A1

STRUCTURE OF THE HUMAN BRAIN, SPINAL CORD AND PERIPHERAL NERVE

Microscopic Anatomy

CONTENT

INTRODUCTION

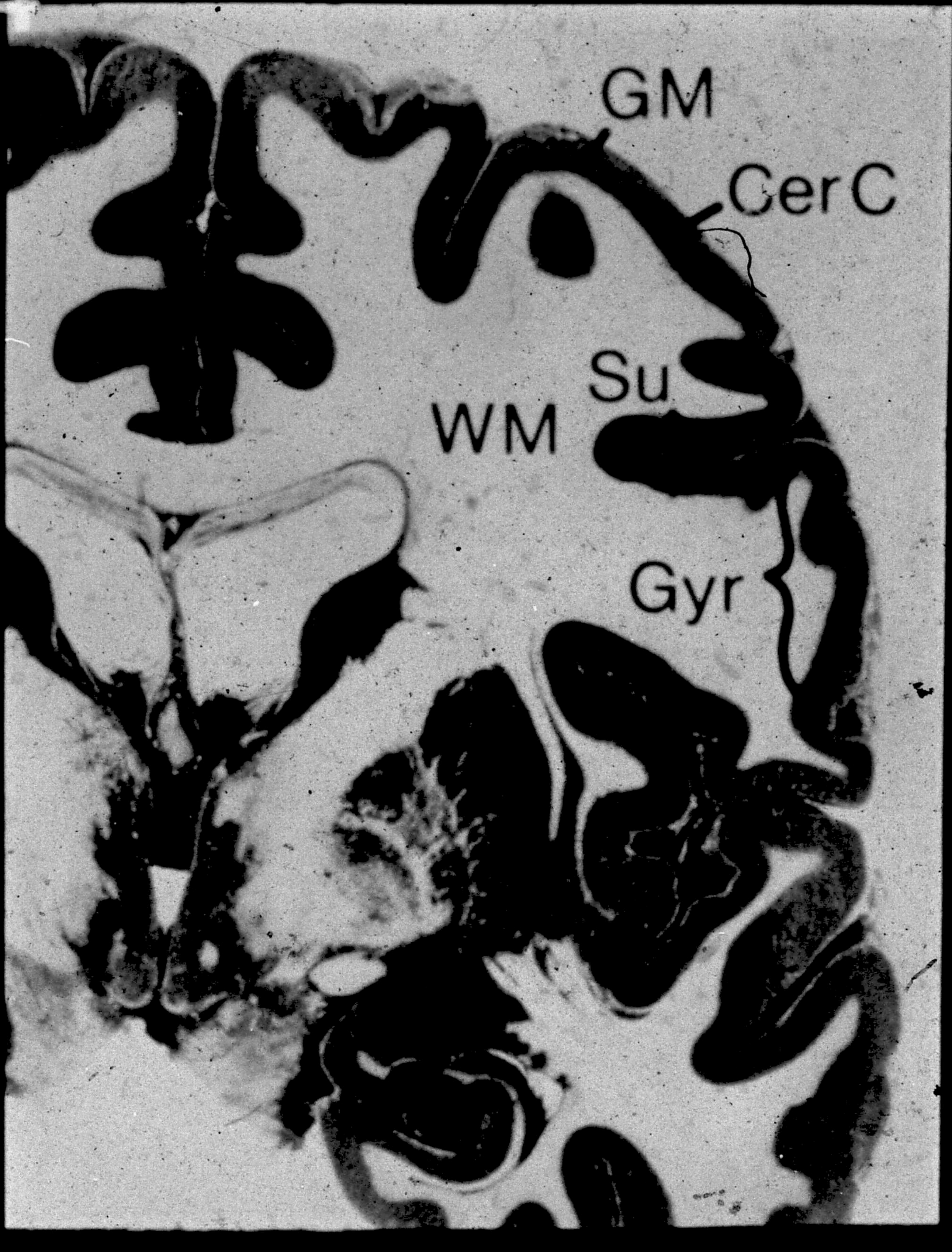
The microscopic anatomy presented in this microfiche card is an accounting of the cellular constituents found in the central and peripheral nervous system. The central nervous system (CNS) consists of the brain and spinal cord. The peripheral nervous system (PNS) consists of the cranial and spinal nerves and their associated ganglia. In order to better understand the fundamentals of the nervous system, it may be helpful to define the building blocks (cellular elements) of which it is comprised before assembling its parts.

There are two classes of cells in the CNS excluding those of blood vessels: 1) neuron and 2) neuroglia. The *neuron* is the basic functional unit of the nervous system. It consists of a cell body, its processes (dendrites, axon) and its terminal endings. The *neuroglia* are the interstitial (matrix) cells of the CNS. There are four kinds of neuroglia: *astrocytes, oligodendroglia* (sometimes referred to as macroglia), and *ependyma* all of which are derived from ectoderm; and *microglia* which is derived from mesoderm.

The CNS consists of gray and white matter. *Gray matter* houses the neuron cell bodies and an intricate meshwork of processes of neurons and neuroglia called *neuropil.* *White matter* consists of relatively long processes of neuron cell bodies, the greatest amount of which is invested in a myelin sheath (fat). Both gray and white matter share in neuroglial elements and blood vessels.

The PNS contains motor and sensory axons and their specialized peripheral endings. Both motor and sensory axons and ganglia are invested in a specialized covering of Schwann cell cytoplasm and myelin.

A4

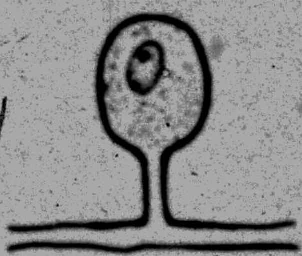


SECTION THROUGH HUMAN FOREBRAIN

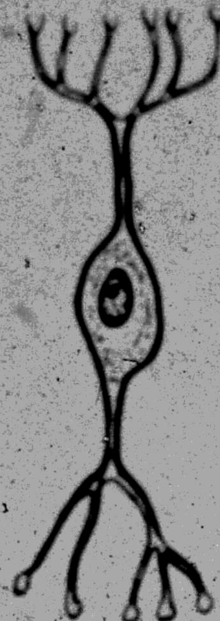
WM – White Matter Su – Sulcus
Gyr – Gyrus GM – Grey Matter
CerC – Cerebral Cortex

