On the histology and function of the mammalian superior cervical ganglion / by W. Hale White.

Superior Cervical
ganglia.

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ON THE HISTOLOGY AND FUNCTION OF THE MAMMALIAN SUPERIOR CERVICAL GANGLION.

By W. HALE WHITE, M.D. Pl. III.

In a paper published in the *Transactions of the Royal Medico-Chirurgical Society*, Vol. LXVIII., I showed that the variations of the human superior cervical ganglion were very great, and bore no relation to the cause of death.

These variations were:—**1.** In size. **2.** In the condition of the nerve cells. **3.** In the amount and character of the connective tissue. **4.** In the proportion of the nerve cells to the other parts of the ganglion. **5.** In vascularity. The last two depend so considerably upon the point at which the section is taken, that as a rule it is difficult to say much about them; but the other three variations are so great and so almost without parallel in any other organs of the body, that I have tried to account for them by the examination of the sympathetic ganglia of human fœtuses and of the lower animals. For the sake of uniformity of comparison the superior cervical ganglion has been chosen, and in every case the account of the appearances of the ganglion has been written without my knowing either the cause of death, or the animal from which the specimen was taken. These points have been found out, and added to the description after it was written. All the specimens were prepared in precisely the same way. They were hardened in chromic acid and alcohol, imbedded in gum, cut with a freezing microtome, stained in log-wood, and mounted in Canada balsam.

In the first place as regards size. Out of forty-one adult human superior cervical ganglia examined, the largest had a diameter of 11·5 millimeters, the smallest had but a diameter of 4·75 millimeters. Among the forty-six lower animals examined no ganglion was quite so large as the largest human one, but some were smaller than the smallest, so that in the series of forty-six animals, ranging in size from very large ones as the horse, to very small ones as the bat, the variation in size of

the ganglion was about the same as in the single species man. The semilunar and other ganglia in man are equally variable. With the lower animals, the size of the superior cervical ganglion most undoubtedly varies directly as the size of the animal. Thus the larger ganglia, among the animals examined, came from the hyæna, the horse, the chacma baboon and the dog, whilst the smaller were taken from the bat, the ichneumon, the opossum, the dasyure, the coati, the rat, and the fennec fox.

In the second place let us examine the nerve cells. For convenience of description the nerve cells of sympathetic ganglia may be divided into three groups, but many intermediate forms are to be found. *Group* 1. The cells have tapering processes, they are deeply stained by logwood, and lie in the centre of their capsular space, their margins are sharply defined; the nucleus is visible but does not contrast very strongly with the rest of the cell. *Group* 2. The cells completely fill the capsules, they have no processes, they are moderately stained by logwood, their margins are not so well defined as in group 1; sometimes the nucleus is visible, sometimes it is not. *Group* 3. The cells completely fill their capsules, they have no processes, they are faintly stained by logwood, but the nucleus is deeply stained, and has a clear space around it; many nucleoli may be seen. All three groups are found both in man and the lower animals; it is exceptional to find that all the cells of any ganglion belong entirely to the same group. The cells of the first group are as a rule much smaller than those of the other two.

All observers have noticed the peculiar granular pigmented appearance so common in the cells of the human sympathetic ganglia; it does not appear to have attracted much attention from those who have examined ganglia of the lower animals. It has already been described by myself and others, so that here one need only say that it affects all three groups of cells. In its extreme degree the cell is reduced to a minute mass of granular brilliant yellow pigment in the centre of its capsular space; sometimes it is present only in part of the cell; the nucleus is the last part to be altered; the cell may maintain its normal size and all degrees between this and a minute granular mass may be seen; the cell is often granular without any pigmentation, and sometimes the outline of the cell is vague and ill defined and in other specimens it is sharply defined. The brilliant yellow colour of the pigmentation is strongly suggestive that it is directly derived from the blood, and should the researches of Adamkiewicz[1] on the blood supply of the ganglion

[1] *Der Blutkreislauf der Ganglienkelle.* Berlin, 1886.

cells be confirmed, they will explain the yellow colour of the pigmentation. This granular pigmentary change certainly cannot be due to alteration after death, for many of the sections prepared from ganglia of the lower animals and some of the sections prepared from human ganglia showed little or none of it, whilst others prepared in a precisely similar way showed it in abundance.

