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GENERAL REVIEWS AND SUMMARIES
THE NEURONE

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The controversy as to the relationship of the endocellular network of Golgi (Binnennetz) and the trophospongium of Holmgren still continues. Ross (15) from his work on the nerve cells of the crayfish concludes that the trophospongium is a framework in the perikaryoplasm extending in from without and is non-nervous; and may contain nuclei and occasionally blood capillaries and serves both a nutritive and supporting function. Holmgren believed that Golgi's reticular apparatus and his trophospongium were identical and that the Saftkanälchen are developments by a dissolution process of the trophospongium. Ross thinks that the trophospongium is not only not identical with the reticular apparatus but entirely unrelated to it.

Cajal (1) studied the effect of experimental traumatism of the cerebrum on the reticular apparatus in the cortical cells. He found that an incision in the brain brings about complete destruction of the net only in those cells most severely injured. The net in cells near the incision while deformed in some instances showed no noteworthy abnormality. He thinks that this indicates that Golgi's net has considerable fixity of structure and firmness of texture since if it were of fluid consistence it would be found dispersed through the perikaryoplasm or massed together into larger droplets. Cajal also shows that the section of a peripheral axone has no effect on the structure of the Golgi apparatus. He believes that the Golgi net represents a canalicular system filled with a lipoid-containing substance reacting to silver impregnation and that these canals are for the most part fixed.

Pappenheimer (13) believes that the Golgi apparatus, Nissl bodies and mitochondria are different entities as they can be stained

in the same cell. As yet, however, no one has observed the net in the living cell. The Golgi net has been found in nearly all kinds of cells including those of the embryo and is described as breaking into fragments during mitosis and distributed evenly to the daughter cells. The net exhibits polarity, being found on the side of the nucleus toward the free surface and away from the blood supply. As fragmentation of the net occurs in ganglion cells after section of the axone, which however is denied by Cajal, and in lead and strychnine poisoning and traumatic injury, he believes that the net may be of solid form. Because of the capricious action of silver impregnations a new method of staining and more experimental work are needed to solve the morphology and genetic relationship of Golgi's reticular apparatus.

Little has been added recently to our knowledge of Nissl substance. There does not yet seem to be any absolute certainty as to whether this material exists in the form in which we find it in fixed and stained sections or whether it is simply a precipitation product. However, even if the latter supposition be true, it represents at least a chemical differentiation of the perikaryoplasm. Some observers claim that they can see Nissl bodies in the living cell, while others deny their existence there. Substances closely allied to these bodies have been found in many kinds of cells other than nerve cells and to such materials including Nissl bodies the general term chromidial substance is applied. Chemically Nissl bodies are generally believed to be a nucleo-protein containing iron which is elaborated by the nucleus.

Cowdry (3) has tried to solve the riddle of the "chromophile" cell at least as far as its finer morphology is concerned. He studied this condition in white mice and finds that chromophile cells vary in structure. Usually the cell as a whole and also the nucleus are shrunken. In some cells the mitochondria are increased either in number or sometimes as a diffuse material. As a rule no corresponding change in Nissl substance is noted, and Golgi's reticular apparatus seems to be unchanged.

Cowdry discovered some interesting facts relating to the distribution of the chromophile cells. They may exist singly or in groups of varying size in all stages of the chromophilic condition with unaltered cells scattered among them. He found chromophile cells more abundant in the cerebral and cerebellar cortex than anywhere else, rarely present in the olfactory bulb, corpora striata, thalami and cord, and infrequent in the medulla and the cranial

and spinal ganglia. He concludes that the chromophile condition is not an artefact but can be seen in the fresh cell where the material exists in the fluid state and can be stained vitally by methylene blue and that it is not associated with a pathological change in the animal. As chromophile cells are found in young mice as well as adults he considers that they are not an expression of senility.

The observations of Flesch (7) on chromophile cells do not wholly accord with those of Cowdry. Flesch finds more chromophile cells in all animals in the cells of the Gasserian ganglion than in the spinal ganglion and that chromophile cells are larger than the normal cell. Also he finds chromophile cells are less in number in young animals than old. As the nerve cells of the embryo are exclusively mesochrome he believes that both chromophobe and chromophile forms are derived from the mesochrome.

During the last three years there has been an intensive study of the mitochondria by various observers. Duesberg has suggested in order to clarify the nomenclature that the term chondriosomes be adopted as the general term instead of mitochondria, which is reserved for the granular form while the filamentous form he calls chondriocontes. In studying the nerve cells of fish embryos he finds chondriosomes in the form of granules already uniting to form filaments parallel to the long axis of the cell as early as three days after fertilization. Meves and Duesberg believe that in cell division there is an equal partition of chondriosomes between the two daughter cells.

