlich's triacid stain they are tinged sometimes with the acid fuchsin, sometimes with the orange. In Heidenhain's iron hæmatoxylin they stain black. Lubarsch found them in large numbers in atrophic conditions of the brain. The probability is that they are products of the cell protoplasm, rather than of the nucleus. Some of them may be swollen and altered cell granules. It is not impossible that fine granules in the cell protoplasm undergo chemical change and fuse to form the fuchsin bodies. Again it has been suggested that they may have their origin from lecithin. Lubarsch found that pure lecithin yields the same staining reactions as do the fuchsin bodies; on the other hand, pure lecithin is easily soluble in alcohol, while the fuchsin bodies are not.

Ad (*b*). Corpora amylacea have long been known in the central nervous system. Their origin and significance have been much disputed, but there can be no doubt that they are very numerous in atrophic and degenerated portions of the brain and spinal cord. Under normal conditions they appear in the third decade of life and are never absent in people over forty. In the cerebrum they are found in the lining of the ventricles and in the tractus olfactorius; they are less frequently found in the cerebellum. Redlich supposed that they had their origin in the nuclei of neuroglia cells. According to a widespread opinion they arise from the coagulation of myelin. It is not unlikely that some of them at least have their origin through the union with normal tissue juices of altered cell protoplasm exuded from the cell. Spiller believes that at least a portion of the corpora amylacea have been derived from altered blood-vessels. The colloid bodies described by Bevan Lewis and also by Spiller would seem to be closely related either to Russell's fuchsin bodies or to the corpora amylacea.

Recent studies make it seem certain that greater differentiation among these structures than that ordinarily made is necessary. Thus Siegert has divided them into corpora versicolorata (including the "corpora amylacea" of th central nervous system) and corpora flava (including the "corpora arenacea" of the central nervous system). The corpora versicolorata, so-called because they take a variegated tint in iodine or bromine, yield the "amyloid reaction" with aniline dyes, and are further characterized by their brittleness and their morphology. They may be, (*a*) spherical, ovate, or polygonal with rounded angles; (*b*) concentrically lamellated, and (*c*) sometimes radially striated. They never arise through direct transformation of cells, nor do they become calcified. The corpora flava, on the other hand, behave differently in solutions of the halogens (chlorine, bromine, iodine), staining of a yellow color only in Lugol's solution; they do not yield the amyloid reaction with the aniline dyes. They are waxy rather than brittle; they vary greatly in their morphology, being sometimes smoothly spherical, sometimes very irregularly shaped. Concentric lamellation may not be visible in them and they are never radially striated. Unlike the corpora versicolorata the corpora flava are said to arise directly from the transformation of cells and to show a decided tendency to become calcified.

References Bearing upon Albuminous Degenerations.

Klebs, E.: Handbuch der allgemeinen Pathologie, Bd. ii., S. 100.
Redlich, E.: Die Amyloidkörperchen des Nervensystem. Jahrb. f. Psychiat., Bd. x. (1892), 1–68.
Siegert: Untersuchungen über die Corpora amylacea sive amyloidea. Arch. f. path. Anat., etc., Berl., Bd. cxxix., S. 513.
Lubarsch, O.: Die albuminösen Degenerationen. Ergebn. d. allg. path. Morphol. u. Physiol., Wiesb., 1895, SS. 180–200.
Spiller, W. G.: On Amyloid, Colloid, Hyaloid, and Granular Bodies in the Central Nervous System. N. York M. J., 1898, August 13th.

(*b*) Secondary Degeneration, and Modifications in the Neurone following upon Injury to the Axone.—The nutritive centre of a neurone is in the perikaryon. The trophic influence emanates from the nucleus. If any part of a neurone be severed from its connections with the nucleus, the separated part dies. In case it is a medullated axone, which suffers solution of continuity, not only does the whole axone, distal from the lesion, undergo disintegration, but the myelin sheath degenerates in the same area and the nucleated sheath of Schwann or neurilemma undergoes important modifications. These phenomena taken in their totality are usually designated as secondary or Wallerian degeneration.