Reference to the appended list of human superior cervical ganglia shows that the only ones which can be said to be but moderately affected are numbers 4, 5, 13, 14, 15, 17, 36. Forty-one ganglia are described, so that 83 per cent. of human superior cervical ganglia may be said to possess considerably degenerate cells, and even the remaining 17 per cent. are not entirely free from degeneration. This is a result so astounding that it might be thought that the condition here described as degenerative is really normal for sympathetic cells, but that cannot be, for it is impossible to conceive that the minute masses of pigmented granular matter can be normal nerve cells; all stages may be seen between what I have already described as the normal types of sympathetic ganglion cells and these granular masses; and, lastly, many lower animals and human fœtuses have cells corresponding to the usual type of nerve cells. Other observers, who have examined a large number of human sympathetic ganglia are agreed as to the frequency of this change, for example, Giovanni[1] shows how common pigment granules are. His tables, and mine also demonstrate that this degenerate condition bears no relation to the cause of death. We seem therefore forced to the conclusion, that although the nerve cells cannot be called normal, nevertheless it must be allowed that the normal human superior cervical ganglion contains large numbers of cells in all stages of pigmentary granular degeneration.

In order to see whether this condition is frequent in the lower animals I have examined the superior cervical ganglion from 46 mammals. I have not extended my researches to cold-blooded animals, for Gaskell[2] says "The evidence then strongly points to the conclusion that in those cold-blooded animals, which possess a cervical sympathetic of the same nature as that found in mammalia, no superior cervical ganglion exists." In the table at the end of this paper the animals are roughly grouped according to their position in the class Mammalia.

Among the ten old-world apes examined, four, namely the vervet

[1] *Patologia del Simpatico*, p. 117 et seq.

[2] "On the structure and function of visceral nerves." This *Journal*, Jan. 1886, p. 55.

monkey, the malbruck monkey, the rhesus monkey (two specimens) presented much degeneration of the nerve cells.

In the case of the rhesus monkeys this was very striking, for with each, on looking at the sections, I wrote down that they more nearly resembled the human type than any I had previously seen. This was done without knowing at all from what animals they were taken.

I have only looked at one new-world monkey, viz. the squirrel monkey; it will be noticed that the cells are degenerate looking, slightly granular, ill formed and non-nucleated.

There is nothing much to be said for or against the cells of the bat.

Twenty-two Carnivora have been examined. Among them there are none that show anything like sufficient granular change to enable one to say they resemble the usual human type. The sections with the most degenerate cells were taken from the ocelot and the raccoon-like dog, but in neither of these is there any pigmentation, and the granular change is but slight. A few others show an occasional degenerate cell, but certainly not so often as one finds such cells even in the human central nervous system.

Eight Ungulates have been looked at; with the exception of a trace of a granular appearance in the cells of the naked-eared deer and the axis deer, none of the animals show anything but normal healthy-looking nerve cells.

Two Rodents and two Marsupials have been examined, and in all the cells were normal.

Thus we see that man presents by far the largest proportion of granular, pigmented, degenerate looking, sympathetic nerve cells; next come the monkeys; the carnivora show a very small proportion, the ungulates hardly any, and the animals lower in the scale none at all. Also in those classes in which the proportion of degenerate cells is highest the absolute amount of degeneration is greatest.