A5

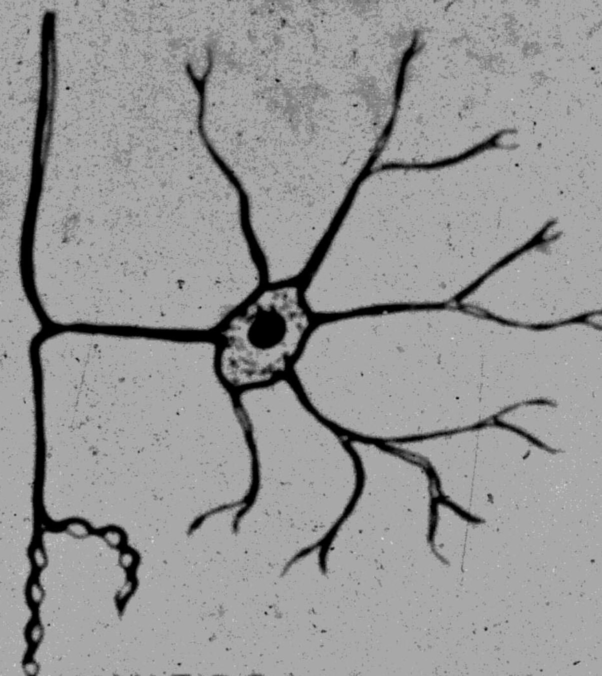
NEURON TYPES



UNIPOLAR

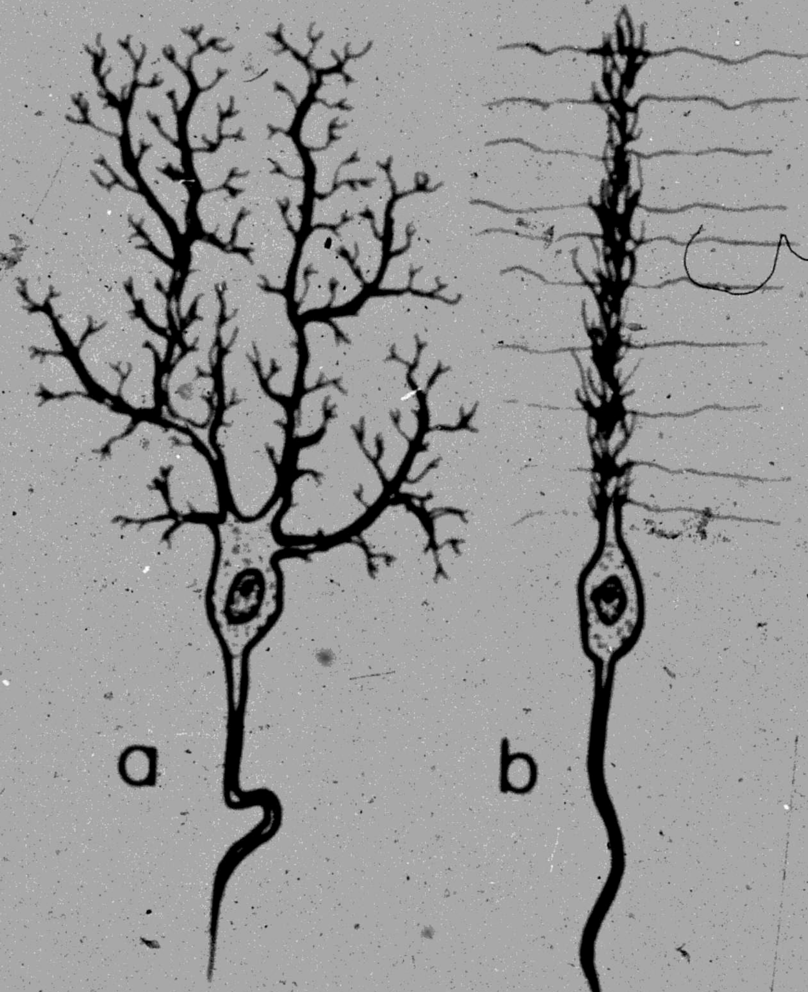


BIPOLAR



MULTIPOLAR - Stellate

MULTIPOLAR - Pyramidal

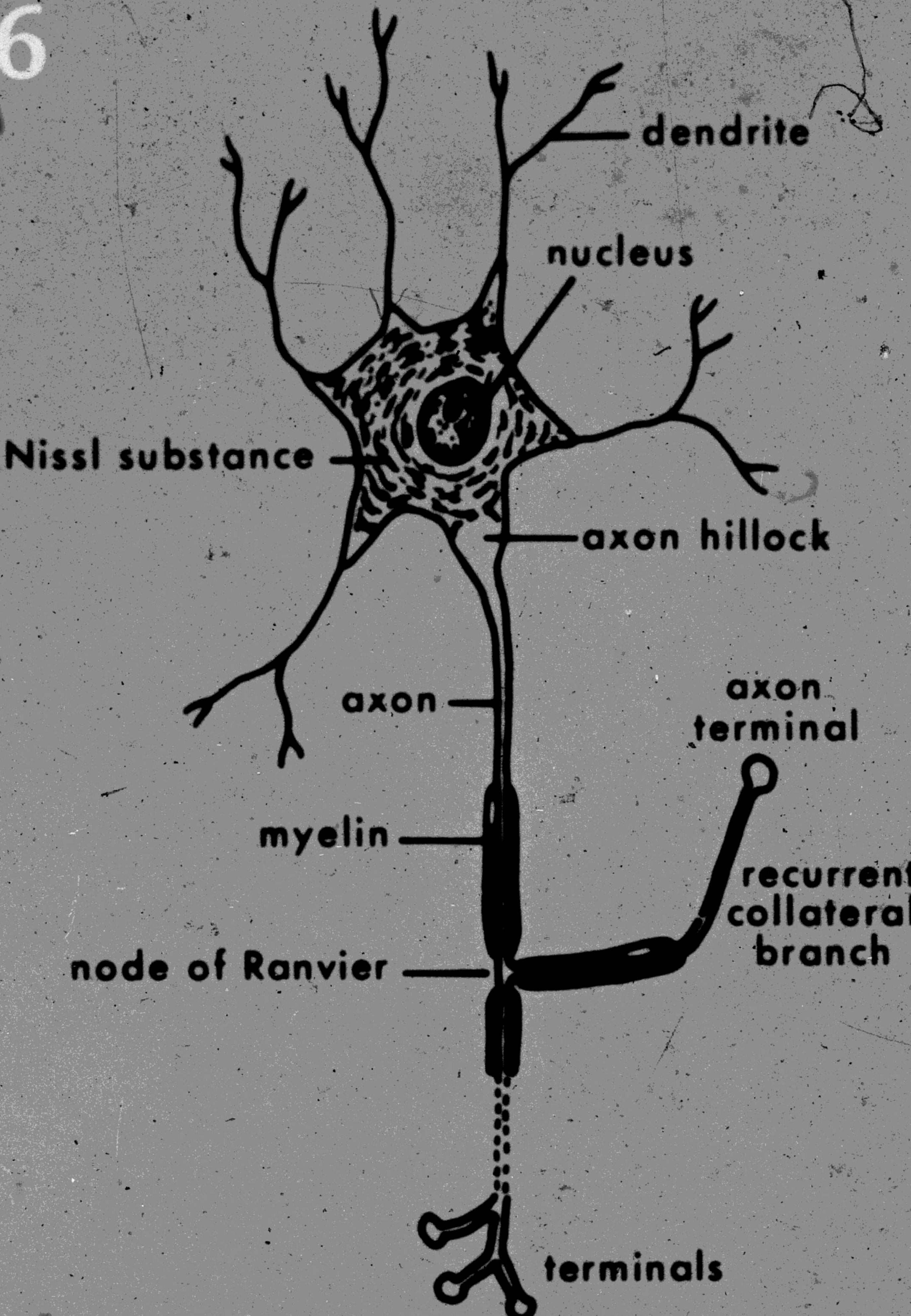


PURKINJE CELL OF CEREBELLUM

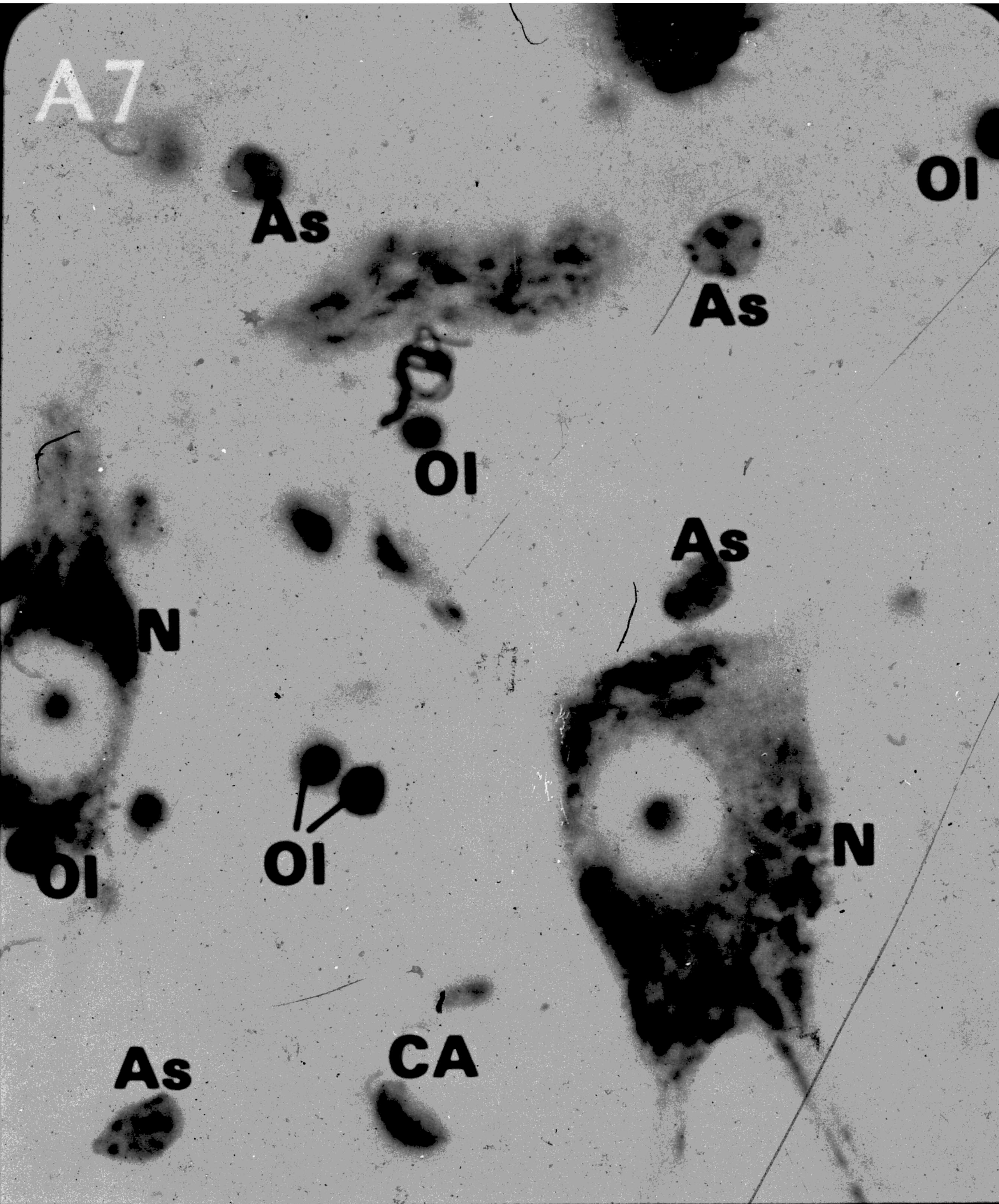
a. cut in plane perpendicular to parallel fibers