In the early part of the last century it was known that interruptions of the connection of peripheral nerves with the central system could lead to their degeneration (Nasse, Valantin, Stannius). The first careful study of the subject, with establishment of a law, was that undertaken by Waller, and from him the process has derived its name. He described it in detail—the coagulative breaking up of the myelin sheath and the dissolution of the axis cylinder. If a motor nerve is cut, all the fibres in the peripheral end degenerate completely as far as the muscles which they supply, the central end either remaining entirely intact or perhaps, as a result of the trauma, degenerating as far as the first node of Ranvier. If a sensory nerve be cut distalward from the spinal ganglion, all the sensory fibres of that nerve degenerate to the very periphery, though the portion of the nerve still in connection with the ganglion, as well as the central intramedullary continuation of the nerve, remain undegenerated. On the other hand, if a dorsal root of a spinal nerve is severed between the ganglion and the spinal cord, the portion of the nerve attached to the ganglion does not undergo degeneration, but that connected with the cord degenerates typically, not only in the portion outside the cord, but also throughout its whole intramedullary extent. This is the proof which has been brought for the view that the cell bodies in the spinal ganglia are the trophic centres for the peripheral sensory neurones. Following upon Waller's investigations came the observations of Türck, which demonstrated that the same law holds within the confines of the central nervous system—for example, for the pyramidal tract. Since Türck's studies a host of observations have established the general validity of the law for all groups of neurones. When an axone degenerates, the retrogressive process involves not only the main axone but also its terminals, together with the collaterals belonging to it with their terminals.

The study of secondary degenerations has been much facilitated by the introduction of Weigert's myelin sheath stain and the osmic-bichromate method of Marchi and Alghieri.

The finer histology of secondary degeneration has been studied by Homén, Howell and Huber, Tooth, von Notthaft, Ceni, and others. Von Notthaft subdivides the changes which occur in the nerve after section into two stages, the first including the alterations which take place during the first three days (fragmentation of myelin and of axone for a distance of one or two internodes on each side of lesion), probably due to trauma. The second stage, beginning on the second or third day and confining itself to that part of the fibre cellulifugal from the lesion, represents the true Wallerian secondary degeneration; it is not the direct result of the trauma, but is due to the severance of that part of the neurone from the trophic influence of the nucleus. In this second stage the axone swells up and undergoes fragmentation, and

the myelin disintegrates into droplets cellulifugally from the lesion, as far as the peripheral termination. By the fourth day a multiplication of the nuclei of the neurilemma can be made out. Liquefaction of the myelin begins by the sixth or seventh day and continues until the sixtieth or eightieth day, when all of it is dissolved and most of it has been absorbed. The absorption is complete by the end of three or four months. If the degeneration affect medullated nerve fibres inside the central nervous system, neuroglia cells can be seen undergoing proliferation after some forty-five or fifty days (Ceni). This proliferation ceases at the end of three months and sclerosis follows.

Marchi's method demonstrates the existence of degenerating fibres as early as eight or ten days after the lesion, and will continue to demonstrate their presence until all the myelin of the degenerating fibres has been absorbed, that is, until some three months have elapsed after the injury. At a later period we have to resort to Weigert's method; the areas which have degenerated show, of course, an absence of black fibres. Marchi's method is far more delicate than Weigert's; the former will reveal single degenerated fibres; the latter can be relied upon only when there is a considerable area of lightening in the region otherwise uniformly filled with black fibres. Anatomists have applied these methods most extensively in experimental work for the determination of the course followed by the medullated axones of the various groups of neurones of which the nervous system is made up. Pathologists utilize them to study the secondary degenerations which accompany various diseases of the nervous system in human beings.

For many years it was believed that the cellulifugal alteration, described by Waller, was the only one which occurred after axone lesion, but the introduction of more delicate methods still has revealed the fact that surprising changes occur in the neurones cellulipetal from the lesion, and particularly in the cell body or perikaryon itself. Nissl by the application of his methylene-blue-and-soap method has demonstrated definite alterations in the cell body as early as a few hours after axone lesion. The changes are most marked, however, when animals are killed from eight to fifteen days after the operation in which the axones have been cut. Nissl refers to this method of study as "the method of primary irritation." His results have been confirmed by Flatau, Marinesco, Lugaro, Van Gehuchten, Erlanger and myself, and many others.