Taking next the third point. I propose to consider the amount and character of the interstitial tissue; we may say at once that it is not of much value, for by far the greater amount of the connective tissue has to support the blood vessels, and the size of the blood vessels seen in any section depends upon the point at which it is taken. The usual vascular arrangement is for a vessel to enter somewhere at the side of the ganglion, and then after having reached its axis to run vertically in this, sending off branches peripherally which anastomose with minute offsets of vessels, which enter from the fibrous sheath of the ganglion and converge towards the centre of it. But this, the more frequent

arrangement, is subject to many variations. It will thus be evident that if the section happen to be made at the point at which the main vessel enters much fibrous tissue will be seen. Sometimes the fibrous capsule around the ganglion is very thick; it appears to be thicker the smaller the ganglion; often it contains so much elastic fibre that it contracts into a wavy band like the elastic part of the inner coat of an artery. Axman long ago drew attention[1] to the thickness of the capsule in some animals.

In many sections one sees the interstitial tissue crowded with bodies darkly stained with logwood. Some of these no doubt are axis cylinders, some are the nuclei of the fibrous tissue, but by far the greater number are small cells quite indistinguishable from white blood corpuscles or lymph corpuscles, in fact Giovanni[2] and Foa[3] call them leucocytes. In calling them by this name I do not wish to imply that it is definitely proved that they are all leucocytes, but it probably is so, for I have seen them passing from the interior of a blood vessel; I have seen them between the ganglion cell and its capsule, which interval is asserted by Adamkiewicz[4] to be a lymphatic space continuous with the perivascular space of the vessel supplying the cell; they are indistinguishable from leucocytes, indeed some observers, as just mentioned, regard them as such; and lastly I have twice observed in the semilunar ganglion taken from children masses of lymphoid tissue in the substance of the ganglion. Sometimes these leucocytes are so numerous as quite to obscure the structure of the ganglion. I had hoped to find some decided difference between men and animals with regard to the amount of this infiltration with leucocytes, but am sorry to say I have not found any. I showed some cases of diabetes at the Pathological Society[5] in which it was more marked than in any specimen I have examined, and said I thought it might have a real relation to some cases of diabetes; but in further researches I have found the same infiltration with leucocytes, although not so extreme, in other human specimens (especially those from cases of purpura haemorrhagica) and in those taken from Mammalia generally. Whether when in excess it is to be regarded as evidence of inflammation is doubtful, perhaps it bears some relation to diabetes, purpura and

[1] *Beiträge zur Mikroskopischen Anatomie und Physiologie des Ganglien-Nervensystems des menschen und der Wirbelthiere;* von Carl Axman. Berlin, 1853.

[2] *Op. cit.*

[3] *Rivista Clinica di Bologna*, 1874, p. 206.

[4] *Op. cit.*

[5] *Path. Trans.* Vol. 36.

other obscure diseases which may have caused death in those animals in which it was found. There is no connection whatever between the amount of it and the degree of degeneration of the nerve cells.

I have examined the superior cervical ganglion of ten human fœtuses. Types of all varieties of nerve cells were present, but although they were often very small, apparently because they had not yet fully grown, none were degenerate or pigmented.

From an examination then of 41 adult human superior cervical ganglia, 46 other mammalian and 10 human fœtal similar ganglia—which means the examination of about a thousand sections, for a large number of sections of each ganglion were made—I believe myself justified in the following conclusions.

Firstly:—that human adult ganglia vary as much in size as do the largest and smallest of other mammals, and that the size of the ganglion in other mammals varies directly as the size of the animal.

Secondly:—that human superior cervical ganglia present granular pigmented atrophic cells much more frequently than other mammals; that this condition, though present to some degree in monkeys, diminishes regularly as we descend lower in the mammalian scale, till at last it is not seen at all.

Thirdly:—that human fœtal ganglia do not show any of these changes in their nerve cells. Here I may mention that the only child whose cervical ganglia I examined also showed healthy cells.

These facts seem to show that the superior cervical ganglion is becoming less and less functionally important the higher we ascend in the animal scale, till in the human adult its minimum of importance is reached. It is in fact an atrophied degenerate organ, like the coccyx or the appendix cæci. So that although I do not pretend to have discovered whatever function the superior cervical ganglion may have in lower Mammalia, it is probable that it is dying out in us.