b. cut in plane of parallel fibers

A6



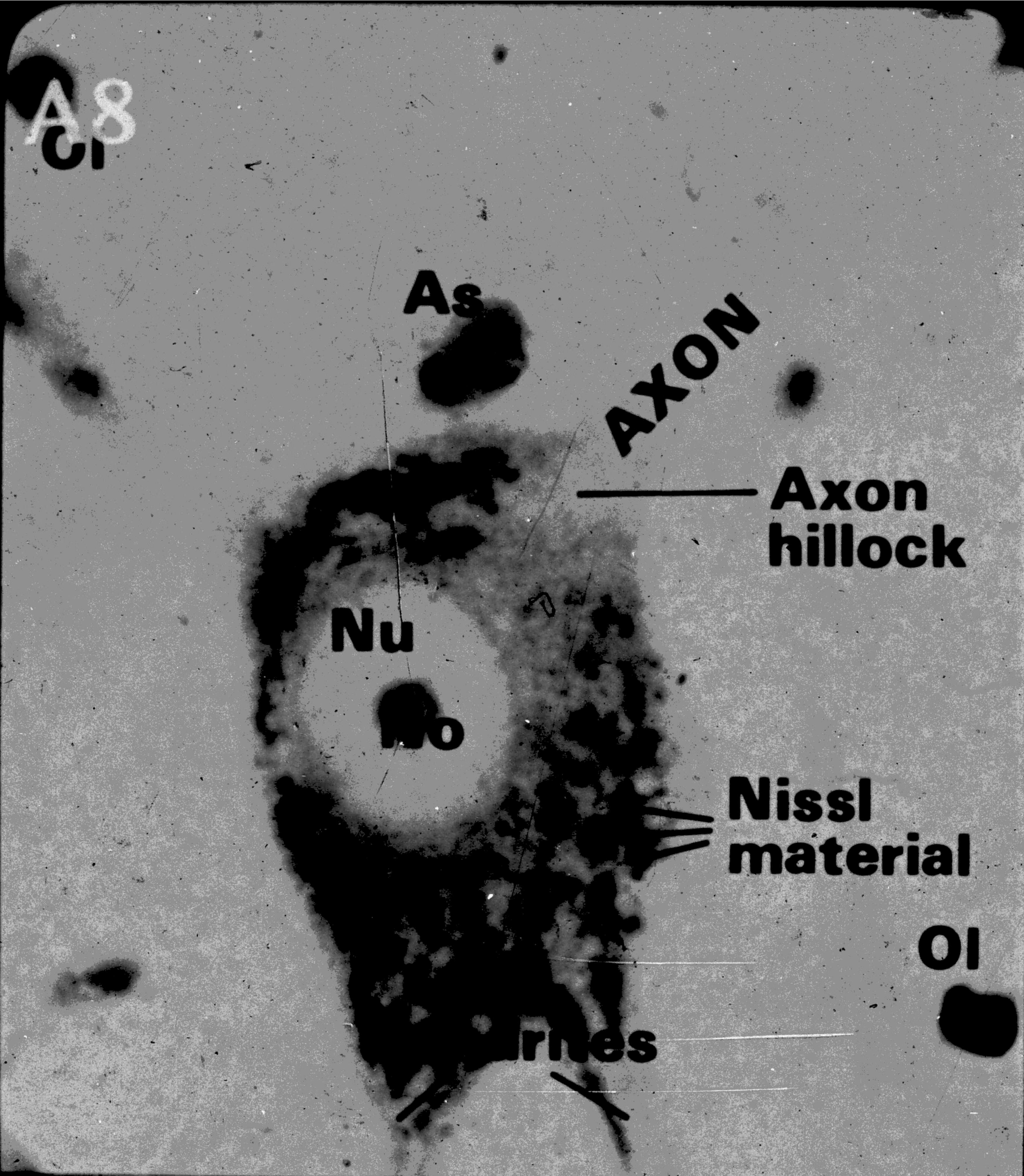
NORMAL MULTIPOLAR NEURON



NEURONS AND NEUROGLIA

SPINAL CORD

N · Neuron soma
As · Astroglia
Ol · Oligodendroglia
CA · Capillary



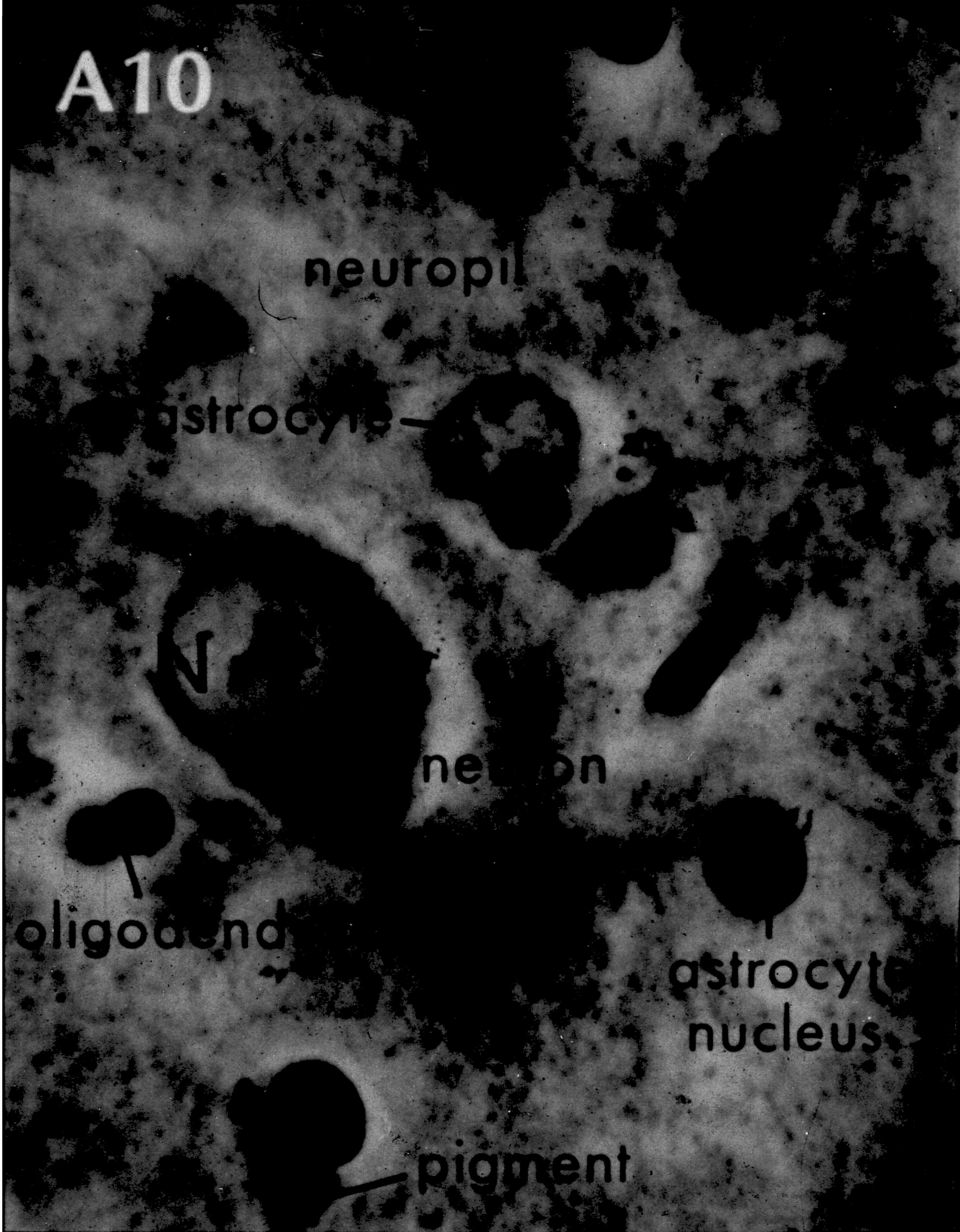
NEURON AND NEUROGLIA

SPINAL CORD

Ol · Oligodendroglia
As · Astroglia

Nu · Nucleus
No · Nucleolus

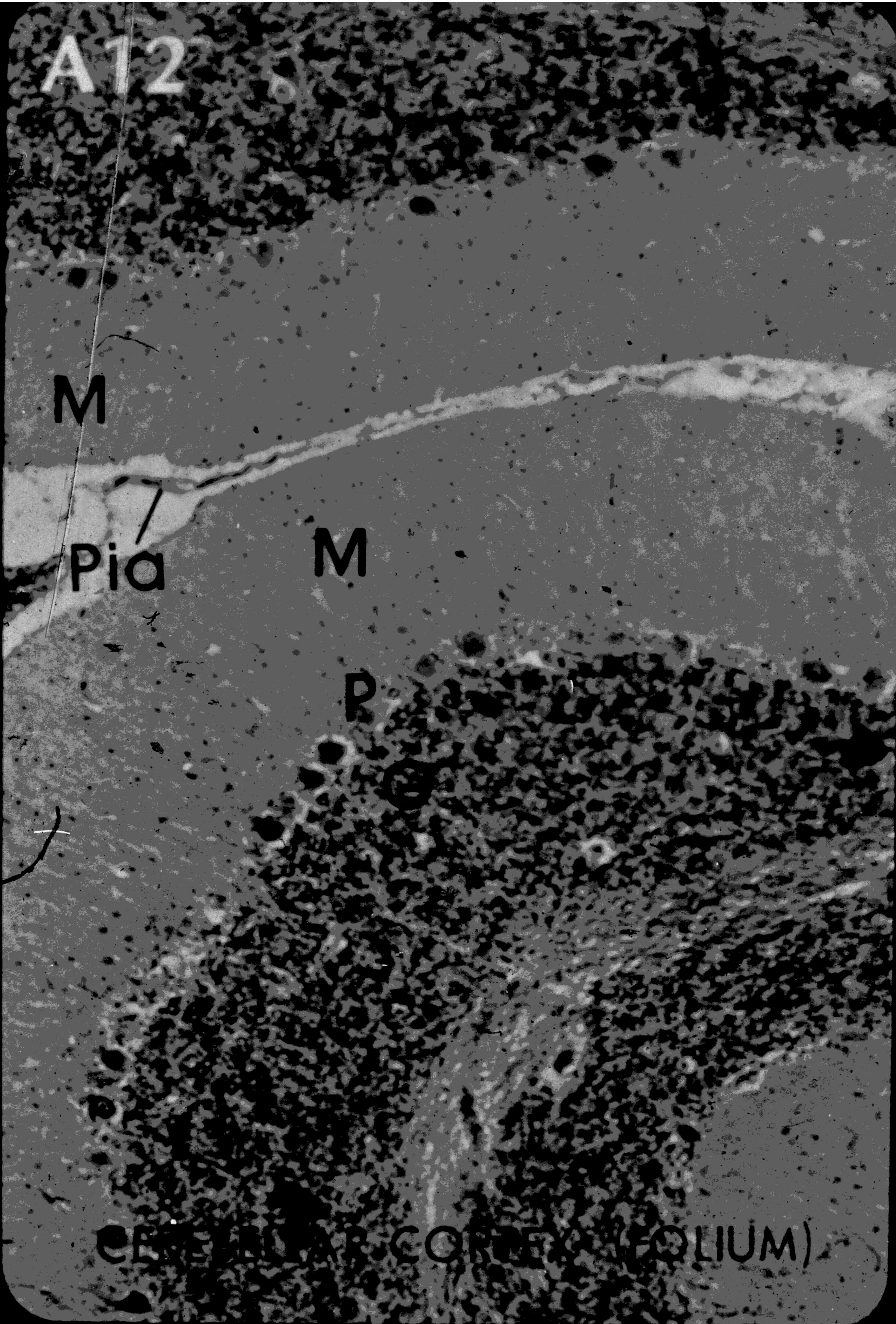
MULTIPOLAR NEURONS
(NEUROFIBRILS)

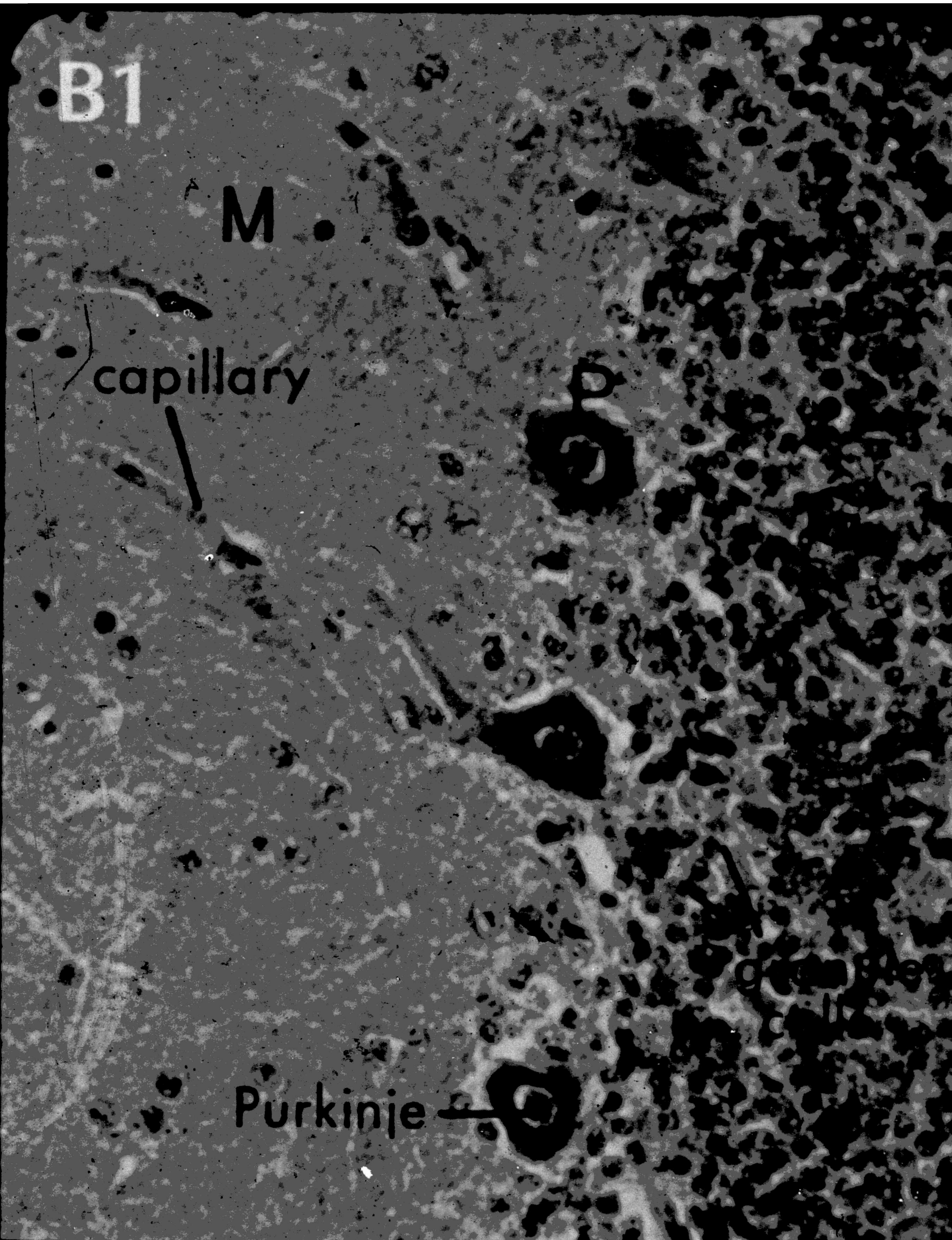


CEREBRAL CORTEX - NEURONS, NEUROGLIA AND PIGMENT

BETZ CELL, CEREBRAL CORTEX
(heavy metal method)

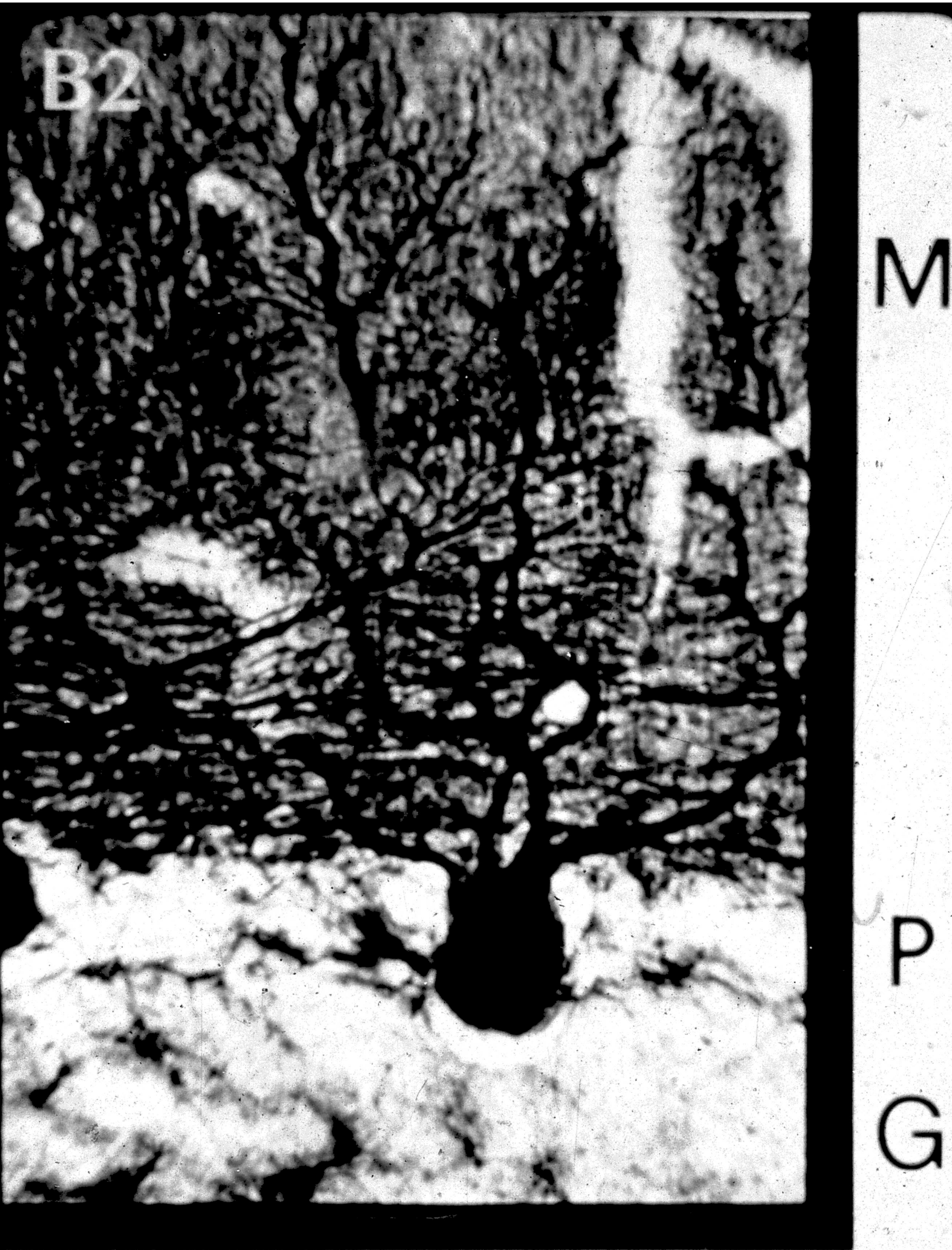
BETZ CELL, CEREBRAL CORTEX
(heavy metal method)


A12
M
Pia
M
P
CEREBELLAR CORTEX (FOLIUM)