The change which takes place in the cell bodies of the nucleus nervi facialis, for example, after section of the nerve trunk near the pes anserina, consist chiefly in alterations in the tigroid masses, in a moderate swelling of the perikaryon, and in a displacement of the nucleus toward the axone hillock. The change seems to affect the tigroid masses first. The spindles lose their typical stichochrome arrangement, break up into minute particles, become scattered diffusely throughout the cell, and finally undergo solution, the solvent process affecting the tigroid masses in the interior of the cell first, and extending gradually toward the periphery. This disintegration and solution of the tigroid has been variously designated. Marinesco calls it *chromatolysis;* van Gehuchten, *chromolysis;* Retterer, *chromophilysis;* Kohnstamm gives it the name *tigrolysis*, and the latter term is the one which I prefer.

Marinesco has described two distinct stages of the process: (1) A stage of *reaction*, in which the tigroid undergoes the changes above described; and (2) a phase of *repair*, during which the tigroid elements are restored to a more or less normal appearance. The first stage begins soon after section, and reaches its maximum in from fifteen to twenty days. The second stage lasts longer. It is essentially a phase of regeneration, and as in many cases of regeneration the elements regenerated are produced in excess; the individual tigroid masses are larger and more numerous than in the normal cell. During the first stage (that of reaction) the cell is swollen; during the second (that of repair) it gradually returns to its normal size. The nucleus, markedly displaced toward the axone hillock during the first stage, slowly reassumes its former position in the centre of the cell during the stage of repair. A few cells in motor nuclei, after section, fail to undergo this repair, and van Gehuchten assumes that in them the turgescence of the cell has taken place so suddenly during the first stage and the propulsion of the nucleus has been so violent that the latter has been completely expelled from the cell body. Such cells, deprived of their nuclei, necessarily undergo total degeneration. It was thought by Marinesco that the stage of repair was conditional upon regeneration of the distal end of the axone, but Nissl, van Gehuchten, and Foà have shown that this is an error, and that the altered cells return to their normal state entirely independently of the phenomena of regeneration at the point of section. At least this seems true of experiments upon animals, though there are some observations upon the spinal cord of human beings following upon amputation, which indicate that cells still tigrolytic may be observed in the cord for from three to seven months after the operation.

There would appear to be an intimate relation between the degree of injury to the axone and the changes which take place in the perikaryon, for when nerves are torn out, the effects are very different from those which follow simple section of a nerve. Thus Ballet and Marinesco showed that if a nerve be torn out, a large number of the cells undergo complete destruction and are absorbed. This may explain the cellulipetal secondary degenerations obtained by von Gudden's method (*vide infra*).

One of the more recent developments of the study by Nissl's method indicates that tigrolysis occurs constantly after section of a cerebral nerve, but may or may not occur after section of a spinal nerve, though it inevitably follows the tearing out of the same spinal nerve (Van Gehuchten and de Neeff). The inference has been drawn that the lower motor neurones in the spinal cord of the rabbit and dog possess a greater resistance to experimental injury than do the lower motor neurones of the medulla, pons, and midbrain.

The method introduced by Nissl is of very great importance to anatomy, since by means of it the exact cell bodies which give off the motor axones to individual muscles can be easily localized in the central system.

It is now much easier to understand the early investigations bearing upon atrophy of the motor roots and gray matter of the spinal cord after amputation. The younger the individual at the time of amputation, and the longer the time elapsing between the operation and death, the more marked are the alterations. It would appear that if an amputation be done early in life, many of the neurones concerned in innervating the amputated limb undergo complete degeneration and disappear totally, that is to say, in addition to the Wallerian cellulifugal degeneration, which of course occurs in the amputated stump, there takes place in young individuals a slow atrophy or slow cellulipetal secondary degeneration of the whole neurone, notwithstanding the fact that the perikaryon with its nucleus is left in the mutilated neurone. This vulnerability of neurones in young animals is especially well illustrated by the long series of experiments which were made by von Gudden. The distinguished Bavarian investigator showed that after removal of an eye in a young rabbit, in the course of some months not only did a total degeneration of the optic nerve of the same side and partial degeneration of the optic tract of the other side take place, but also extensive degeneration occurred in the superior colliculus of the corpora quadrigemina and lateral geniculate body of the opposite side. This general observation showed immediately what regions of the gray matter are intimately related with the optic nerve. The study of the microscopic changes in these primary optic centres proved that this method permits one to draw also important conclusions concerning the finer histological connections of the axones of the optic nerve with their centres of origin and of termination. Thus while in the superior colliculus after the operation above mentioned entire rows of nerve cells had

