HISTOLOGICAL CHANGES OF THE SPINAL GANGLIA, THE SPINAL CORD AND THE MEDULLA OBLONGATA, CAUSED BY REPEATED APPLICATION OF STRONG ELECTRIC CURRENTS

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INTRODUCTION

In case of accidental electrocution or of death following electroshock treatment, there are usually only slight morphological changes in the central nervous sysem, detectable by routine staining techniques. However, it seems improbable that there do occur truely no morphological changes. More changes might become recognizable by frequent repetition of electrical shocks. In addition, it is questioned, whether they might occur not only in the area covered by the current pathway, but also transneuronally to a wide extent in the whole central nervous system. All these problems are subjected to the present research.

EXPERIMENTAL ANIMALS AND METHODS

As experimental animals, mature and fairly large domesticated cats were used. The cat was fastened to a fixing table in prone position, and the hairs growing at the back of the paw and at the elbow of the forelimb on the right side were cut with shears as short as possible, in an extent measuring 3 cm × 2 cm in both areas. Each area was pinched with a copper clip, which was attached to the end of a copper wire coming from each of the two poles of a slidac which could adjust voltage. Thus with the two poles set on the back of the paw and the elbow of the forelimb on the right side, the following experiment was carried out. Every possible effort should be made to protect the skin, taking care not to stick copper wires into the subcutaneous tissue or into the musculature and to avoide the injury to the skin by hair cut. No anesthesia, general or local, was used. A definite amount of electricity, as shown in Table 1, was transmitted once a day. Caution was exercised that the electric current might not pass to any part of the body other than that to which it was planned to pass, and if there was ill contact of the electrodes, we could know it immediately by a galvanometer placed in the circuit of the current or by the lack of micturition or of shreak of the animal, which occurred usually at the time of electrification.

Symptomatology in Electrified Cats: Transmission of current as mentioned above caused the cat to shriek during the whole course of the transmission. Motor unrest was intense. Involuntary micturition occurred at the onset of current.

Table 1. Tabulated Summary of the Experiment

Animal No	Sex	Voltage	Duration of current transmission (minutes)	Days for which electrification was repeated	Motor paralysis (awkward walking) appeared	Sensory paralysis appeared	Days for which the animal lived after the final transmission
I	♂	40	1	30	after 10 days	——	1
II	♀	40	2	40	after 9 days	——	2
III	♂	40	2	60	after 20 days	——	2
IV	♀	50	5	90	after 45 days	——	7
V	♀	50	30	13	after 6 days	after 12 days	21
VI	♀	40	30	30	after 10 days	after 29 days	7
VII	♂	40	Ist day, 30. 2nd day, 180 (3 hrs.).	2	after 2 days	after 4 days. The forelimb fell off	16
VIII	♀	40	1	12	——	——	Accidental death. No autopsy
IX	♂	20	1	60	——	——	2
X	♂	right forelimb was amputated					60

No general convulsions took place. After stoppage of current, the animal appeared quite well and walked with the right forelimb which have been electrified. As the experiment was planned to cover a long period of time, care was taken to protect the right forelimb; for the purpose of preventing an accidental injury, the limb was put in a sack (bandage was not applied for fear of causing circulatory disturbance), and to prevent suppuration, penicillin was administered. The electrification repeated for a week did not give rise to ulcer, but, if it was continued longer than a week, there developed gradually ulcer and necrosis and the distal portion of the limb finally fell off. However, as long as the animal shrieked by electrification, the experiment was continued, because it seemed evident that the sensation of the limb was not completely paralized. Thus in one case (No. IV) successive electrifications were given for a period of 90 days. In this animal there were the most remarkable changes in the central nervous system. If the voltage was too high, or if the duration of the current transmission in a day was too long, as in the case of cat No. VII, in which it was for 180 minutes (3 hours), the leg became necrotic and fell off 4 days after the electrification was started. If, on the contrary, the duration of time was too short (1-2 minutes), as in the cases of cats Nos. I, II or III, it was also unfit for the experiment, because the nervous changes were too slight. After the final current transmission, all experimental animals were left alive for several days, and then bled to death. Immediately after death, the spinal ganglia, the spinal cord and the brain were removed and examined grossly. Only in cat No. VII a fairly extensive bleeding was seen in the subarachnoidal space, while in the others no remarkable changes

were grossly perceived. The specimens were promptly subjected to dehydration fixation by use of 95% alcohol. The details of the fixation will be mentioned later. Then after celloidin embedding, the spinal ganglia were cut in 3-5μ, and the spinal cord and the medulla oblongata in 10-15μ. Subsequently, Nissl staining technique was applied to them by use of thionin solution. The histological changes were as follows.

HISTOLOGICAL CHANGES

1) The Spinal Ganglia (Figs. 1 and 3)

Since the current was passed from the back of the paw to the elbow of the forelimb on the right, changes in the spinal ganglia occurred at the levels of right C_6, C_7 and C_8, sometimes extending to right C_5 and Th_1, but no changes whatever were found on the left side. And the most notable change took place at right C_7 (Table 2). With regard to cellular changes, it was observed that there were cell swelling, eccentral location of the nucleus (Fig. 8), pyknosis,

Table 2. Changes in Nerve Cells in the Spinal Ganglia

			C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	Th_1	Th_2	Th_3	Th_4	Th_5
I	r	spinal ganglion	−	−	−	−	−	−	−	−	−	−	−	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		ventral horn	−	−	−	−	−	−	−	−	−	−	−	−	−
	l	ventral horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		spinal ganglion	−	−	−	−	−	−	−	−	−	−	−	−	−
II	r	spinal ganglion	−	−	−	−	−	−	−	−	−	−	−	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		ventral horn	−	−	−	−	−	−	−	−	−	−	−	−	−
	l	ventral horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		spinal ganglion	−	−	−	−	−	−	−	−	−	−	−	−	−
III	r	spinal ganglion	−	−	−	−	−	÷	+	−	−	−	−	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		ventral horn	−	−	−	−	−	−	−	−	−	−	−	−	−
	l	ventral horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		spinal ganglion	−	−	−	−	−	−	−	−	−	−	−	−	−
IV	r	spinal ganglion	−	−	−	−	++	++	+++	+++	+	−	−	−	−
		dorsal horn	−	−	+	+	+	++	+++	+++	+++	−	−	−	−
		ventral horn	+	+	+	++	++	++	+++	+++	+++	++	++	++	++
	l	ventral horn	+	+	+	+	++	++	+++	+++	++	++	++	++	++
		dorsal horn	−	−	−	−	−	−	+	−	÷	−	−	−	−
		spinal ganglion	−	−	−	−	−	−	−	−	−	−	−	−	−