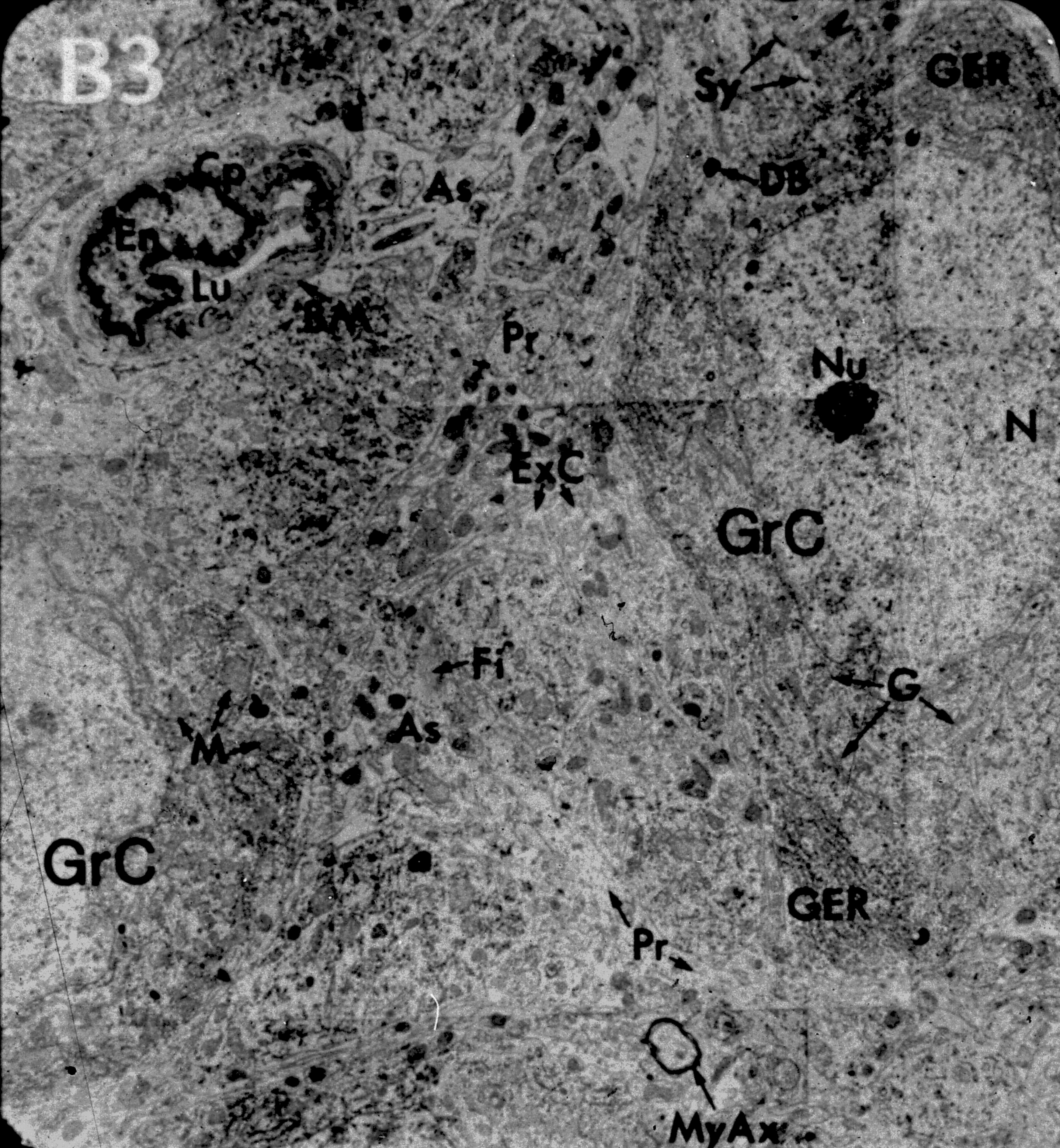
CEREBELLAR CORTEX

M = molecular P = Purkinje G = Granule cells



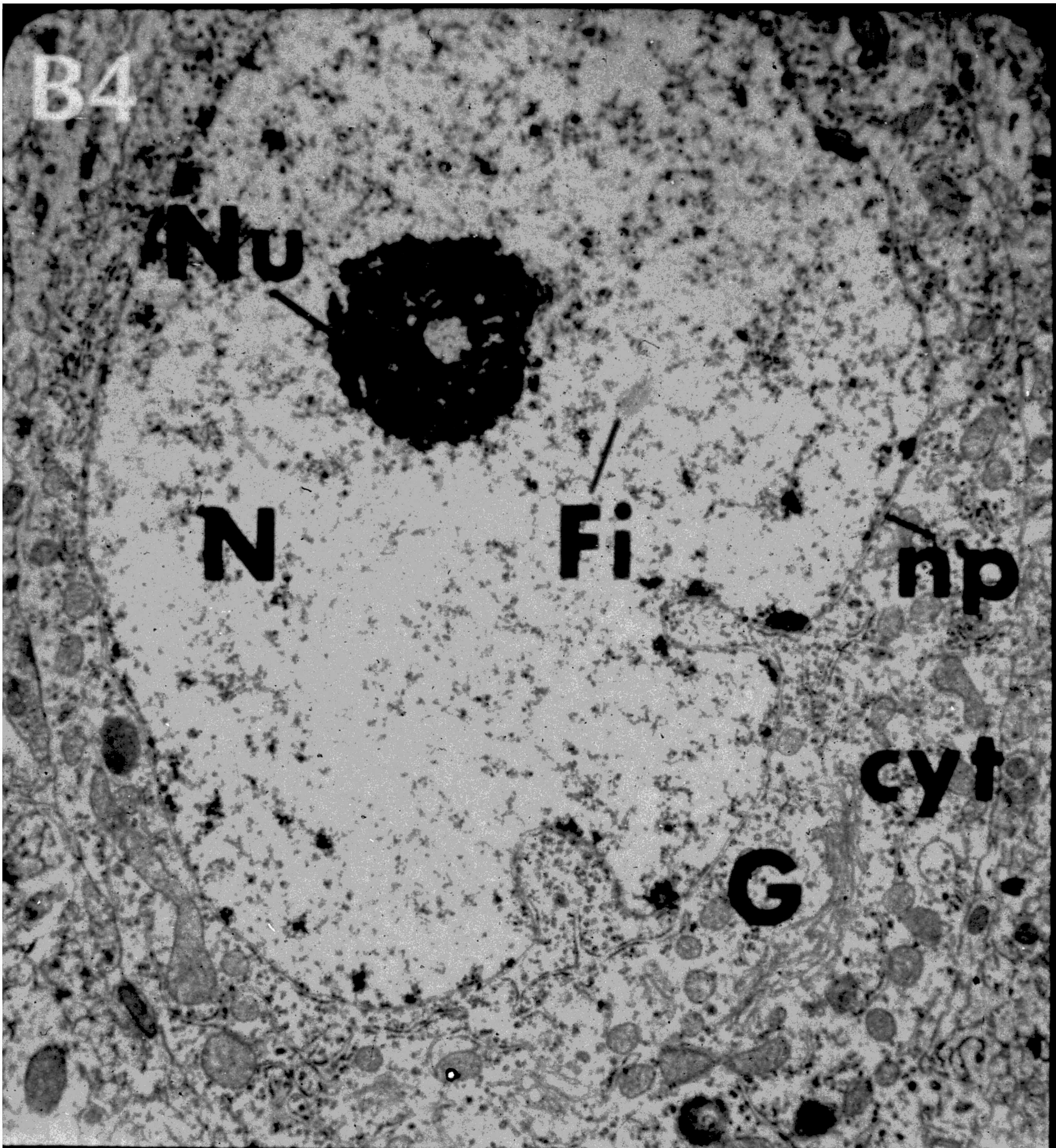
CEREBELLAR CORTEX

M - molecular layer   P - Purkinje cell layer
G - Granule cell layer



NORMAL BRAIN

As–astrocyte	ExC–extracellular	M–mitochondria
Cp–capillary	DB–dense body	GrC–granule cell
Pr–process	Fi–fibrils of astrocyte	En–endothelium
GER–granular endoplasmic reticulum		Lu–lumen
MyAx–myelinated axon	N–nucleus	Sy–synapse
BM–basement membrane	Nu–nucleolus	G–Golgi

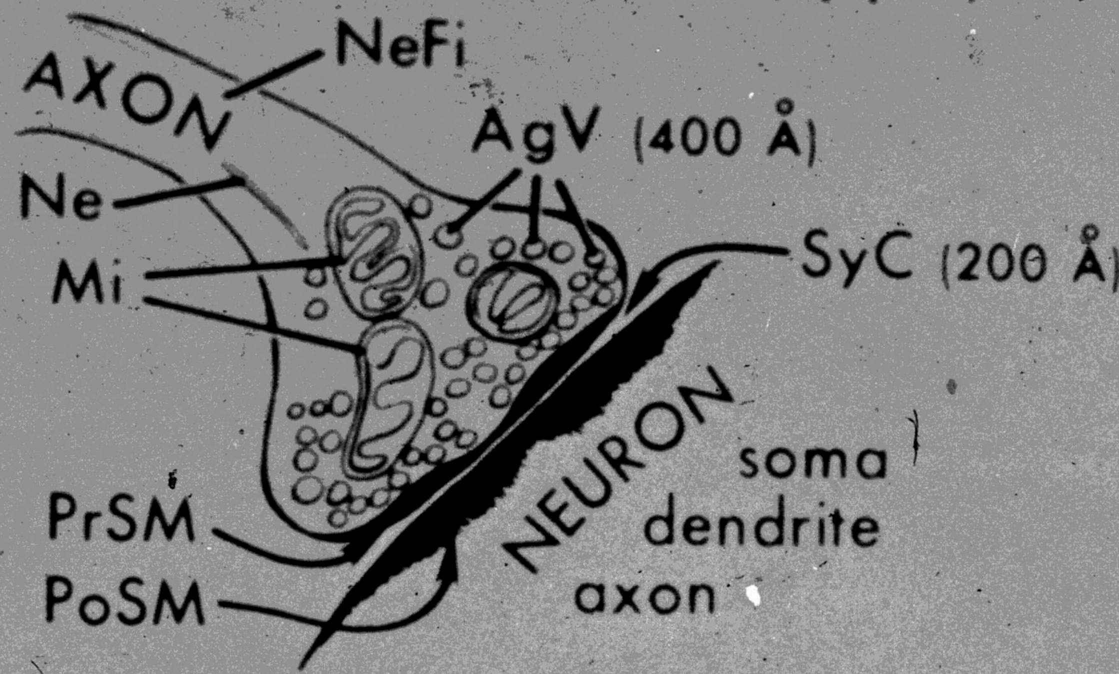


PYRAMIDAL NEURON

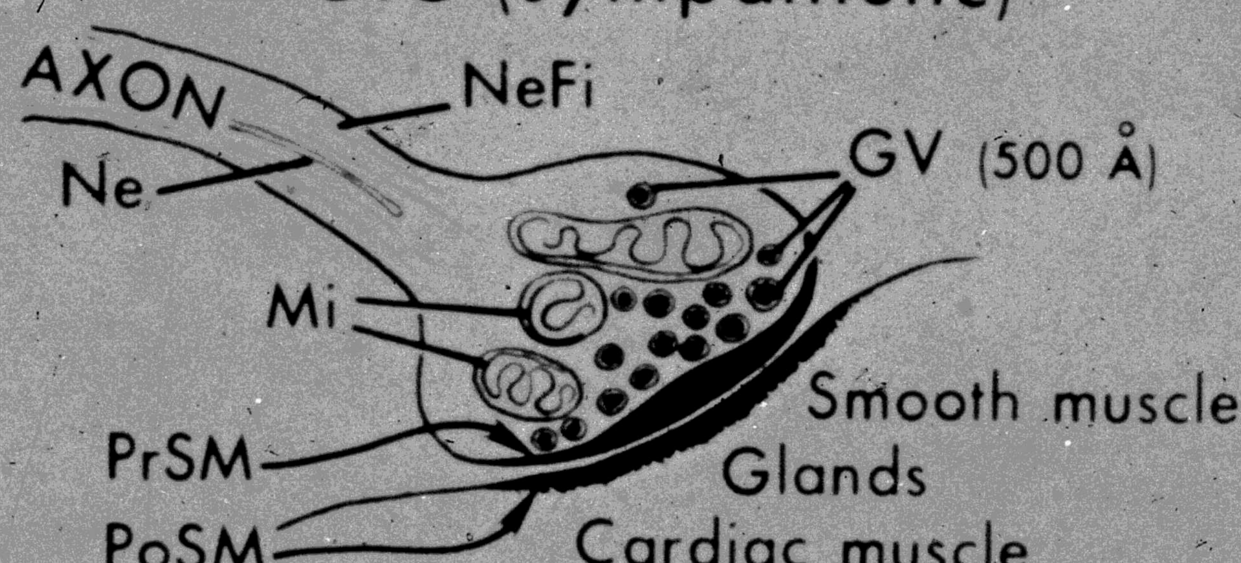
G-Golgi
Fi-fibrils
N-nucleus
np-nuclear pore
Nu-nucleolus
Cyt-cytoplasm

B5

CHOLINERGIC (type)



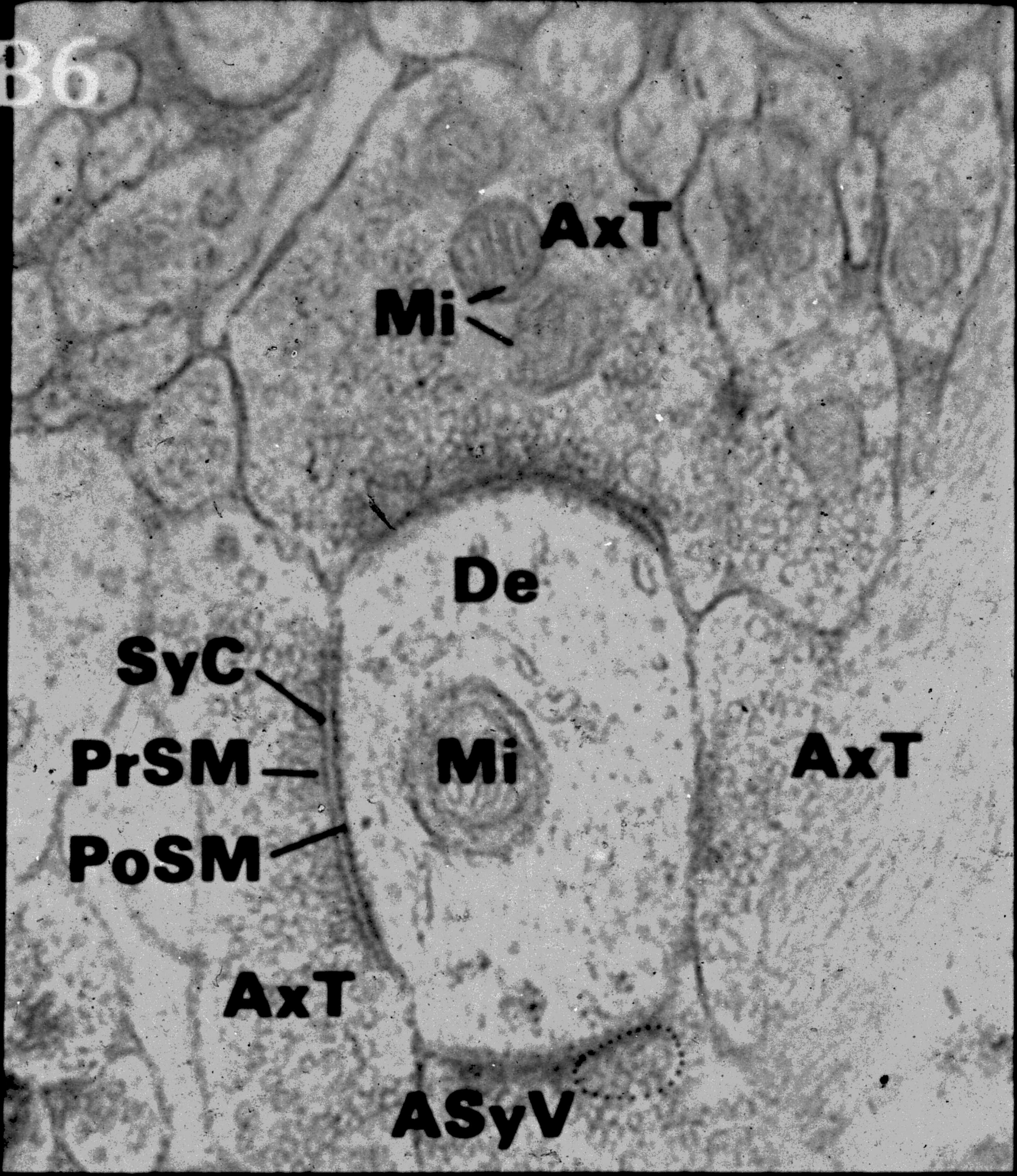
ADRENERGIC (sympathetic)