The Lewises (11) have given a very interesting account of the mitochondria observed in the living cells of the chick in cultures. They find that the mitochondria may be evenly scattered through the perikaryoplasm or radiating around the central body or at one side of the nucleus. They change shape, size and number, even branching and forming a network, and move about passing from one cell to another through anastomosing processes and migrate from nucleus to periphery and return. An increase in size and number occurs during the growth period and just before mitosis. They are of the opinion that the mitochondria have a somewhat characteristic appearance in the different kinds of cells and in the nerve cell are more likely to be small granules and short rods. CO_2 and acids cause them to degenerate, heat causes them to change shape and decrease in number, alkalies and hypotonic solutions cause them to swell, hypertonic solutions shrink them and chloroform and ether dissolve them. They found no evidence that either glycogen granules

or fat droplets are formed from them or that they divide during mitosis or are evenly distributed to the daughter cells as some observers describe. There is some evidence that mitochondria decrease as nerve cells become senile and as the result of fatigue.

Nicholson (12) thinks that there are differences in quality and form in the mitochondria in different cells of the central nervous system of white mice. In the cerebral and ventral horn cells they are filamentous, while rod-like and granular forms are characteristic of the cells in the mesencephalic nucleus of the 5th nerve and the Gasserian ganglion. Also in the same cell they are more likely to be granular near the nucleus and always elongated in the processes. They may lie between the Nissl bodies or be buried in them. Also there are microchemical differences as some are more readily soluble in acetic acid than others. In view of the work of the Lewises, who have shown that mitochondria are constantly changing in shape, one is sceptical of the significance of these differences described.

Thurlow (17) studied mitochondria in motor and sensory cells but found no characteristic differences. Some sensory cells contained more mitochondria than motor cells and others less. The number of mitochondria however in the cells of the same group were about the same and he believes that there is a definite mitochondrial cytoplasmic ratio.

Little is known of the relation of mitochondria to diseased conditions. They may have some relation to fatty degeneration as they have been shown to have some connection with the formation of fat droplets in phosphorous poisoning. As cholin is found in the cerebro-spinal fluid in organic in contradistinction to functional disease of the nervous system there is some evidence that the mitochondria are connected with its formation, Cowdry (4) suggests that a study of the mitochondrial content of nerve cells in disease of the nervous system may yield valuable information.

The evidence from various sources seems to show that mitochondria are definite, discrete, formed elements found in all kinds of cells and at all ages and chemically are a lipoid albumen. They are not related genetically to the neurofibrils, Nissl bodies nor the Golgi net. Functionally they are connected with the fundamental metabolic processes such as occur in all cells, possibly of a respiratory nature. They are therefore less specific substances than Nissl bodies or the neurofibrils.

Turning to more general facts about the neurone Carpenter and Conel find in sympathetic ganglia not only Dogiel's motor type of

cell with thick dendrites but also his sensory type with slender dendrites. As they also find the intermediate type, they conclude that Dogiel's types are only the extremes of the variations occurring in multipolar sympathetic cells.

Greenman (8) finds that the number of fibers in the peroneal nerve of the albino rat increases with age until 250 days is reached and the number begins to decrease after 335 days of age. Also the sectional area of the fibers decrease with advancing age. Electrical stimulation has no effect on the sectional area of the nerve fibers.

Ransom (14) has shown that in spinal ganglia there are all sorts of variations from the fundamental type of cell with T-shaped axones and that simple unipolar cells may be transformed under experimental conditions into complex multipolar cells and such cells may return to their original simple form. This brings up the question of the possibility of the individual neurone in situ changing its form.

There has been a renewal of the attempt begun a number of years ago by Hodge to try to correlate the various structures in the nerve cell with their function. Smallwood and Phillips studied the size of the nucleus in the nerve cells of the antennal lobes of the bee and found that the nuclei vary greatly during all the stages of the bee and therefore question the validity of Crile's conclusion that the nuclei of nerve cells are smaller in shock and Hodge's conclusion that they are smaller in fatigue.

Dolley (5) and his pupils in various papers have tried to show a correlation between structure and function in the Purkinje cell of the cerebellum. Dolley holds that there is a constant relation of the volume of the nucleus to the volume of cytoplasm in the resting cell. The relation he calls the nuclear-plasma coefficient $\frac{\text{volume of cytoplasm}}{\text{volume of nucleus}}$. He contends that the resting cell of Purkinje

has no basichromatin except in the karyosome, that the plasma shows no edema nor vacuolation and also that there is a certain mass relation of nucleus to cytoplasm. During activity the cell and nucleus shrink, the chromatin decreases and there is an "upset" of the nucleus-plasma relation in favor of the nucleus, *i. e.*, nucleus is relatively large, and a dissolution of Nissl bodies occur. The coefficient continues to decrease as activity proceeds.

Kocher (10) studied the effects of activity on the cells of the motor cortex, in the spinal cord and cerebellum in dogs and cats in carefully controlled experiments. He was unable to find any of the various changes described by Dolley as resulting from fatigue, such

as changes in Nissl bodies, changes in actual size or relative size of nucleus or in any of the other constituents of the nerve cell. The impartial observer apparently must reserve for the present his judgment in the matter.