V	r	spinal ganglion	−	−	−	−	−	+	++	+	+	−	−	−	−
		dorsal horn	−	−	−	−	+	+	++	+	÷	−	−	−	−
		ventral horn	÷	+	+	÷	+	+	+	+	+	+	+	÷	−
	1	ventral horn	÷	+	+	÷	+	+	+	+	÷	÷	÷	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		spinal ganglion	−	−	−	−	−	−	−	−	÷	−	−	−	−
VI	r	spinal ganglion	−	−	−	−	−	++	+++	++	−	−	−	−	−
		dorsal horn	+	−	−	−	−	+	+	+	−	−	−	−	−
		ventral horn	+	+	÷	+	+	+	+	+	÷	÷	−	−	−
	1	ventral horn	+	+	÷	+	+	+	+	+	÷	÷	−	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		spinal ganglion	−	−	−	−	−	−	−	−	−	−	−	−	−
VII	r	spinal ganglion	−	−	−	−	+	++	+++	++	+	÷	−	−	−
		dorsal horn	−	+	+	+	+	+	++	+	+	÷	−	−	−
		ventral horn	+	+	+	++	++	+	++	++	++	++	++	+	+
	1	ventral horn	+	+	+	++	++	+	++	+	+	+	+	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		spinal ganglion	−	−	−	−	−	−	−	−	−	−	−	−	−
IX	r	spinal ganglion	−	−	−	−	−	−	+	−	−	−	−	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		ventral horn	−	−	−	−	−	−	−	−	−	−	−	−	−
	1	ventral horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		spinal ganglion	−	−	−	−	−	−	−	−	−	−	−	−	−
X	r	spinal ganglion	−	−	−	−	−	++	+++	++	−	−	−	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		ventral horn	−	−	−	−	−	−	−	−	−	−	−	−	−
	1	ventral horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		dorsal horn	−	−	−	−	−	−	−	−	−	−	−	−	−
		spinal ganglion	−	−	−	−	−	−	−	−	−	−	−	−	−

tigrolysis, and liquefaction, thus leading to shrinkage of cells, and that the circular arrangement of satellite cells around a ganglion cell was distorted. The shrinkage of the cytoplasm was in some areas quite intense, the cytoplasm containing no distinct nucleus and adhering to one side of the cell membrane (Fig. 2 and 4). Tigroid bodies of some cells changed to irregular and indistinct strands, while in other cells, they underwent a complete dissolution to a state of liquefaction (Fig. 5, upper left and lower right). If the shrinkage and liquefaction are further advanced, the cell membrane disappears and the preexistence of a cell is scarcely recognized by the presence of an empty space outlined by satellite cells (Fig. 2, upper part; Fig. 6, center). Also the satellite cells always shrink, as a ganglion cell does, and the circular arrangement around a ganglion cell is distorted,

with the number of satellite cells diminishing (Fig. 4). In a control animal, in which no electrification was done and a forelimb was amputated (Table 1, Cat No X), the histological examination of the spinal ganglia was made in order to see how the retrograde degeneration occurred (Table 2, X). The examination showed that the ganglion cells of C_6, C_7 and C_8 were largely almost normal and that only some cells showed tigrolysis and liquefaction, while cytoplasmic shrinkage was not to be seen (Fig. 10).

2) The Spinal Cord

A) Dorsal Horn.

Cellular changes in the dorsal horn, especially in its marginal and apical portions, are found at the levels of C_6, C_7 and C_8, where there were more remarkable changes in the spinal ganglia, sometimes also at the levels of C_5 and Th_1. In the dorsal horns at other levels, that is, C_3, C_4, etc. in case Ⅳ in Table 2, there are changes in the cells at the bases of the dorsal horns and at the lateral horns. All of these changes, as in the case of the spinal ganglia, are found only on the right side, especially at the levels corresponding to the area, where the current was passed, but not at all on the left side. Details of changes are described in the following.

a) Cellulae posteromarginales and substantia gelationosa (Fig. 11); There are cell swelling, pyknosis, tigrolysis and vanishment of stainable substanec in the central portion of the cytoplasm, and also displacement of nucleolus close to the cell membrane (Fig. 12).

b) Nucleus proprius cornu dorsalis (Fig. 13); Here are also pyknosis and tigrolysis (Fig. 16), foamy change of the peripheral cytoplasm (Fig. 15), and dissolution of stainable substance (Fig. 14) resembling vacuolation.

c) Nucleus dorsalis (Fig. 17); This nucleus is situated insides the base of the dorsal horn. Tigrolysis, pyknosis and shrinkage of cells are present. The cells are faintly stained, look like ghost cells (Fig. 18), and are accompanied by glial satellitosis and neuronophagia (Fig. 19).

d) Nucleus reticularis spinalis (Fig. 20); This lies in the outer portion of the base of the dorsal horn. Tigrolysis, pyknosis and shrinkage of cells resembling ghost-cells (Eig. 21) are demonstrated. There are also glial satellitosis (Fig. 22) and neuronophagia.

B) Ventral Horn.

Changes in the cells in the ventral horn are not limited to the unilateral side of the lower cervical segments, as are in the case of the dorsal horn, but are found at nearly all levels bilaterally, although there are some differences in degree. More pronounced changes are present at the levels, where the cells in the dorsal horns are affected the most intensely. Another characteristic is the fact there is found no particular difference between the right side, to which the current was transmitted, and the left side unelectrified. Cellular changes are described below in detail:

a) Nucleus proprius cornu ventralis (Fig. 23); In this nucleus, lying in the

central part of the ventral horn, tigrolysis and pyknosis are particularly remarkable, no tigroid strand is found, and the cytoplasm shows a reticular appearance as a result of inhomogeneous liquefaction. Some have nucleolus and others have not (Fig. 24, 25).

b) Nucleus ventromedialis; There are tigrolysis, pyknosis, a sort of vacuolation in the outer portion of the cytoplasm and eccentral location of nucleolus (Fig. 26). Tigrolysis is pronounced, but there remain tigroid strands and a nucleolus is also found (Fig. 27).

c) Nucleus myorabdoticus lateralis; This is the largest cell group in the ventral horn, and shows tigrolysis, pyknosis and slight shrinkage of cells (Fig. 28). The tigrolysis is fairly distinct, Nissl substance appearing in very delicate strands. However there is no complete liquefaction, and a nucleolus is remaining (Fig. 29).

3) The Medulla Oblongata (Table 3)

a) Nucleus funiculi cuneati or nucleus cuneatus (BURDACH) (Fig. 30); Tigrolysis, pyknosis and vacuolation-like changes occupying fairly wide areas of the cytoplasm. As a result of the tigrolysis, normal features of NISSL substance are indistinct, the cytoplasm presenting a reticular appearance (Figs. 31, 32, 33, 34).

Table 3, Changes in Nerve Cells in the Medulla Oblongata

		p m d	R, h, sol	grac	d mo vag	cun	l cun	Sp V	pa r	mag fr, mo fr	l ret	Supra sp	fac	amb	ac ol	inf ol
I	upper end	−						−	−	−			−		−	−
	upper portion	−	−		−		−	−	−	−				−	−	−
	middle portion	−	−		−		−	−			−			−	−	−
	lower portion			−	−	−	−	−			−	−		−	−	−
	lower end			−		−		−				−		−		
II	upper end	−						−	−	−			−		−	−
	upper portion	−	−		−		−	−	−	−				−	−	−
	middle portion	−	−		−		−	−			−			−	−	−
	lower portion			−	−	−	−	−			−	−		−	−	−
	lower end			−		−		−				−		−		
III	upper end	−						−	−	−			−		−	−
	upper portion	−	−		−		−	−	−	−				−	−	−
	middle portion	−	−		−		−	−			−			−	−	−
	lower portion			−	−	−	−	−			−	−		−	−	−
	lower end			−		−		−				−		−		
IV	upper end	−						+	++	−			−		+	+
	upper portion	−	−		−		−	++	+	−				−	+	+
	middle portion	−	−		−		−	++			−			−	+	+
	lower portion			÷	++	+++	−	++			−	+		+	+	+
	lower end			−		+++		+				++		+		

V	upper end	−						−	−	−			−		÷	÷
	upper portion	−	−		−		−	−	−	−				−	+	+
	middle portion	−	−		−		−	+			−			−	−	−
	lower portion			−	+	+	−	+			−	−		−	−	÷
	lower end			−		++		+				+		−		
VI	upper end	−						−	−	−			−		+	++
	upper portion	−	−		−		−	++	−	−				−	+	−
	middle portion	−	−		−		−	++			−			−	++	+
	lower portion			−	−	+	−	++			−	−		−	−	−
	lower end			−		+		÷				−		−		
VII	upper end	−						−	−	−			−		−	−
	upper portion	−	−		−		−	++	−	−				−	−	−
	middle portion	−	−		−		−	+			−			−	−	−
	lower portion			−	+	+	−	−			−	+		−	−	−
	lower end			−		++		−				+		+		
IX	upper end	−						−	−	−			−		−	−
	upper portion	−	−		−		−	−	−	−				−	−	−
	middle portion	−	−		−		−	−			−			−	−	−
	lower portion			−	−	−	−	−			−	−		−	−	−
	lower end			−		−		−				−		−		
X	upper end	−						−	−	−			−		−	−
	upper portion	−	−		−		−	−	−	−				−	−	−
	middle portion	−	−		−		−	−			−			−	−	−
	lower portion			−	−	−	−	−			−	−		−	−	−
	lower end			−		−		−				−		−		