SYNAPTIC TERMINALS

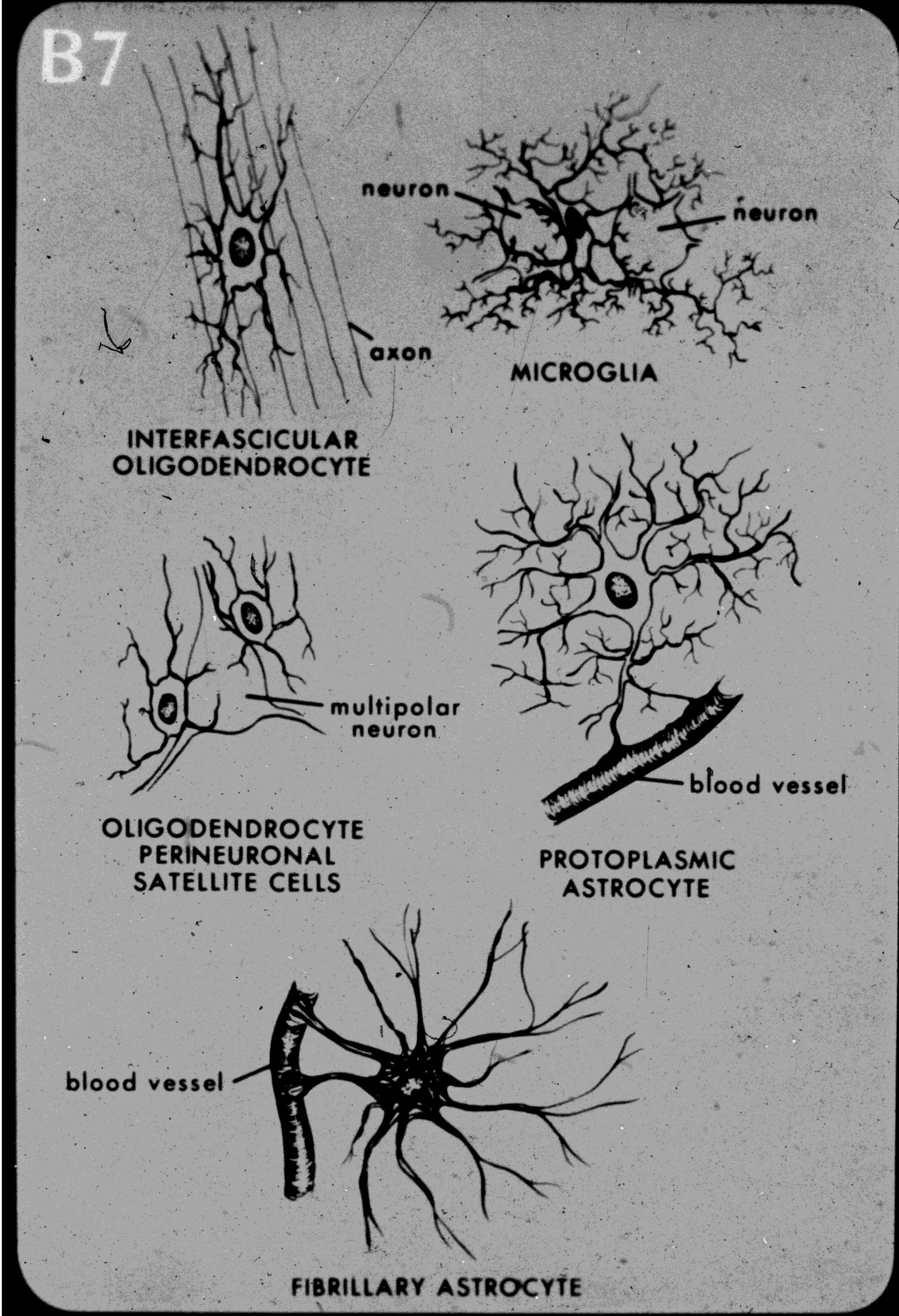
Ne · Neurotubule
NeFi · Neurofilament
Mi · Mitochondria
SyC · Synaptic cleft

GV · Granular vescicles
AgV · Agranular vescicles
PrSM · Presynaptic membrane
PoSM · Postsynaptic membrane



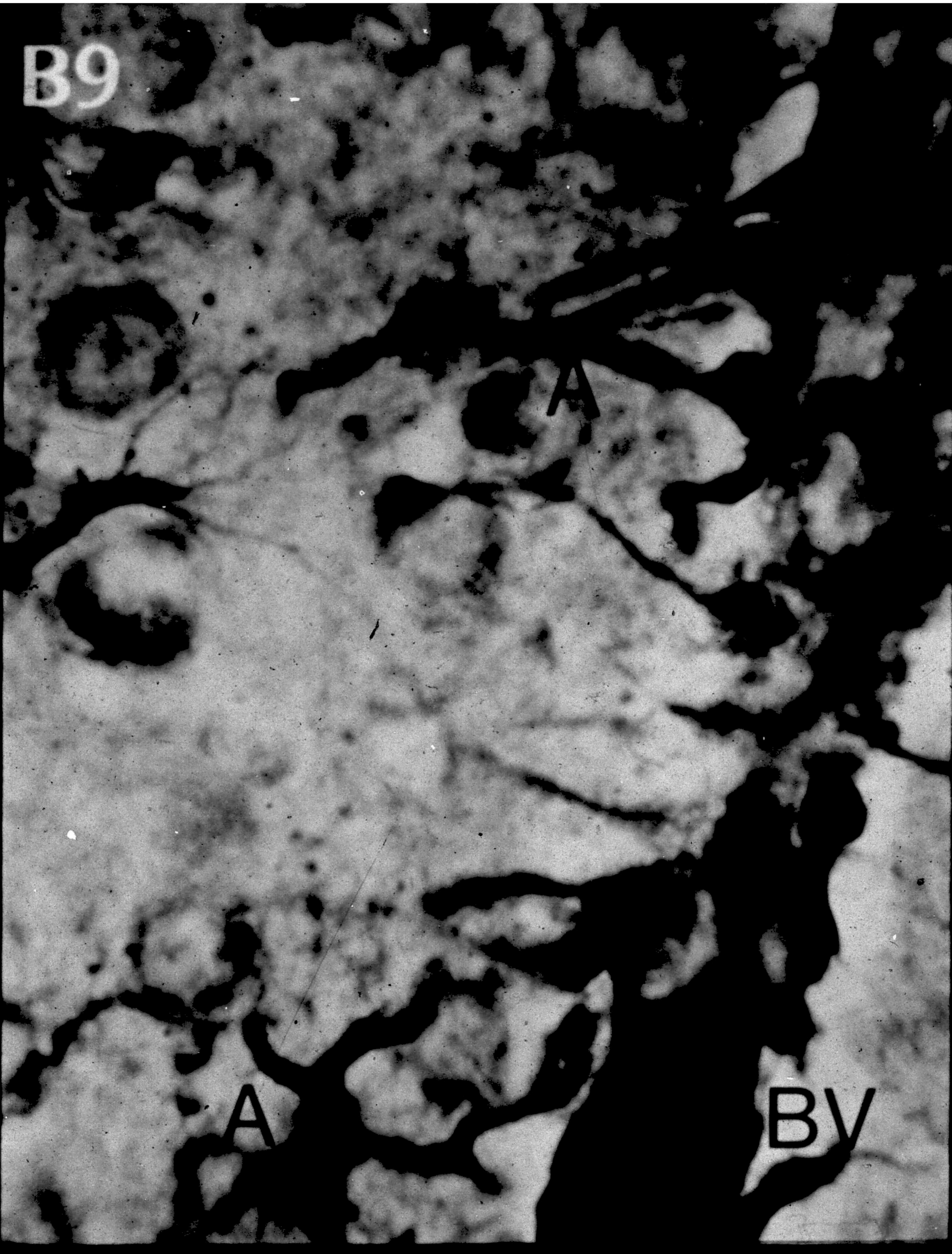
SYNAPTIC TERMINALS
AXODENDRITIC

Mi · Mitochondria
Sy C · Synaptic cleft
Pr SM · Presynaptic membrane
PoSM · Postsynaptic membrane
ASyV · Agranular synaptic vescicles
AxT · Axon terminal
De · Dendrite


B7
neuron
neuron
axon
MICROGLIA
INTERFASCICULAR
OLIGODENDROCYTE
multipolar
neuron
blood vessel
OLIGODENDROCYTE
PERINEURONAL
SATELLITE CELLS
PROTOPLASMIC
ASTROCYTE
blood vessel
FIBRILLARY ASTROCYTE