disappeared from the superficial layer of gray matter, in the lateral geniculate body the ganglion cells were but very little altered; but between them, and especially in the gelatinous substance lying in the lateral part of this nucleus, there had been a very great loss by absorption of fine nerve fibres, the terminals of the optic nerve. It was easy to interpret these observations. Where as a result of the lesion there had occurred cellulifugal degeneration of the ground substance in direct continuation with cellulifugal degeneration of nerve fibres in the optic tract and optic nerve, we have to deal with the nucleus of termination of the axones of neurones, the cell bodies of which are situated in the retina. On the other hand, in the part of the colliculus superior where there had been a cellulipetal disappearance of ganglion cells, as a result of the removal of the eye, it was evident that we have to deal with a nucleus of origin of centrifugal axones which run out through the optic tract and optic nerve to the eye. That this conclusion is correct, the application of the methods of Golgi and of Flechsig to the problem have left no doubt.

Von Gudden and his pupils utilized this cellulipetal secondary degeneration in young animals in extending widely our knowledge of the anatomy of the brain. By it the nuclear origin of the various cerebral nerves were very exactly defined, and later, the connections of the lemniscus, the brachium conjunctivum, the cerebrocortical pontal paths, and various other tracts were determined and their centres of origin and of termination accurately established.

A study of a large series of pathological cases in human beings following upon hemorrhage, softening, or pressure from various causes in the brain has proven that in human beings also the cellulipetal degeneration (corresponding to the experiments of von Gudden) occurs as well as the typical cellulifugal secondary degeneration of Waller. What is more, a study of human cases reveals the fact that if a neurone of a high order fails to receive its normal impulses from a set of neurones of the next lower order, owing to degeneration of the latter, the former undergoes a slow diminution in size throughout its whole extent (diminution in size of lemniscus accompanying sclerosis of posterior funiculi of cord). Again, if a set of neurones in a neurone chain is unable, through degeneration of the next higher group of neurones in the chain, to pass on its impulses to the latter, it undergoes a slow atrophy, all the neurones of the set gradually diminishing in size. This is well shown when, for example, the somæsthetic area of the cortex is destroyed and secondary degeneration of the thalamocortical neurone system results; the lesion is followed in the course of years by marked diminution in the volume of the lemniscus medialis, of the stratum interolivare lemnisci, and of the nucleus funiculi gracilis and nucleus funiculi cuneati of the opposite side, the cell bodies of which give rise to the axones of the lemniscus.

Bethe also studied the degenerative changes in the axis cylinder after section of the nerve. He states that the first change is the disappearance from the fibrillæ of a substance which is primarily colored by basic dyes, and that with the disappearance of the primary colorability of the nerve there disappears its excitability. There follows a breaking up of the primitive fibrillæ into large and later into fine granules; at the same time a breaking up of the medullary sheath with ellipsoid formation. Degeneration is always apparent in the primitive fibrillæ before such is seen in the medullary sheath. This degeneration does not occur in the whole nerve at the same time, but is first apparent near the seat of the lesion from which it can be traced at later periods toward the periphery. Corresponding changes are found in the central stump, though here the degeneration is limited in extent, though certain fibres may be seen degenerating far toward the cord. He denies that in the central stump degeneration ends at the first nerve of Ranvier nearest to the point of lesion (traumatic degeneration). From his investigations he confirms the opinion that sensory fibres degenerate more quickly than motor, and he further states that thicker fibres, both motor and sensory, earlier show signs of degeneration than finer fibres.

References Bearing upon Secondary Degenerations of the Neurone and Modifications Following upon Injury to the Axone.

Waller, A.: Experiments on the Section of the Glossopharyngeal and Hypoglossal Nerves of the Frog, and Observations of the Alterations Produced Thereby in the Structure of their Primitive Fibres. Phil. Tr., Lond., 1850, p. 423.

Türck, L.: Ueber secundäre Erkrankung einzelner Rückenmarkstränge und ihrer Fortsetzungen zum Gehirne. Ztschr. d. k.-k. Gesellsch. d. Aerzte zu Wien (1852), ii., 51; 1853, ii., 289.