Explanation of abbreviations in Table 3

p. m d : nucleus paramedianus dorsalis (JACOBSOHN)
R, h, sol. : nucleus Rolleri, nucleus of hypoglossal nerve, nucleus of tractus solitarius
grac : nucleus gracilis (GOLL)
d mo vag dorsal motor nucleus of vagus
cun : nucleus cuneatus (BURDACH)
l cun : lateral cuneate nucleus (MONAKOW)
Sp V : nucleus of the spinal tract of the trigeminal
par : nucleus pallidus of raphé
mag fr : magnocellular nucleus of reticular formation
mo fr : motor cells of formatio reticularis
l ret : lateral reticular nucleus
Supra sp : supraspinal nucleus
fac : nucleus of facial nerve
amb : nucleus ambiguus
ac ol : accessory olivary nucleus
inf ol : inferior olivary nucleus

However, in lateral cuneate nucleus (MONAKOW), which is located a little further rostrally, there is no change.

b) Dorsal motor nucleus of vagus (Fig. 35), nucleus ambiguus and nucleus

supraspinalis; They show remarkable changes, as in the case of nucleus cuneatus, but the changes occur only at the level where nucleus cuneatus is seen. For instance with regard to dorsal motor nucleus of vagus, when the nucleus is examined near the central canal in the lower portion of the medulla oblongata, there is a remarkable change, while no change is found in the same nucleus at the level of the middle portion of the medulla oblongata. Also, as regards nucleus ambiguus, a change is demonstrated at the level, where nucleus cuneatus and nucleus supraspinalis are appearing, but there is no change in the middle portion of the medulla oblongata, where lateral cuneate nucleus (MONAKOW) is seen.

c) Nucleus of the spinal tract of the trigeminal (Fig. 37); A rather remarkable change is present at nearly all levels of the medulla oblongata (Fig. 38); py nosis, tigrolysis and vacuolation.

d) Olivary nucleus; tigrolysis and pyknosis are not much distinct in any case But the more rostral, the cell change appears to be. In superior olivery nucleus there occurs also a change, but less markedly (Fig. 39).

e) Nucleus pallidus of raphé; There is a change only in one instance (No. Ⅳ); tigrolysis, pyknosis and vacuolation of the cytoplasm (Fig. 40).

Thus, in the lower portion of the medulla oblongata, remarkable changes are seen in nucleus cuneatus(BURDACH), dorsal motor nucleus of vagus, nucleus ambiguus, nucleus of the spinal tract of the trigeminal, and supraspinal nucleus. But in the middle portion of the medulla oblongata no change occurs in the former three nuclei and also in lateral cuneate nucleus (MONAKOW); only in nucleus of the spinal tract of the trigeminal there is a change. Further, in the upper portion of the medulla oblongata, a change takes place in nucleus of the spinal tract of the trigeminal, olivary nucleus and occasionally in nucleus pallidus of raphé, but no change occurs in reticular formation, or in nucleus of facial nerve.

COMMENT

1) The morphological changes in nerve cells of the spinal cord and the medulla oblongata, observed in the present experiment, are considered to have occurred transneuronally.

It is natural that repeated electrification applied to the right forelimb causes a remarkable change in the nerve cells of primary sensory neurone, i. e. spinal ganglia of C_6 ,C_7 and C_8, especially C_7 on the right side. However, in this experiment, there are also remarkable changes in the cells of secondary sensory neurone in the dorsal horn of the cervical cord, e. g. cellulae posteromarginales and nuleus proprius cornu dorsalis etc. According to KURU, cellulae posteromarginales are the cells of secondary neurone communicating pain and temperature sensibilities to thethalamus and nucleus proprius cornu dorsalis communicates tactile sensibility to the thalamus. Occasionally some changes take place also in the posterior horns of C_5 and Th_1. But at other levels of the spinal cord, changes are found only at the base of the dorsal horn and in the lateral horn, but not in the marginal zone of the dorsal horn or in nucleus proprius. Also, no change is seen in spinal

ganglion cells and dorsal horn cells on the left side unelectrified. In the medulla oblongata, remarkable changes occur in nucleus cuneatus and in its adjacent nuclei, e. g. dorsal motor nucleus of vagus, nucleus ambiguus and nucleus supraspinalis, but a little further rostrally in the middle of the medulla oblongata, changes are slight. From the facts above mentioned, it is understood that repeated electric shocks coming from the peripheral nerves cause morphological changes transneuronally in certain nerve cell groups in the dorsal and ventral horns of the spinal cord and in the lower portion of the medulla oblongata.

2) Resistance of nerve cells to electricity. In the right C_7 spinal ganglion of cat No. Ⅳ, which shows the most conspicuous changes, there are remaining normal nerve cells intermingled among degenerated ones. But in the same animal, no normal cells are seen in the dorsal and ventral horns of the spinal cord at the same level. Also, in cats Nos. Ⅴ and Ⅵ (Table 2), only a slight change is found in spinal ganglia, whereas there are remarkable changes in the dorsal horn (the marginal zone and the base) and in the ventral horn on both sides. Again, in cat No. Ⅳ, which shows severe changes in spinal ganglia and in the marginal zones of the dorsal horns of C_5, C_6, C_7, C_8 and Th_1 on the right side, no change whatever is found in those structures on the opposite side. And yet there are remarkable changes at the bases of the dorsal horns from C_1 to Th_5 and in the whole ventral horns on both sides. All these facts seem to suggest that the sensory nerve cells are more resistant to a transneuronally transmitted electric shock than the motor nerve cells. Further, in view of that the motor nerve cells, such as those in the ventral horn of the spinal cord, or the dorsal motor neucleus of vagus etc. suffer morphological changes far reaching rostral and caudalwards, it seems that centripetal impulses due to an electric shock may spread to and cause damage of motor nerve cells to a wide extent in the spinal cord and the medulla oblongata.

3) There may be a question as to whether the changes in the nerve cells demonstrated in the present experiment might be due to the insufficient technique of fixation and staining of the nervous tissue. In case that fixation or staining of the central nervous system is imperfect, it sometimes happens that normal nerve cells appear like pathological ones in NISSL preparations. Keeping this well in mind, I have made every effort to avoid possible errors. I have removed the brain, the spinal cord and the spinal ganglion within 30 minutes after death or within one hour at the longest, and cut into very small pieces, wh ch were immediately put into 95% alcohol. This was exchanged every 8 hours on the first day. On the 2nd-5th day, they were immersed in pure alcohol which was exchanged once every day. On the 6-8th day they were kept in absolute alcohol which was again exchanged once every day. On the 9th day they were placed in the equal amount of absolute alcohol and ether, and beginning on this day for a week, they were immersed in 2% solution of celloidin, then for a week in 4% solution of celloidin, and lastly for a week in 8% solution of celloidin, after which they were taken out and dried gradually for about 10 days. NISSL staining

was then done. By so doing, I could confirm that in the case of control animals, to which the current was not transmitted, all nerve cells, without any exception, were stained beautifully demonstrating the typical appearance of normal nerve cells. In addition, in cats Nos. I, II and III (Table 2), in which no change took place, all nerve cells showed morphological features characteristic of normal nerve cells. Thus I believe that the changes in the nerve cells, which I have judged as pathological, are not postmortem artefacts.