B8

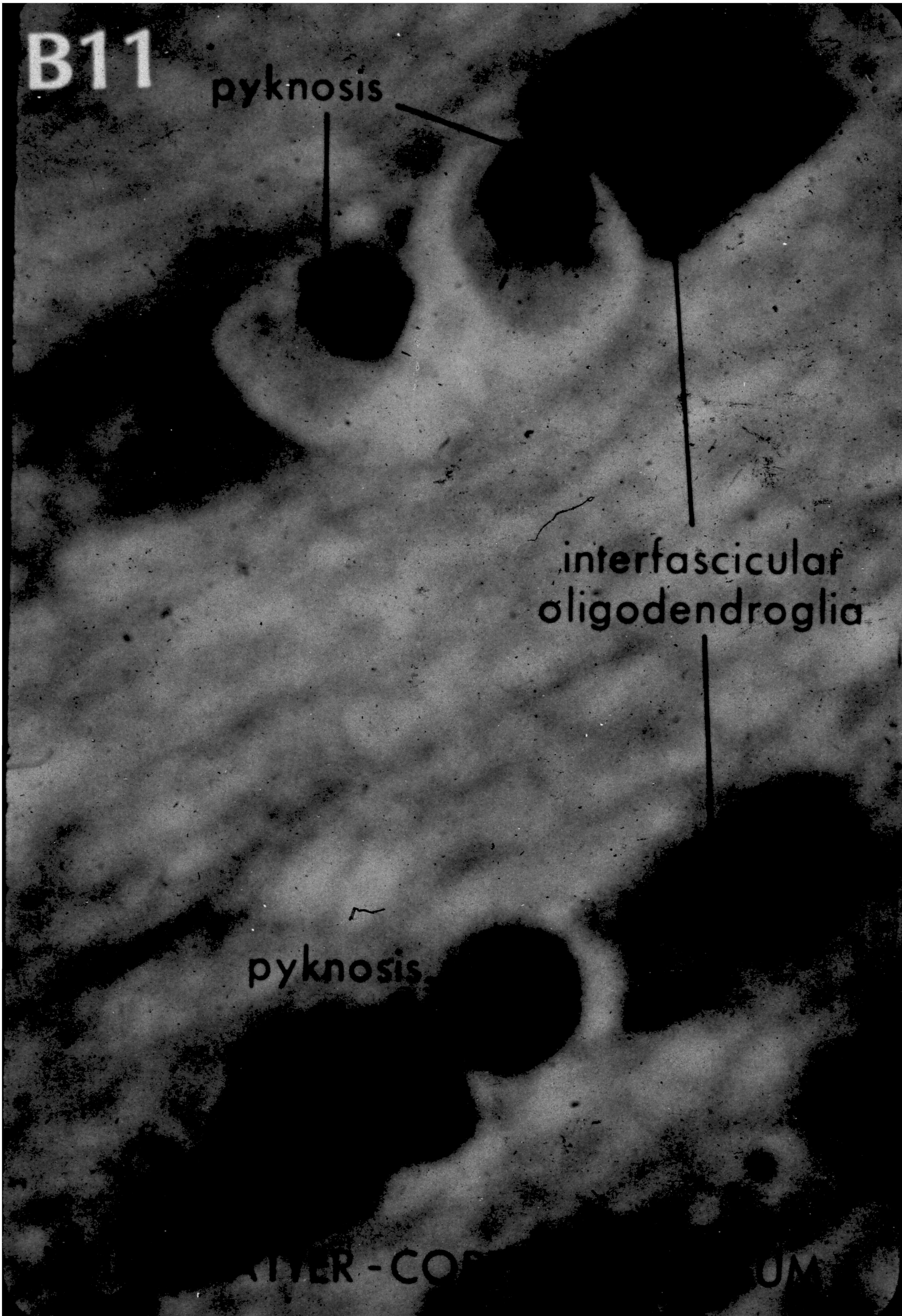
FIBRILLARY ASTROCYTES - BLOOD VESSEL



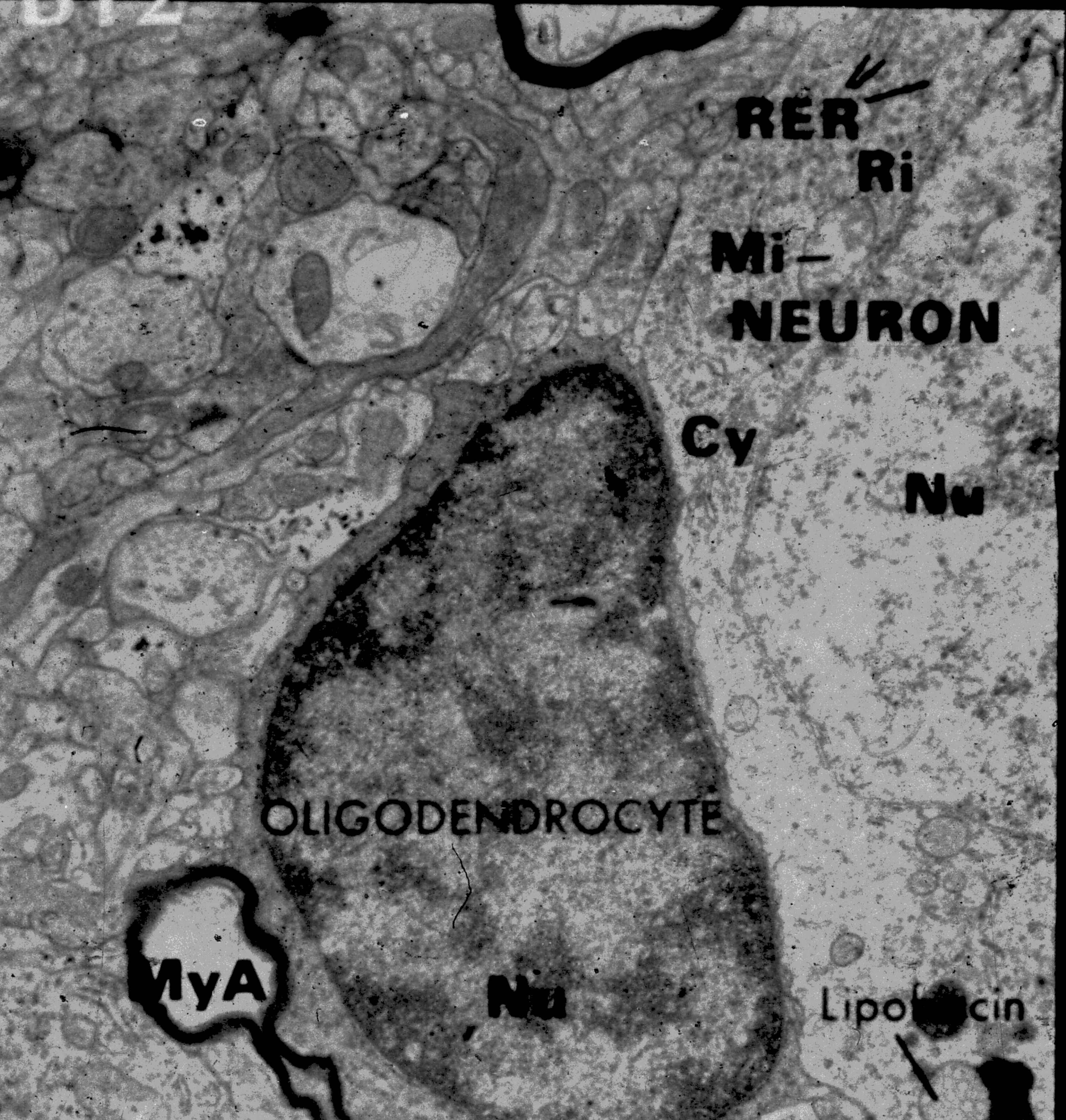
CAPILLARY
ASTROGLIAL PSEUDOPODIA

BV-blood vessel A - astrocyte

PROTOPLASMIC ASTROCYTES

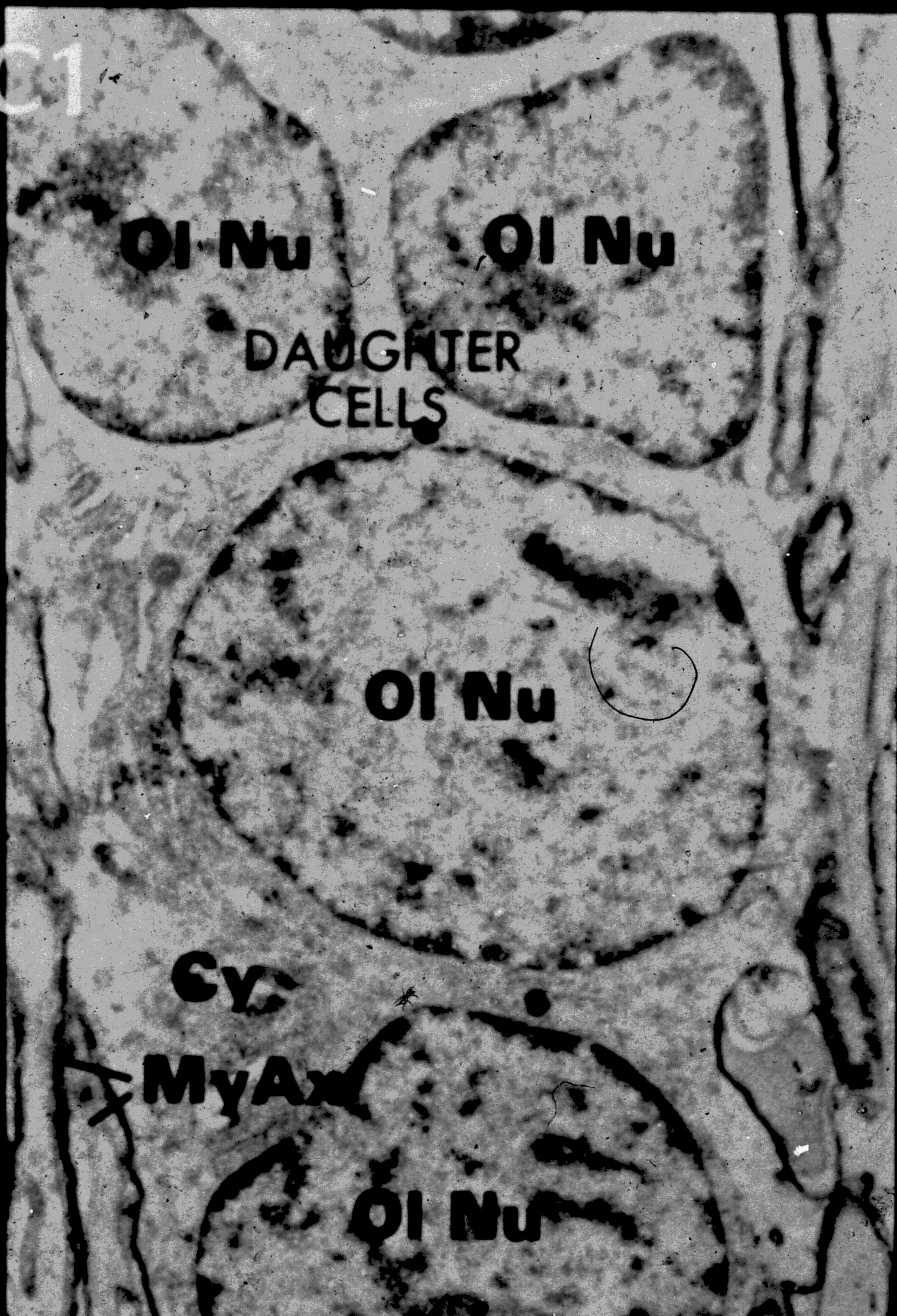

B11
pyknosis
interfascicular
oligodendroglia
pyknosis

B12



PERINEURONAL OLIGODENDROCYTE

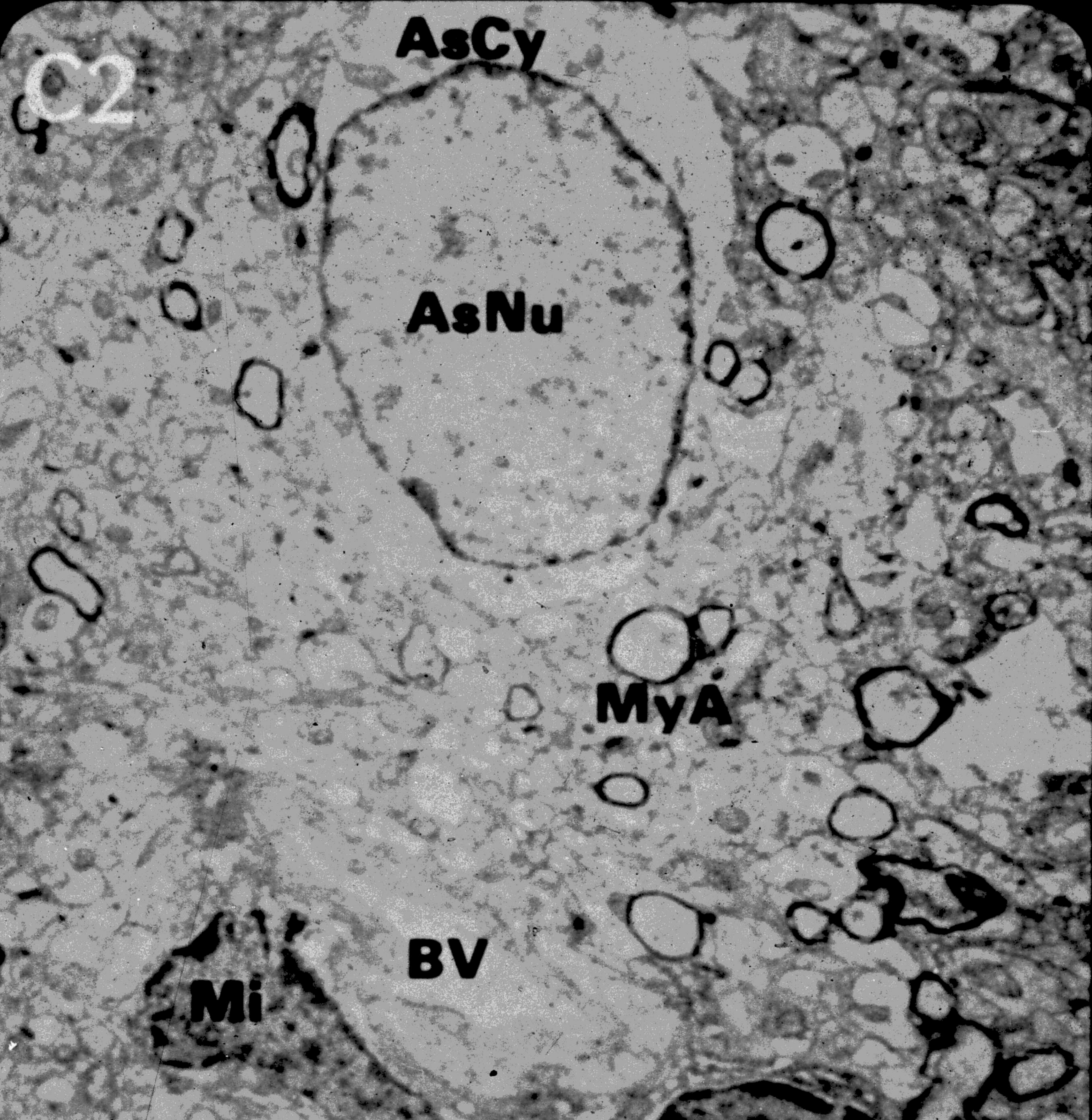
MyA · Myelinated axon
Nu · Nucleus
Cy · Cytoplasm
Ri · Ribosomes
RER · Rough endoplasmic reticulum
Mi · Mitochondrion