Kappers (9) in a long article defends his theory of neurobiotaxis. This theory assumes that the chief dendrite grows out toward, and its cell body shifts toward, the direction from which the stimulus proceeds, provided that the stimulation is of a nature that these cells respond to, *i. e.*, a correlation exists. He considers this growth of dendrites toward the source of stimulus (stimulo-petal tropism) similar to a kathodic tropism and the growth of the axones away from the stimulus (stimulo-fugal tropism) similar to an anodic tropism.

This theory is an attempt to explain the growth of the dendrites in one direction and the axone in the opposite and the shifting of groups of cells which occur during development. He concluded that correlated function is the fundamental factor in the arrangement of the cells and axones in the nervous system. The theory of neurobiotaxis seems more like a statement of an observed phenomenon than a satisfactory explanation of it. The anatomist has now brought our knowledge of the internal morphology of the neurone to the point where the assistance of the biological chemist and the pathologist is needed to increase our knowledge of the relation of structure to function.

REFERENCES

1. CAJAL, Ramon y. Algundal variaciones fisiologicas y patologicas del aparato reticular de Golgi. *Trab. del Lab. de Invest. Biol.*, 1914, 12, 127.
2. CARPENTER, F. W., & CONEL, J. L. A study of Ganglion Cells in the Sympathetic Nervous System with Especial Reference to Intrinsic Sensory Neurones. *J. of Comp. Neur.*, 1914, 24.
3. COWDRY, E. V. The structure of chromophile cells of the nervous system. *Contr. to Embryology, Carnegie Inst. of Washington*, 4.
4. COWDRY, E. V. The general functional significance of mitochondria. *Amer. J. of Anat.*, 1916, 19.
5. DOLLEY, D. H. Further verification of functional size changes in nerve cell bodies by the use of the polar planimeter. *J. of Comp. Neur.*, 1917, 27.
6. DUESBERG, J. Chondriosomes in the cells of fish-embryos. *Amer. J. of Anat.*, 1917, 21.
7. FLESCH, M. Mikrochemische Demonstrationen über Nervenzellen. *Ärzte Verein Frankfurt a.M.*, 1914, June 15. (Review in *Folia neuro-biologica*, 1916, 10, No. 1.)
8. GREEMAN, M. J. The number, size and axis-sheath relation of the large myelinated fibers in the peroneal nerve of the inbred albino rat—under normal conditions, in disease and after stimulation. *J. of Comp. Neur.*, 1917, 27.

9. KAPPERS, C. U. A. Further contributions on Neurobiotaxis. IX., An attempt to compare the Phenomena of Neurobiotaxis with other Phenomena of Taxis and Tropism. The Dymanic Polarization of the Neurone. *J. of Comp. Neur.*, 1917, 27.
10. KOCHER, B. A. The effect of activity on the histological structure of nerve cells. *J. of Comp. Neur.*, 1916, 26.
11. LEWIS, M. R. and LEWIS, W. H. Mitochondria and other cytoplasmic structures in tissue cultures. *Amer. J. of Anat.*, 1915, 17.
12. NICHOLSON, N. C. Morphological and microchemical variations in mitochondria in the nerve cells of the central nervous system. *Amer. J. of Anat.*, 1916, 20.
13. PAPPENHEIMER, A. M. The Golgi Apparatus. *Anat. Record*, 1916, 11.
14. RANSOM, S. W. Transplantation of the spinal ganglion with observations on the significance of the complex types of spinal ganglion cells. *J. of Comp. Neur.*, 1914, 24.
15. ROSS, L. S. The trophospongium of the Nerve-cell of the Crayfish (*Cambarus*). *J. of Comp. Neur.*, 1915, 25.
16. SMALLWOOD, W. M., & PHILLIPS, R. L. Nuclear size in the nerve cells of the bee during the life cycle. *J. of Comp. Neur.*, 1916, 27.
17. THURLOW, M. DE G. Observations on the mitochondrial content of the cells of the nuclei of the cranial nerves. *Anat. Record*, 1916, 10.

REFLEX MECHANISMS AND THE PHYSIOLOGY OF NERVE AND MUSCLE

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The posthumous book of Keith Lucas (13), in Starling's Monograph series, has been arranged for the press by E. D. Adrian from manuscript left by the author. It sums up in very clear form the recent work on the conduction of the nervous impulse and gives what is virtually a digest of the brilliant investigations of Lucas and Adrian themselves. Their chief experimental device for measuring the intensity of a nervous impulse has been to "set it to face a tract of nerve in which it will undergo a decrement, and determine how far it is able to travel before it is extinguished." Such a region of decrement can be produced by narcotics and by other means. This method seems to have yielded a final demonstration of the all-or-none law for normal nerve fibres, and the authors conclude that, "when a motor nerve is artificially excited with stimuli of varying strengths, the graded contraction of the muscle results solely from variation in the number of fibres brought into action." The separate contraction of isolated muscle fibres has now been