CONCLUSIONS

Repeated electric shock given to the peripheric nerve has produced the most remarkable degeneration in the spinal ganglion cells and less remarkable but definite changes also in the sensory nerve cells of the next neurones, i. e. nerve cells in the dorsal horn of the spinal cord and nucleus cuneatus of the medulla oblongata.

In addition, fairly remarkable changes are also found in the nucleus of the spinal tract of the trigeminal nerve lying adjacent to nucleus cuneatus in the lower portion of the medulla oblongata, and in the ventral horn of the spinal cord, as well as in the dorsal motor nucleus of vagus etc.

References

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Explanation of Plates

Photographs all are taken from thionin-stained preparations.

Fig. 1. Control. Normal spinal ganglion cells. (× 108)

Fig. 2. C_7 spinal ganglion cells of cat No. VI (voltage 50; duration of current transmission, 5 minutes; days of experiment, 90 days); distinct shrinkage of nerve cells is shown. (× 108)

Fig. 3. Control. Normal ganglion cells-Enlargement of Fig. 1. (× 567)

Fig. 4. Enlargement of Fig. 2; cytoplasm is dissolved and adhered to one side of the cell membrane; there is no nucleolus. The arrangement of satellite cells is distorted. Individual satellite cells are also suffering shrinkage and diminishing in number. (× 567)

Fig. 5. Enlargement of right lower portion of Fig. 2 Dissolution of the cytoplasm is severe in a nerve cell lying in the right lower portion, while in other cells tigroid strands are remaining. (× 243)

Fig. 6. C_7 spinal ganglion cells of cat No. VI (voltage 40; duration of current transmission, 30 minutes; days of experiment, 30 days); the cells suffer shrinkage and a cell lying in the central part of the figure has the cell membrane destroyed. (× 243)

Fig. 7. C_7 spinal ganglion cells of cat No. V (voltage 40; duration of current transmission, 30 minutes; days of experiment, 30 days); the cells suffer high-degree shrinkage and liquefaction, but the arrangement of satellite cells is not distorted. (× 243)

Fig. 8. C_7 spinal ganglion cells of cat No. V (voltage 50; duration of current transmission, 30 minutes; days of experiment, 13 days); tigrolysis and eccentric location of nucleus are seen. (× 243)

Fig. 9. C_7 spinal ganglion cells of cat No. VII (voltage 40; duration of current transmission, 3 hours); there is shrinkage of cells, but the arrangement of satellite cells is only slightly distorted. (× 243)

Fig. 10. Control. C_7 spinal ganglion cells of cat No. X (the right forelimb amputated); there are suggested pyknosis, more or less tigrolysis and liquefaction, but no shrinkage. × 243)

The following figures are of cat No. VI, which showed the most conspicuous changes.

Fig. 11. Control. Normal cells of cellulae posteromarginales (left part) and substantia gelatinosa (right part) in the marginal zone of the dorsal horn. (× 405)

Fig. 12. Change in the marginal zone of the dorsal horn due to electroshocks; a nucleolus of a nerve cell is seen displaced to one side of the cell membrane, and stainable substance the central part of the cytoplasm is vanishing (× 405)

Fig. 13. Control. Normal cells of nucleus proprius at the tip of the dorsal horn. (× 567)

Fig. 14. Change in nucleus proprius due to electroshocks; pyknosis and tigrolysis are apparent, nucleus shrunken, and cytoplasm liquefied in the peripheral portion. (× 567)

Fig. 15. Analogous change in nucleus proprius; pyknosis and tigrolysis are intense, and a foamy appearance of the peripheral portion of the cell body. (× 567)

Fig. 16. Other cells of nucleus proprius; cells shrunken, pyknosis tigrolysis and liquefaction. (× 567)

Fig. 17. Control. Normal cells of nucleus dorsalis insides the base of the dorsal horn. (× 252)

Fig. 18. Change in nucleus dorsalis due to electroshocks; pyknosis and tigrolysis. The cells look like ghost cells. (× 252)

Fig. 19. Other cells of nucleus dorsalis; in the lower portion glial neuronophagia is seen. (× 252)

Fig. 20. Control. Normal cells of nucleus reticularis in the outer portion of the base of the dorsal horn. (× 252)

Fig. 21. Change in nucleus reticularis due to electroshocks; pyknosis, tigrolysis, shrinkage of cells, and a ghost cell-like appearance. (× 252)

Fig. 22. Change in nucleus reticularis due to electroshocks; glial satellitosis. (× 252)

Fig. 23. control. Normal cells of the middle portion of the ventral horn. (× 243)

Fig. 24. Change in the same area due to electroshocks; pyknosis and tigrolysis.(× 243)

Fig. 25. Enlargement of Fig. 24; as the result of inhomogeneous tigrolysis the cytoplasm appears reticular. Nucleolus is present in a cell on the left and lacking on the right.(× 540)

Fig. 26. Change in cells insides the ventral horn due to electroshocks. Tigrolysis, pyknosis and liquefaction in the peripheral portion of the cytoplasm. (× 180)

Fig. 27. Enlargementof Fig. 26; despite of more or less tigrolysis, tigroid strands are still remaining. (× 405)

Fig. 28. and 29. Change in cells in the outer zone of the ventral horn; pyknosis and tigrolysis appear to be slight; but when enlarged more greatly (Fig. 29), a definite tigrolysis is seen. (× 180) (× 540)

Fig. 30. Control. Normal cells of nucleus cuneatus of the medulla oblongata. (× 243)

Figs. 31, 32, 33, 34. Change in nucleus cuneatus due to electroshocks; pyknosis are tigrolys is areremarkable, cytoplasm appears reticular in some cells or liquefying in the outer portion in other cells. (× 243) (× 243) (× 567) (× 567)

Fig, 35. Control. Normal cells of dorsal motor nucleus of vagus in the lower portion of the medulla oblongata. (× 243)

Fig. 36. Change in dorsal motor nucleus of vagus in the lower portion of the medulla oblongata due to electroshocks. As in the case of nucleus cuneatus, pyknosis and tigrolysis are remarkable and there is a peripheral liquefaction of the cytoplasm. (× 243)

Fig. 37. Control. Normal cells of nucleus of the spinal tract of the trigeminal. (× 243)

Fig. 38. Change in nucleus of the spinal tract of the trigeminal due to electroshocks. Pyknosis, and liquefaction of the cytoplasm. (× 243)

Fig. 39. Change in olivary nucleus due to electroshocks. The change is not remarkable if compared with the normal case, though some tigrolysis and pyknosis seem to be present. (× 243)

Fig. 40. Change in nucleus pallidus of raphé due to electroshocks. Pyknosis and tigrolysis. (× 243)

和文抄錄

電撃の反復に依る脊髄神経節，脊髄及び延髄の組織学的変化

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波多腰正彦

電撃の事故死又は治療的電撃ショックの場合に，中枢神経系には，普通の染色方法でわかるような形態的変化は大して起らぬものの如くである．併しこのような不著明な変化も何回も電撃を反復することによつて拡大強化されて来るのではないか，而もそれは電流の通路だけでなく，transneuronal に中枢神経全体にも変化を起すのではないか，ということを調べたのが私のこの実験である．

実験には猫を用いて，二つの電極共一方の上肢の前膊（手背と肘関節部）に置いて第1表の如く毎日一回一定の電量を与えた所，猫Ⅳ（50volt, 5分 90日間）が最も長期の刺戟に耐え，又中枢神経に最も変化に富んだ組織像を示した．電圧が高すぎても，又，1回の通電時間が長過ぎ（猫Ⅶ）ても，短か過ぎても猫（Ⅰ—Ⅲ）実験には不適当である．実験動物は全部出血死せしめて，アルコール固定ニッスル染色法を行い次の所見を得た．

組織学的所見．

1) 脊髄神経節（Fig. 1, Fig. 3 は正常像）細胞の tigrolysis, pyknosis, 核小体は染色質と共に溶解して細胞体の一方側に萎縮し，遂には細胞膜の破壊を来す．(Fig 2, Fig.4, Fig.5, Fig.6, Fig.7, Fig.8, Fig.9) 対照例として通電しない動物で上肢を切断して神経節細胞の逆行性変性を見るに，pyknosis の傾向と共に tigrolysis を示すのみで萎縮の像は全く之を欠いている．(Fig. 10).