INTERFASCICULAR OLIGODENDROCYTES

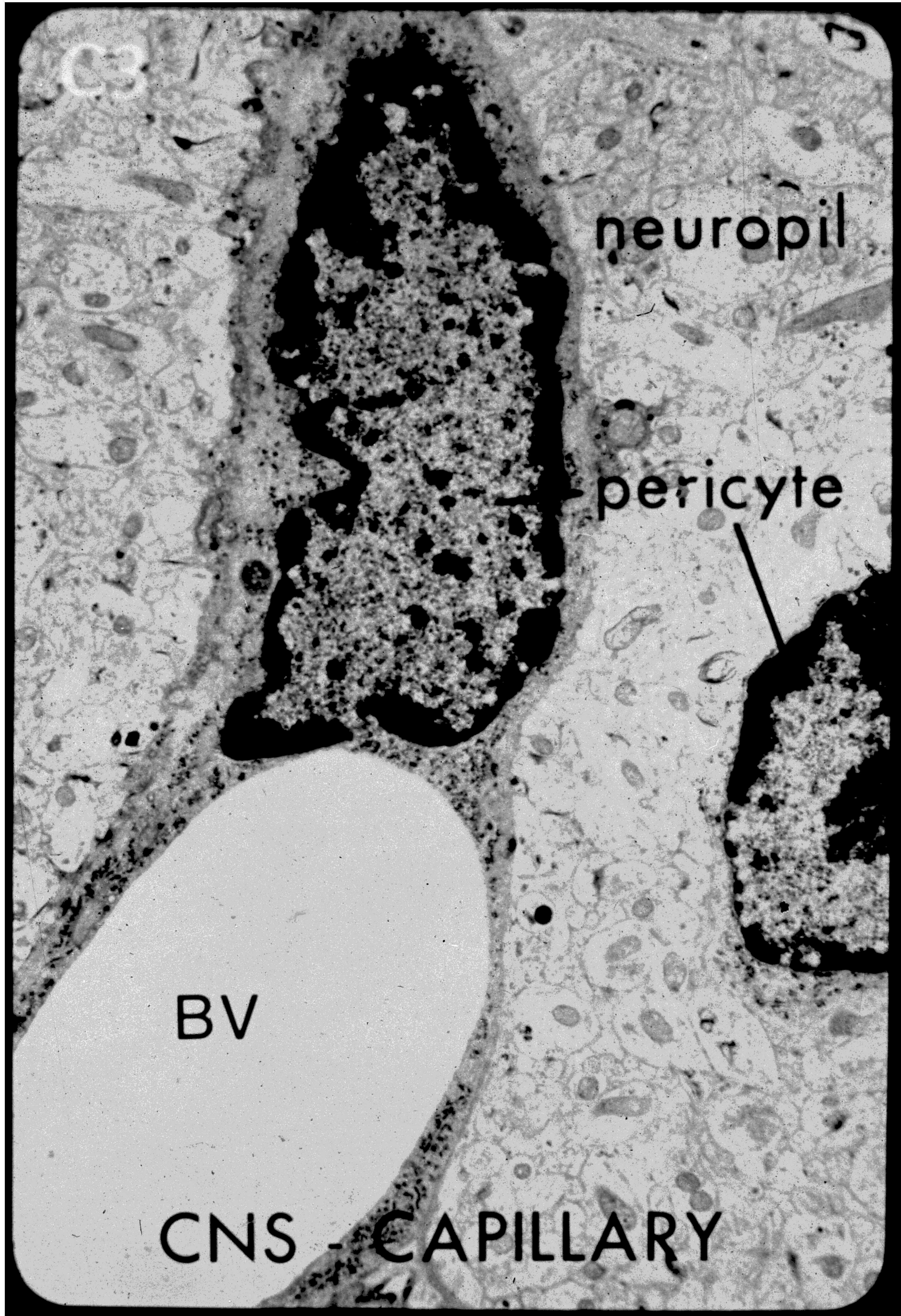
Ol Nu · Oligodendroglial nucleus

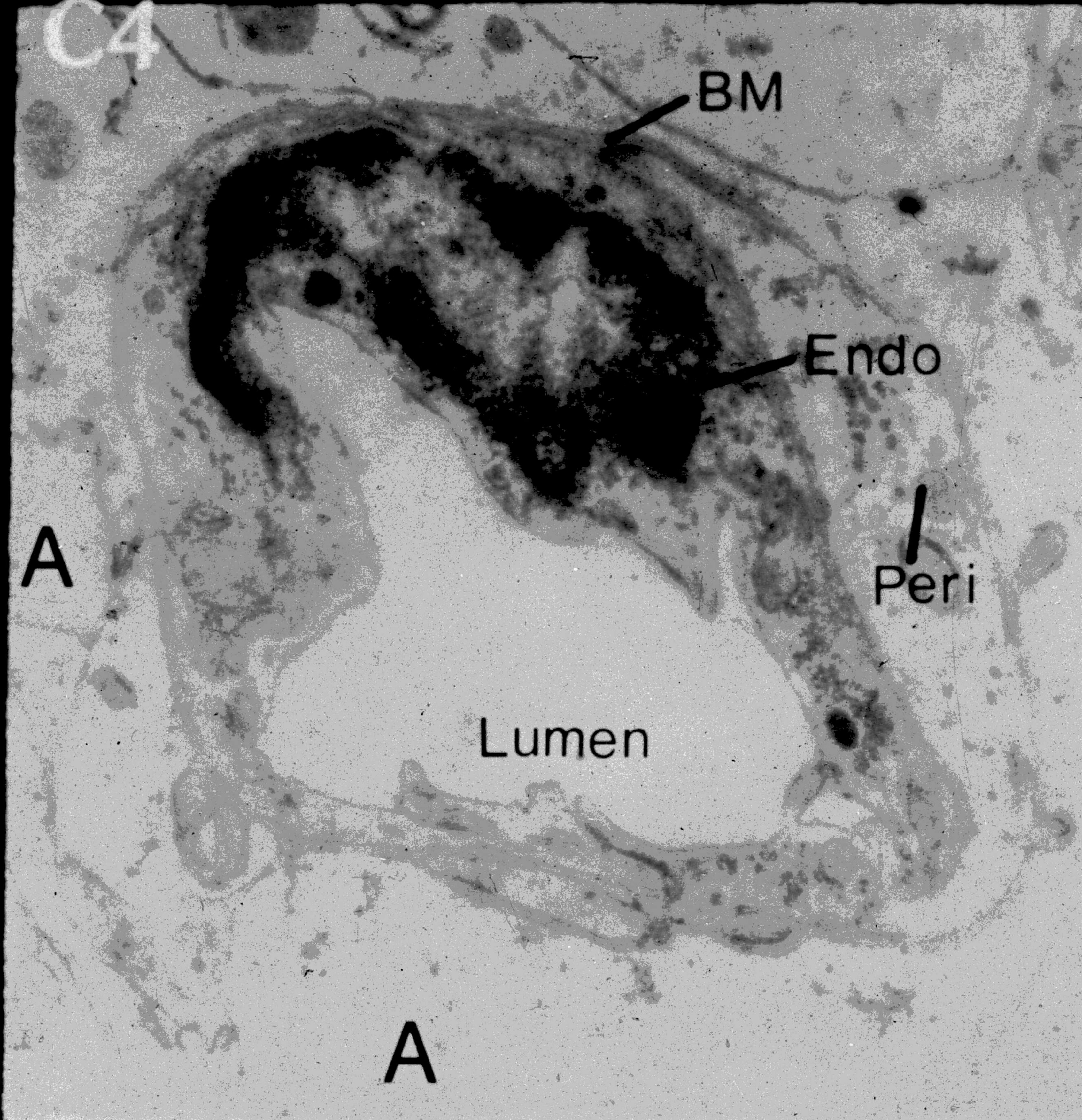
Cy · Cytoplasm MyAx · Myelinated axon



NEUROGLIA AND BLOOD VESSEL

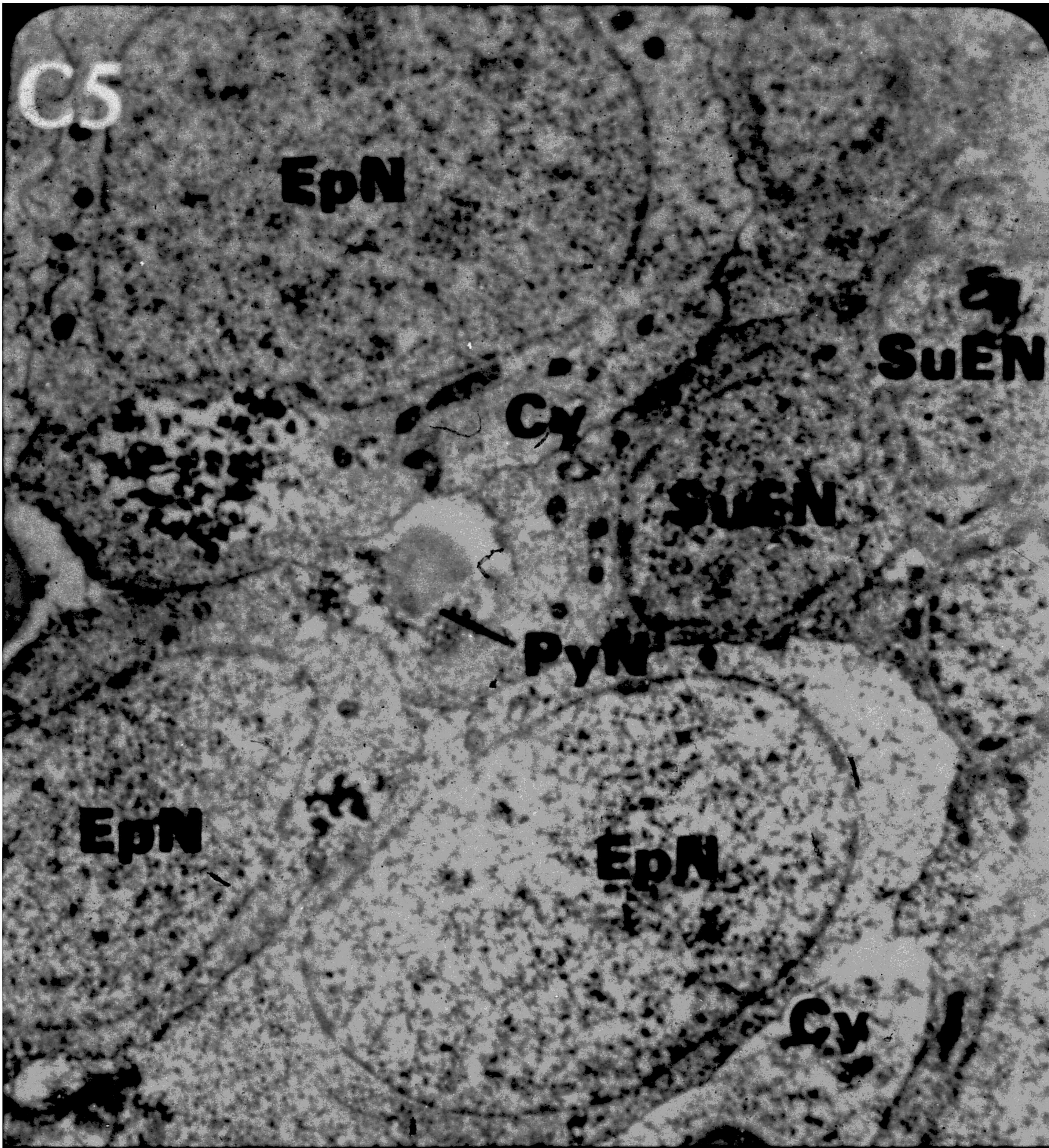
Mi · Microglia
BV · Blood vessel
AsNu · Astrocyte nucleus
AsCy · Astrocyte cytoplasm
MyA · Myelinated axon


C3
neuropil
pericyte
BV
CNS - CAPILLARY



CAPILLARY

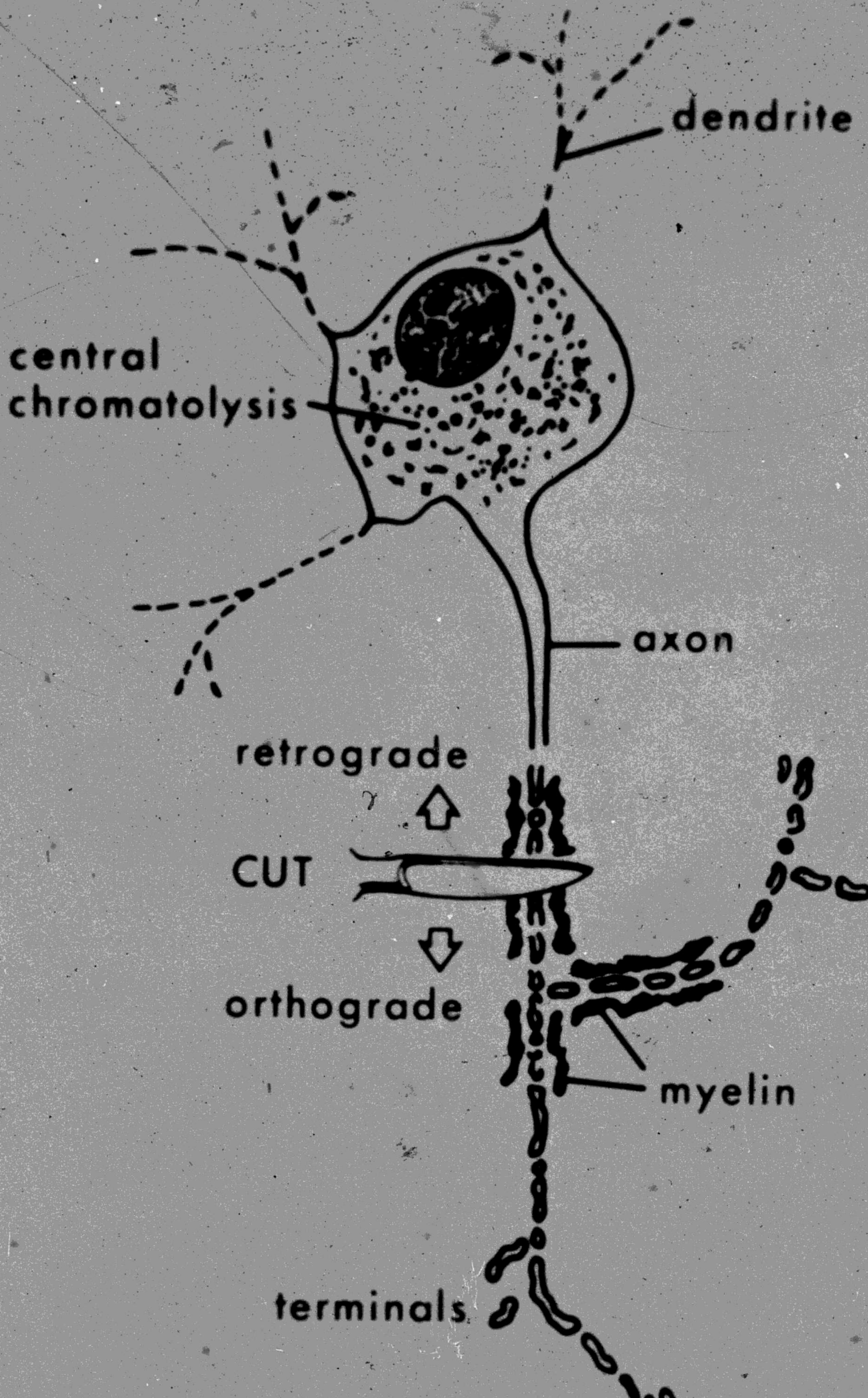
A-astrocyte Peri-pericyte
BM-basement membrane
Endo-endothelium