From a large number of examinations of human semilunar ganglia, I very much suspect that the same is true of it also, and perhaps even of the sympathetic system generally, judging by a few preparations I have made of other ganglia.

It may be that as the cerebro-spinal system increases in importance so the sympathetic diminishes. I would not however put this forward as more than a speculation, except for the superior cervical ganglion.

I know well that pigmented granular cells are often found in the human central nervous system, especially in sections passing through the aqueduct of Sylvius, but they are but rarely atrophic, not many in

number, and may for all we know belong to functions which are dying out.

There are many shortcomings in this paper. I hope to work still further at the subject and so make up for some of them.

In the following tables the word cell always applies to the nerve cells; the word leucocyte is used as explained previously. When any part is not described it may be taken as typically normal.

Human Superior Cervical Ganglia.

The name of the disease from which the patient died is prefixed to each description.

1. Idiopathic Anæmia of Addison.
   Cells irregular in shape, vague, granular, pigmented, many are very small, those not pigmented have stained badly. Large amount of fibrous tissue.

2. Cancer of the Bladder.
   Cells very small, much pigmented. Increased amount of fibrous tissue.

3. Abdominal Aneurysm.
   Cells much degenerated, so that there is not a normal one to be seen, none have stained well, all are reduced to a non-nucleated minute yellowish granular mass. Large amount of fibrous tissue.

4. Phthisis.
   Cells well formed and nucleated with but little pigmentary degeneration.

5. Phthisis.
   Cells for the most part well formed, but many are granular, degenerate looking, but not pigmented.

6. Chronic Bright's Disease.
   Cells mostly small, many pigmented and degenerate, the nucleus being always unaffected.

7. Amputation of Thigh. Bronchopneumonia.
   Cells, some few are normal, but most are pigmented and degenerate, the most extreme being mere dots of pigment. Large amount of fibrous tissue.

8. Purpura Haemorrhagica.
   Some cells normal, others in all stages of pigmentary degeneration. Large amount of fibrous tissue.

9. Atheroma, gangrene of foot.
   Cells extremely pigmented, many are very small. Large amount of fibrous tissue.

10. Cancer of Oesophagus.
    Cells partly normal, but mostly pigmented and shrunken.

11. Growth in the Bladder.
    Cells mostly shrunken and pigmented. Slight excess of leucocytes.

12. Abdominal Aneurysm.
    Cells pigmented and shrunken.

13. Rupture of Intestine.
    Cells mostly normal, a few pigmented. Slight excess of leucocytes.

14. Myxœdema.
    A few pigmented cells, more or less degenerate, with granular contents and no distinct nucleus. Slight excess of leucocytes.

15. Myxœdema.
    The other ganglion from the same case as 14. The same description applies.

16. Chronic Bright's Disease.
    Some of the cells indistinct with pigmentary degeneration.

17. Diphtheria (child).
    Cells normal. Many leucocytes.

18. General Malignant Disease.
    Extreme pigmentary degeneration of cells.

19. General Malignant Disease.
    Cells very small, atrophied, not much pigmentary degeneration.

20. Cardiac Disease.
    Much pigmentary degeneration of cells.

21. Chronic Bright's Disease.
    Cells more degenerate and pigmented than any others examined. Very large amount of fibrous tissue. A few leucocytes.