2) 脊髄

A) 後角

a)後角（頭部）端の膠様質（Cellula eposteromarginales, Substantia gelatinosa）にては（Fig. 11は正常像）細胞の pyknosis, tigrolysis, 原形質の染色質消失と共に核小体の細胞膜への偏在を示す．(Fig. 12)

b) 後角頭部の内側に在る固有核Nucleus proprius cornu dorsalis (Fig. 13は正常像）にては，tigrolysis pyknosis (Fig. 16) 細胞体外縁の泡立ち (Fig. 15) 原形質の染色質消失を示す．(Fig. 14).

c) 後角底の内側の背核 Nucleus dorsalis (Fig. 17は正常像）にては細胞の tigrolysis, pyknosis (Fig. 18) と共に glia の satellitosis, neuronophagia を示す．(Fig. 19).

d) 後角底の外側の網様体 Nucleus reticularis spinalis (Fig. 20は正常像）にては tigrolysis, pyknosis と satellitosis (Fig.22), neurnophagia を示し特に tigrolysis, pyknosis 著しく朦朧像を現す．(Fig.21).

B) 前角

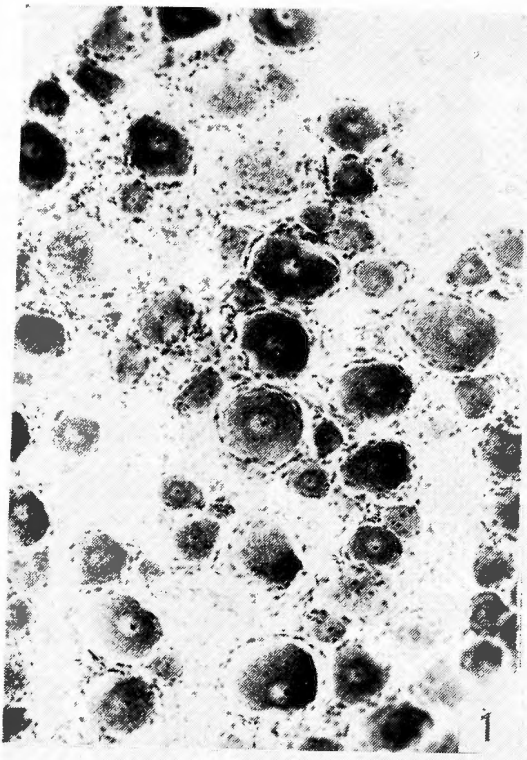
a) 外側の最も大なる細胞群 Nucleus myorabdoticus lateralisにては，細胞の tigrolysis, pyknosis と共に細胞体の中等度の萎縮を示す．(Fig 28, Fig.29).

b) 内側の Nucleus ventromedialis にては細胞の tigrolysis, pyknosis 及び原形質の染色質消失，核小体の細胞膜への偏在を示す．(Fig. 26, Fig. 27)

c) Nucleus proprius cornu ventralis (Fig. 23は正常像）にては，細胞の tigrolysis, pyknosis は特に著しく，朦朧像著明にて，映像を見る如し (Fig. 24, Fig. 25).

3) 延髄 Nucleus cuneatus (Fig. 30は正常像）にては，tigrolysis, pyknosis と共に原形質の染色質消失を示し (Fig. 31, Fig. 32, Fig. 33, Fig.34)，又三叉神経脊髄路核 (Fig. 37は正常像)，迷走神経背側核 (Fig. 35は正常像）にても，同様に tigrolysis, pyknosis と共に原形質の外縁の染色質消失を示す．夫々 (Fig. 38, Fig. 36).

要するに脊髄神経節は最も強き変化を示し，次の neurone たる脊髄の後角及び延髄の Nucleus cuneatus に強き変化を示している．又変化せる後角に連絡する脊髄前角，延髄の Nucleus cuneatus に接する三叉神経脊髄路核及び迷走神経背側核にも相当強き変化を示している．



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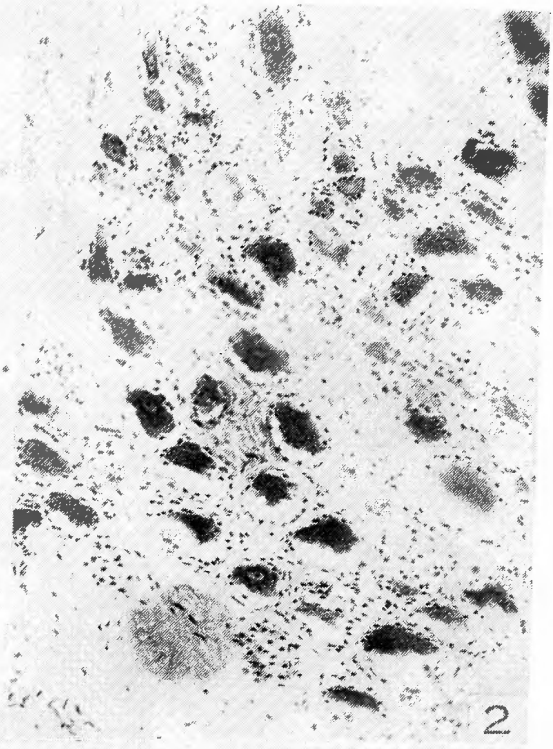

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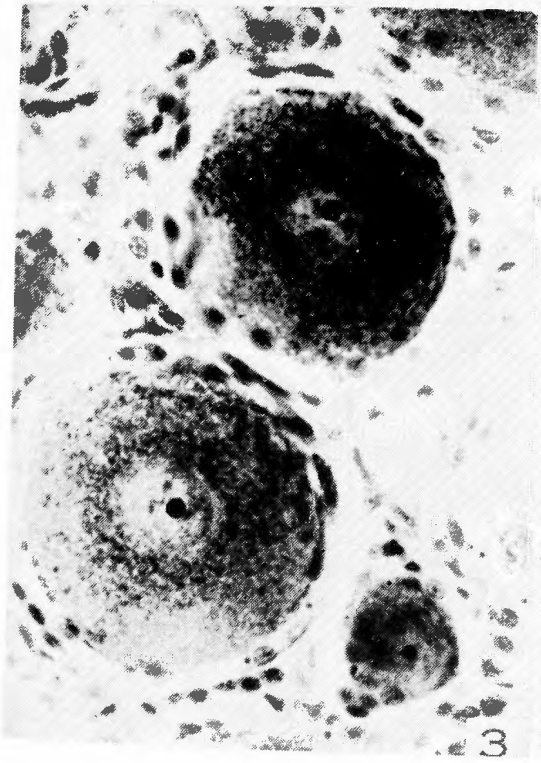