Homén, E. A.: Experimenteller Beitrag zur Pathologie und pathologischen Anatomie des Rückenmarks (speciell mit Hinsicht auf die secundäre Degeneration). Fortschr. d. Med., Berl., Bd. ii. (1885), SS. 267–276. – Contribution expérimentale à la pathologie et à l'anatomie pathologique de la moëlle épinière. Helsingfors (1885), pp. 115, 7 pl., 8vo.

Tooth, H. H.: The Gulstonian Lectures on Secondary Degenerations of the Spinal Cord. London, J. and A. Churchill (1889), pp. 1–77; also in Brit. M. J., London (1889), i., 753, 825, 873.

Notthaft, A. V.: Neue Untersuchungen über den Verlauf der Degeneration- und Regenerationsprocesse an verletzten peripheren Nerven. Ztschr. f. wissensch. Zool., Bd. lv. (1893), SS. 134–188.

Ceni, C.: Sur les fines altérations histologiques de la moëlle épinière dans les dégénérescences secondaires ascendantes et descendantes. (Abstr.) Arch. ital. de biol., Turin, t. xxvi. (1896–97), pp. 97–111; also in Arch. per le sc. med., Torino, xx. (1896), pp. 181–194.

Nissl, F.: Ueber eine neue Untersuchungsmethode des Centralorgans speciell zur Feststellung der Localisation der Nervenzellen. Centralbl. f. Nervenh. u. Psychiat., Coblenz u. Leipz. (1894), Bd. xvii., S. 337.

Marinesco, G.: Des polynévrites en rapport avec les lésions primitives des cellules nerveuses. Rev. neurol., Par., 1896, pp. 129–141.

van Gehuchten, A.: Anatomie du système nerveux de l'homme, 2d ed., Louvain, 1897, pp. 321–330.

Barker, L. F.: The Nervous System and Its Constituent Neurones, New York, 1899, pp. 229–247.

von Gudden, B.: Gesammelte und hinterlassene Abhandlungen. Herausgegeben von H. Grashey. Wiesbaden. 1889.

Monakow, C. von: Gehirnpathologie, Wien. 1897.

Mönckeberg, G., u. A. Bethe: Die Degeneration der markhaltigen Nervenfasern der Wirbelthiere unter hauptsächlicher Berücksichtigung des Verhaltens der Primitivfibrillen. Arch. f. mikr. Anat., Bonn, Bd. liv., 1899, SS. 135–183.

Regeneration of the Neurones.

The topic includes regeneration of the nervous system in whole or in part during embryonic periods, the regeneration of whole neurones in the adult condition, and the regeneration of portions of a neurone after injury.

In connection with regeneration of the nervous system in the embryo much work has been done. Recent studies have revealed a wholly unexpected capacity for regeneration in young phases of the embryo. The doubling of the whole nervous system, or of one end of it, is by no means uncommon. In later embryonic phases the capacity for regeneration becomes less; but until quite a late period, especially in low forms, very considerable regeneration is possible. Interesting as regards the regeneration of the nervous system are the researches of Harrison, who experimented upon the tails of tadpoles. After cutting off the tail, its peripheral nervous system was regenerated from the spinal cord. There first arose a single pair of nerves from cells lying within the cord. A part of these cells wandered into the nerve root and gave rise to a large spinal ganglion. Subsequently groups of cells wandered farther into the periphery along the newly formed nerves and gave rise to from one to three small ganglia to take the place of those ganglia which had been lost through the operation. The total number of ganglia, however, was never completely replaced.

As to the regeneration of whole neurones in adult vertebrates much doubt has been expressed. The prevailing opinion is that if an adult neurone be once entirely destroyed, it can never be regenerated from neighboring neurones. That karyokinetic figures can occur in nerve cells adjacent to an injury has been shown by Tedeschi and Vitzou. The exact histological details of karyokinesis in neurones have been studied in the cerebral cortex of guinea-pigs after introduction of a hot needle by Levi (*cf. Barbacci's Review, loc. cit.*, p. 785).

Most interesting are the various studies which have been made to explain the well-known fact that regeneration of peripheral nerves after lesion occurs. There has been much dispute as to whether the regeneration of nerve fibres is due to an outgrowth of the axone from