22. Chronic Bright's Disease.
    Cells much pigmented.

23. Chronic Bright's Disease.
Cells much degenerated.

24. Chronic Bright's Disease.
Cells vague, much pigmentary degeneration. Many leucocytes.

25. Cerebral Hæmorrhage.
Cells extremely small, degenerate. Many leucocytes.

26. Cerebral Hæmorrhage.
Opposite cervical ganglion to 25. There are not so many degenerate cells.

27. Purpura.
Cells very degenerate.

28. Purpura.
Opposite cervical ganglion to 27, cells the same. Considerable excess of leucocytes.

29. Diabetes.
Many cells pigmented. Excess of leucocytes.

30. Diabetes.
The opposite ganglion to 29. The same description applies except that fewer of the cells are pigmented.

31. Cancer of Bladder.
Cells nearly all much pigmented with pale yellow granules.

32. Diabetes.
Cells atrophied, pigmented, granular. Many leucocytes.

33. Diabetes.
Cells brilliantly pigmented, granular. A few leucocytes.

34. Diabetes.
Most of the cells are deeply pigmented.

35. Purpura.
Several of the cells are small and granular.

36. Purpura.
The cells are well formed, very few are degenerate.

37. Renal Suppuration.
Nearly all the cells are pigmented.

38. Disease not stated.
Many of the cells are only masses of brilliant yellow pigment. There are several leucocytes.

39. Diabetes.
    Half the number of cells are pigmented.

40. Diabetes.
    The fellow to the last. Most of the cells are pigmented and granular.

41. Disease not stated.
    Cells fairly well formed, some granular and pigmented. Shows the central arrangement of the vessels very well.

Lower Mammals.

A. Catarrhina.

1. Sooty Mangabey (Cercocelus fuliginosus).
   No degenerate cells, all fill their capsules; mostly group 3.

2. Chacma Baboon (Cynocephalus porcarius).
   No degenerate cells; mostly group 3. Several leucocytes.

3. Macque Monkey (Macacus cynomologus).
   Exactly like the last.

4. Vervet Monkey (Cercopithecus Lalandii).
   Cells not numerous, very pale, not stained, granular looking, no nuclei, very small; group 1.

5. Malbruck Monkey (Cercopithecus cynosurus).
   Cells very like the last specimen, but more obscure. Very large number of leucocytes.

6. Mona Monkey (Cercopithecus mona).
   Cells well formed; good examples of all varieties.

7. Chacma Baboon (Cynocephalus porcarius).
   Cells good examples of the first two varieties.

8. Rhesus Monkey (Macacus rhesus).
   Cells degenerate, granular, slightly pigmented, some are very small, they are mostly group 1. A few leucocytes.

9. Rhesus Monkey (Macacus rhesus).
   Another animal. Exactly like the last, save that the cells are slightly more pigmented.

10. Bonnet Monkey (Macacus sinicus).
    Cells mostly the 2nd variety; some are indistinct, but on the whole they are well formed.

B. Platyrrhina.

11. Squirrel Monkey (Chrysothrix sciurea).
Some of the cells are degenerate looking and granular, ill formed and non-nucleated; mostly group 1.

C. Chiroptera.

12. Indian Fruit Bat (Pteropus medius).
A few of the cells are ill formed, but not degenerate; group 2.

D. Carnivora.

13. Leopard (Felis pardus).
Cells well formed, good processes, one or two somewhat granular, but no pigmentation.

14. Silver-backed Fox (Canis chama).
Exactly like 13.

15. Ichneumon (Herpestes gracilis).
Cells group 2, hardly a trace of granular change. Abundance of leucocytes.

16. Spotted Hyæna (Hyæna crocuta).
Cells are typical examples of all three varieties.

17. Isabelline Lynx (Felis Isabellina).
Exactly like 16.

18. Coati (Nasna rufa).
Cells rather pale, but good examples of group 1. Abundance of leucocytes.

19. Blotched Genet (Genetta bigrina).
Cells very good, all three varieties.

20. Common Paradoxure (Paradoxurus typus).
Cells all good examples of the second group.

21. White-tailed Ichneumon (Herpestes albicanda).
Most of the cells are typical, others are not well stained and show traces of granular change with disappearance of nuclei, some are very small; chiefly groups 1 and 2.