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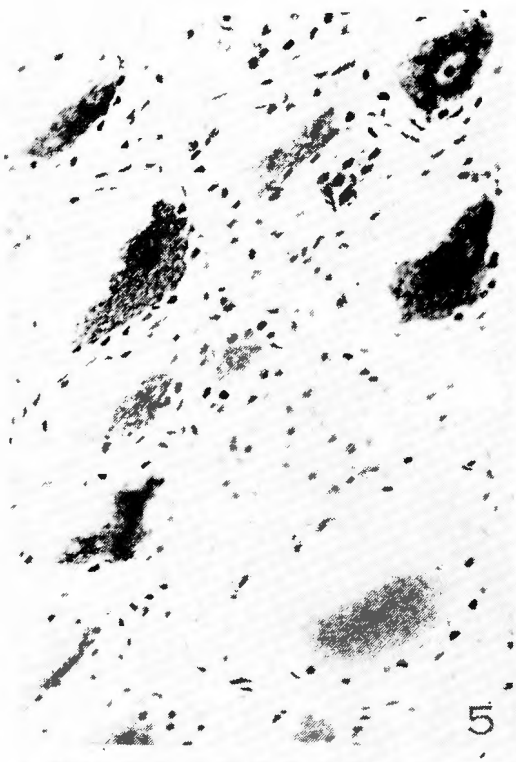
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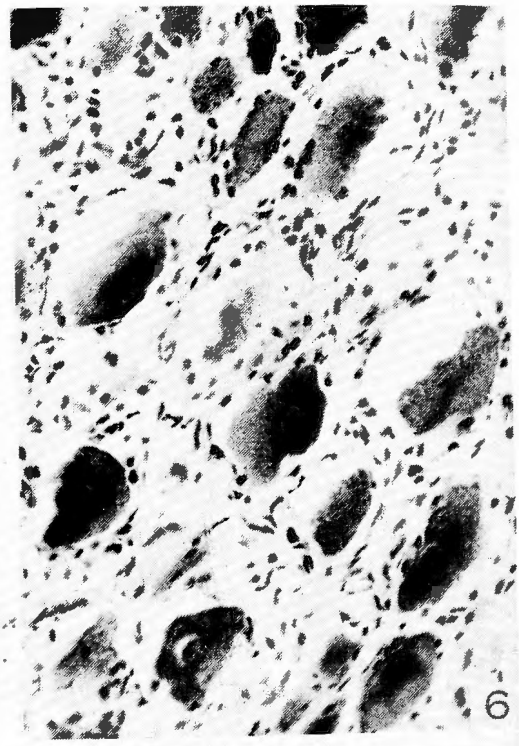
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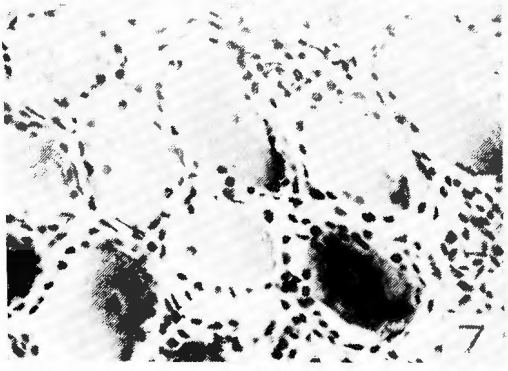
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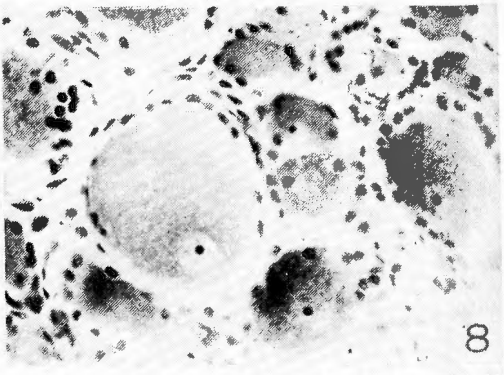
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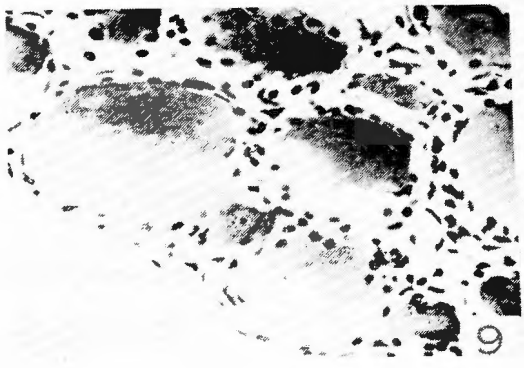
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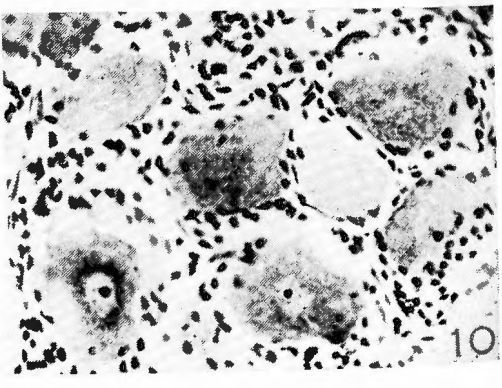
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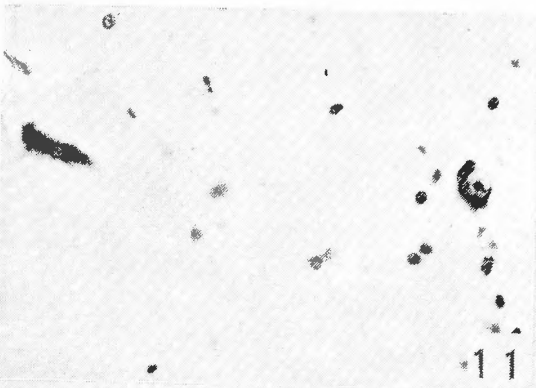
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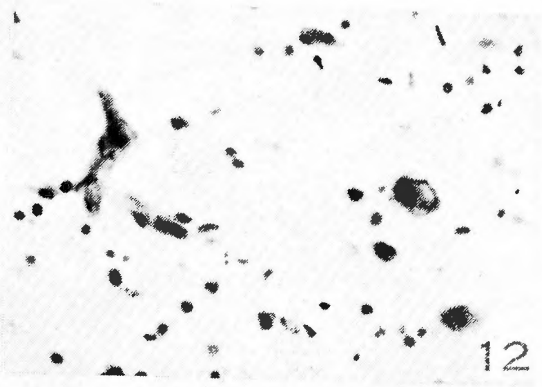
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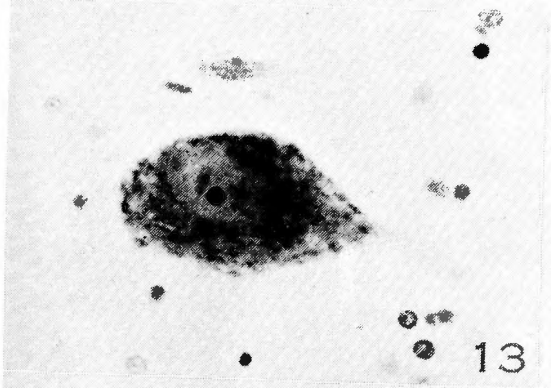
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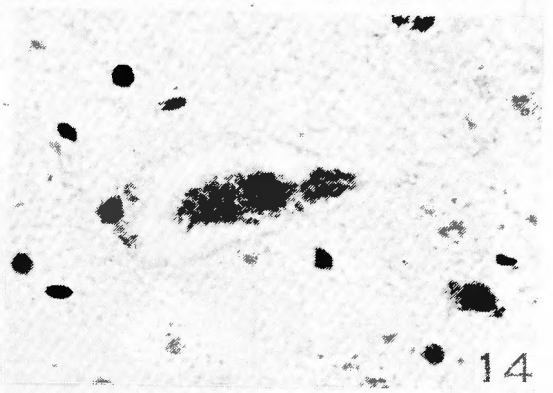
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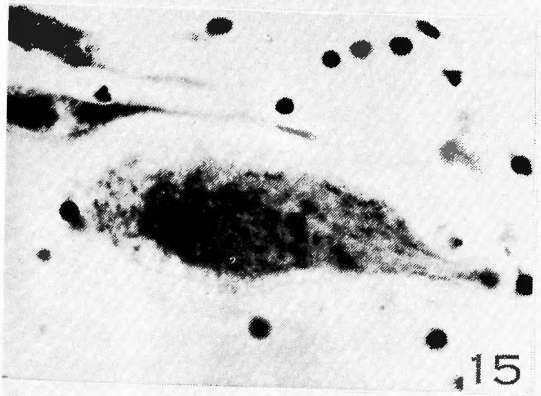
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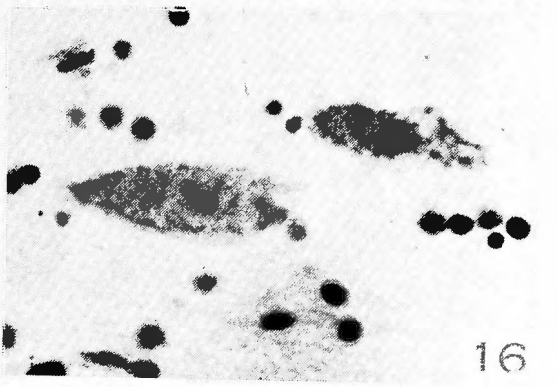
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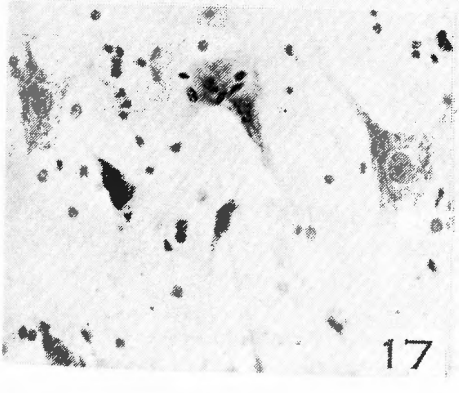
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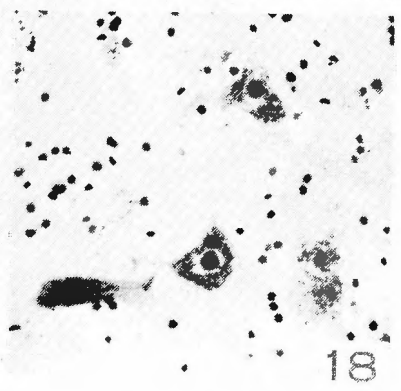
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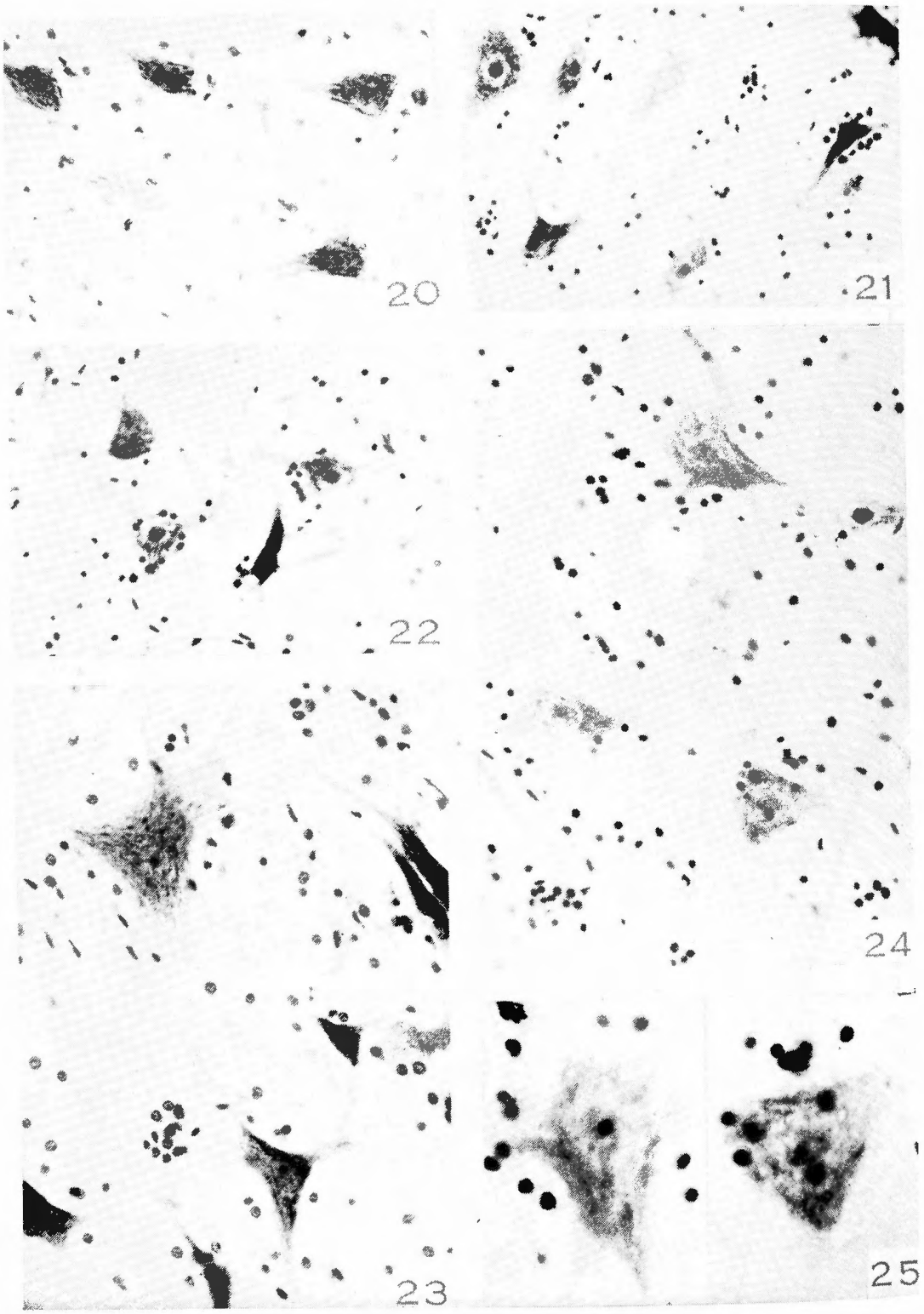

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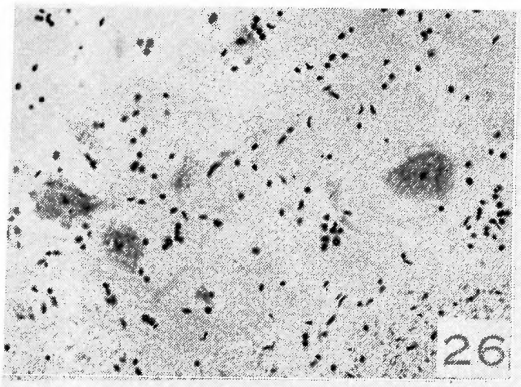

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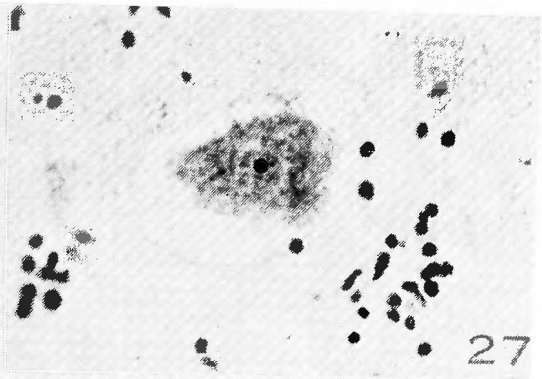