22. Jerdon's Ichneumon (Herpestes Jerdoni).
Cells good examples of group 3.

23. Spotted Hyæna (Hyæna crocuta).
Cells good typical examples of all varieties.

24. Maccarthy's Ichneumon (Herpestes Maccarthii).
Cells good typical examples of all varieties.

25. Ocelot (Felis pardalis).
Cells small and dimly stained, some are very small and degenerate looking, but not distinctly granular or pigmented.

26. Tayra (Galictis barbara).
A few degenerate looking examples of group 1, but nearly all are normal specimens of groups 2 and 3. Abundance of leucocytes.

27. Two spotted Paradoxure (Nandinia binotata).
Cells normal.

28. Raccoon-like Dog (Canis procyonidas).
Cells all group 1; none show nucleus well, many are very small, some have dropped out, those remaining are degenerate.

29. Fennec Fox (Canis pallidus).
Cells typical examples of groups 1 and 2.

30. Common Dog (Canis vulgaris).
Cells good examples of group 2; one or two show a trace of a granular condition.

31. Common Dog (Canis vulgaris).
Perfect typical cells of first two groups.

32. Common Dog (Canis vulgaris).
Exactly like the last.

33. Common Cat (Felis cattus).
Exactly like the last.

34. Common Cat (Felis cattus).
Exactly like the last.

E. Ungulata.

35. Duyker Bok Antelope (Cephalophus mergens).
Cells good typical examples of groups 1 and 2.

36. Horse (Equus caballus).
Cells perfect examples of all varieties.

37. Thar Goat (Capra jemlaica).
Cells very good; mostly group 1.

38. Naked-eared Deer (Cariacus gynnotis).
Cells in all varieties present; some of those of group 1 have not stained well, the nuclei not being evident and there being just a trace of a granular look, but no pigmentation.

39. Axis Deer (Cervus axis).
Much the same as the last. Several leucocytes.

40. Arabian Gazelle (Gazella Arabica).
Normal examples of group 1.

41. Steen Bok Antelope (Neotragus tragulus).
Normal examples of groups 1 and 3.

42. Japanese Hog (Sus leucomystax).
Cells excellent specimens of the first two groups.

F. Rodentia.

43. Crested Porcupine (Hystrix Cristata).
Cells typical examples of groups 2 and 3.

44. Beaver Rat (Hydromys leucogaster).
Cells typical examples of groups 1 and 2.

G. Marsupialia.

45. Crab-eating Opossum (Didelphys cancrivorus).
Cells typical examples of groups 2 and 3.

46. Dasyure (Dasyurus Mangoei).
Cells typical examples of group 2.

EXPLANATION OF FIGURES (Pl. III.).

Fig. 1. Shows the granular pigmented condition of human cells.

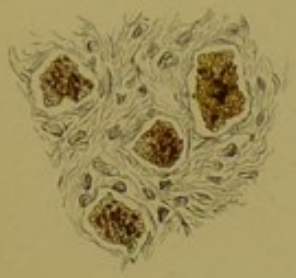
Fig. 2. Shows the granular atrophic pigmented condition of human cells.

Fig. 3. Shows the granular degenerate appearance of the cells from the rhesus monkey. In some sections the cells were even more degenerate and slightly pigmented.

Fig. 4. Shows the large, uniform, well nucleated cells from the cat.

Fig. 5. Shows the uniform well nucleated cells from the Dasyure.

All the above Sympathetic Ganglion cells are drawn to the same scale, viz. with Hartnack Oc. 3, Obj. 7.



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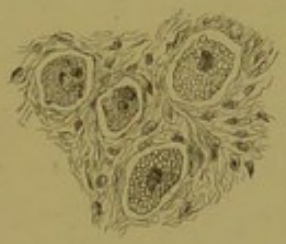

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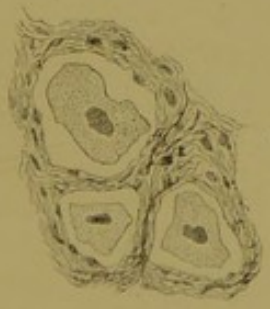

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