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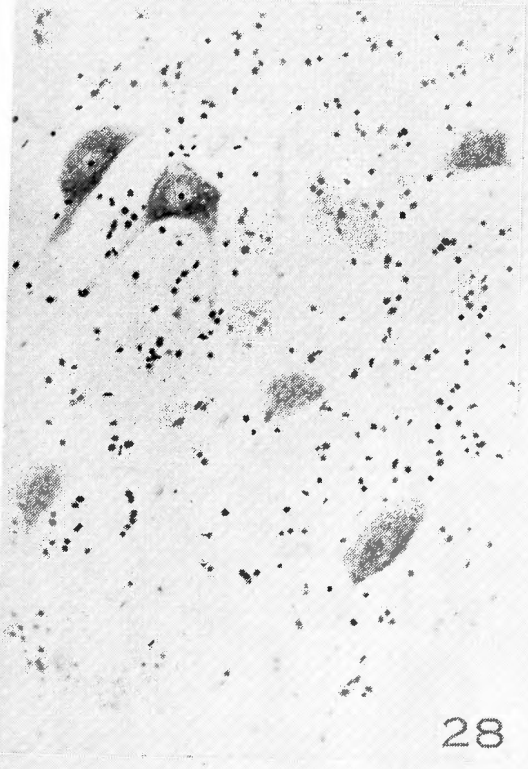

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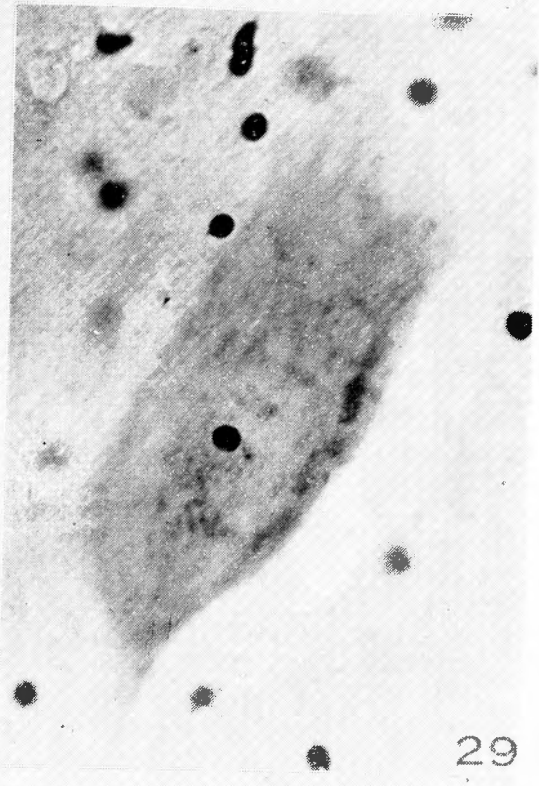

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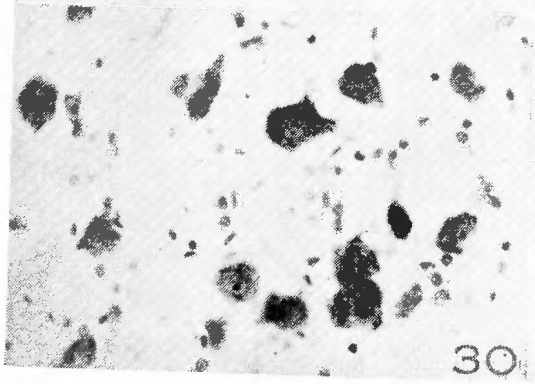

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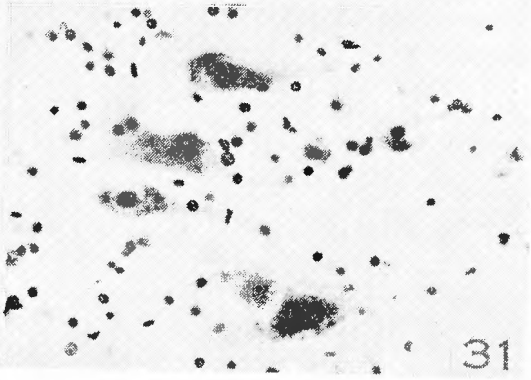

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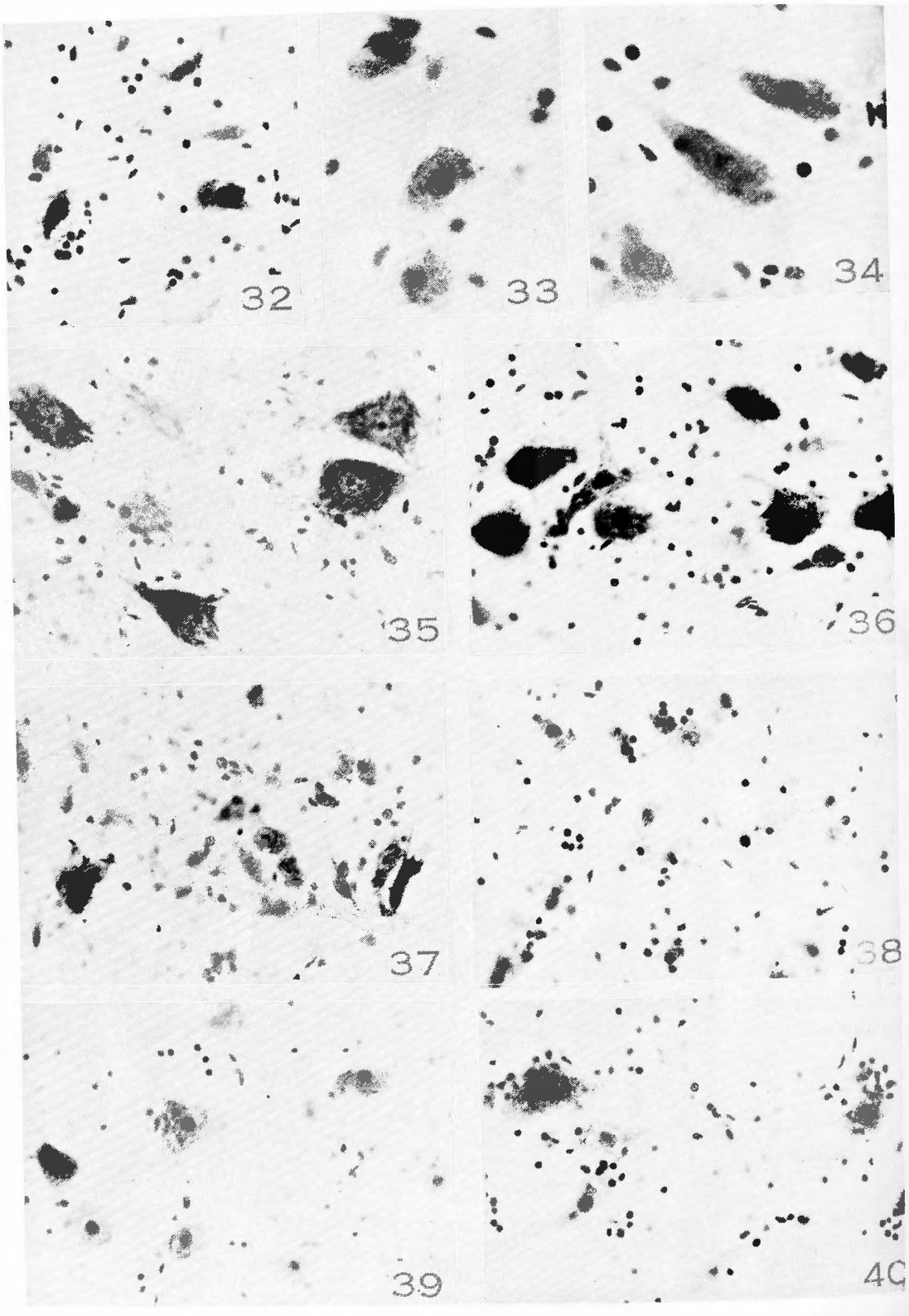

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