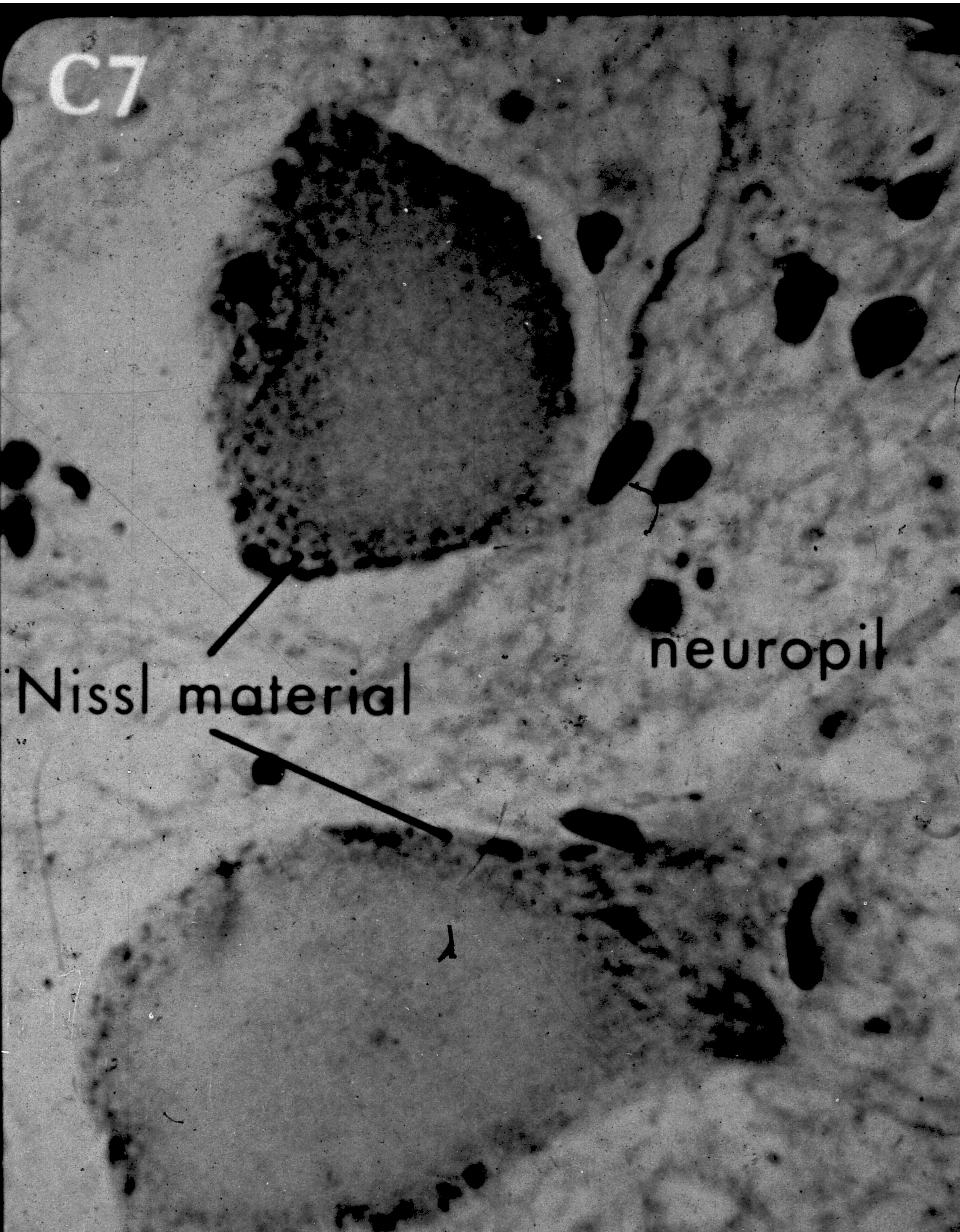
EPENDYMAL AND SUBEPENDYMAL CELLS

EpN · Ependymal cell nucleus
Cy · Cytoplasm
SuEN · Subependymal cell nucleus
PyN · Pyknotic nucleus

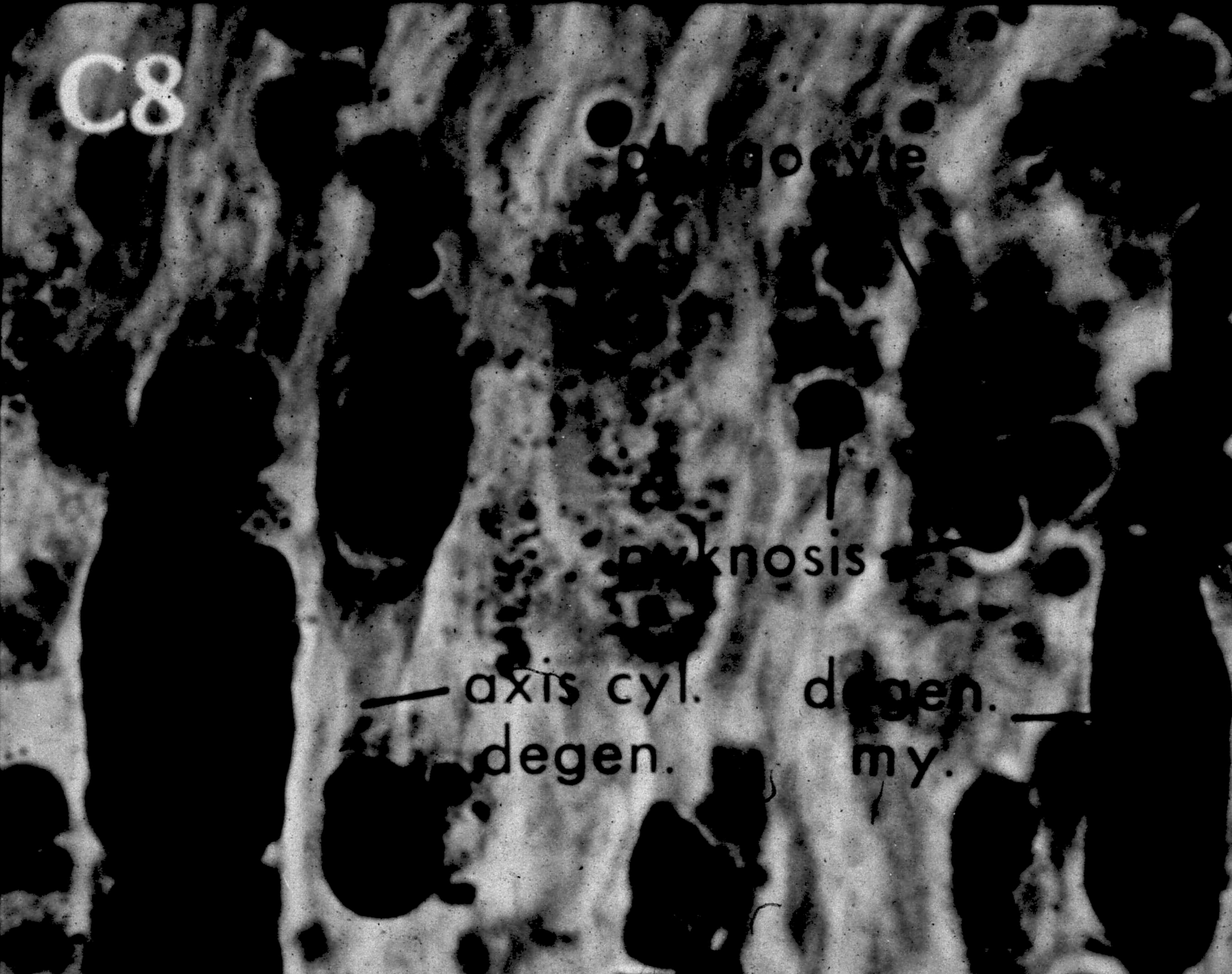
C6



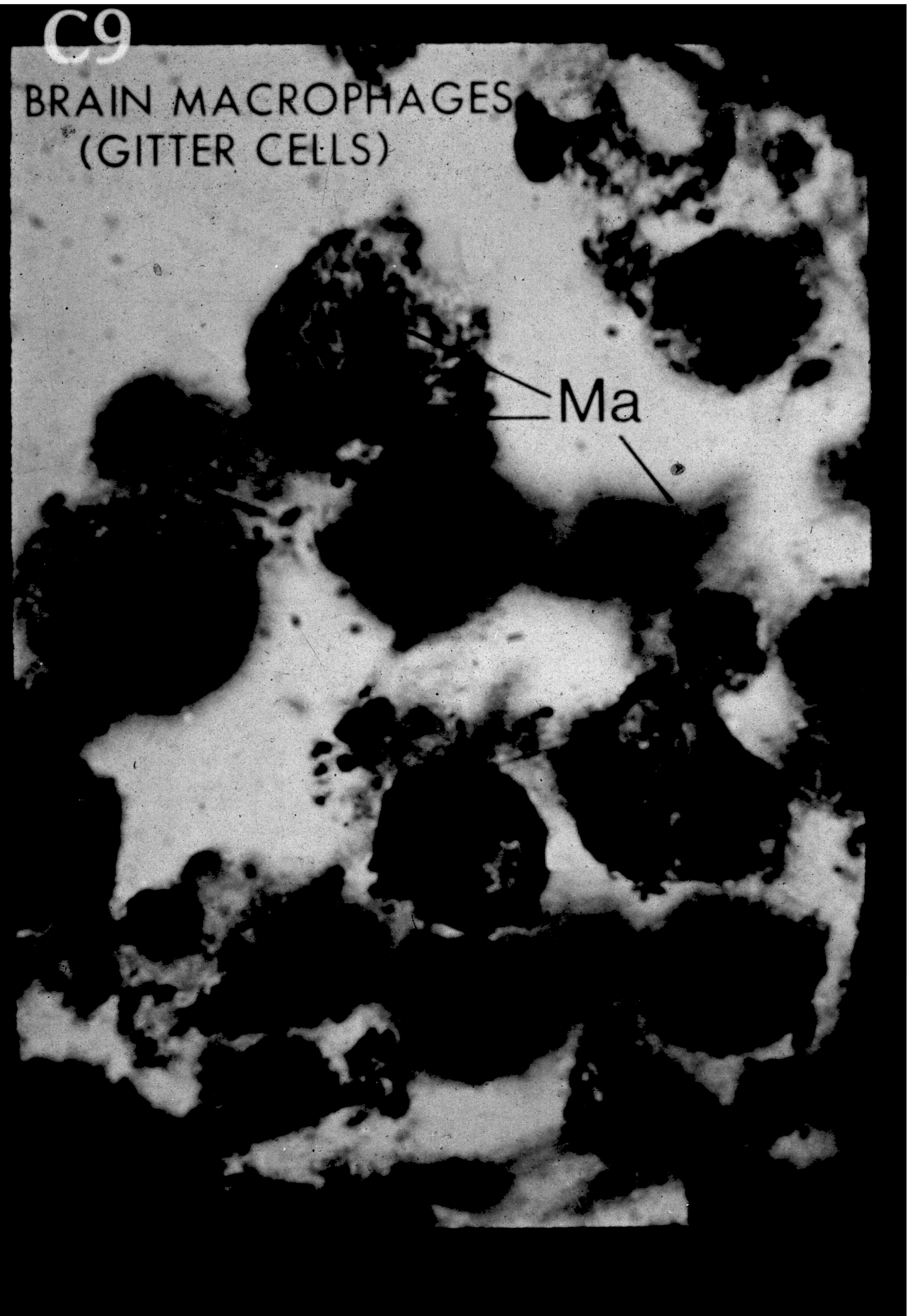
ABNORMAL MULTIPOLAR NEURON (Degeneration)

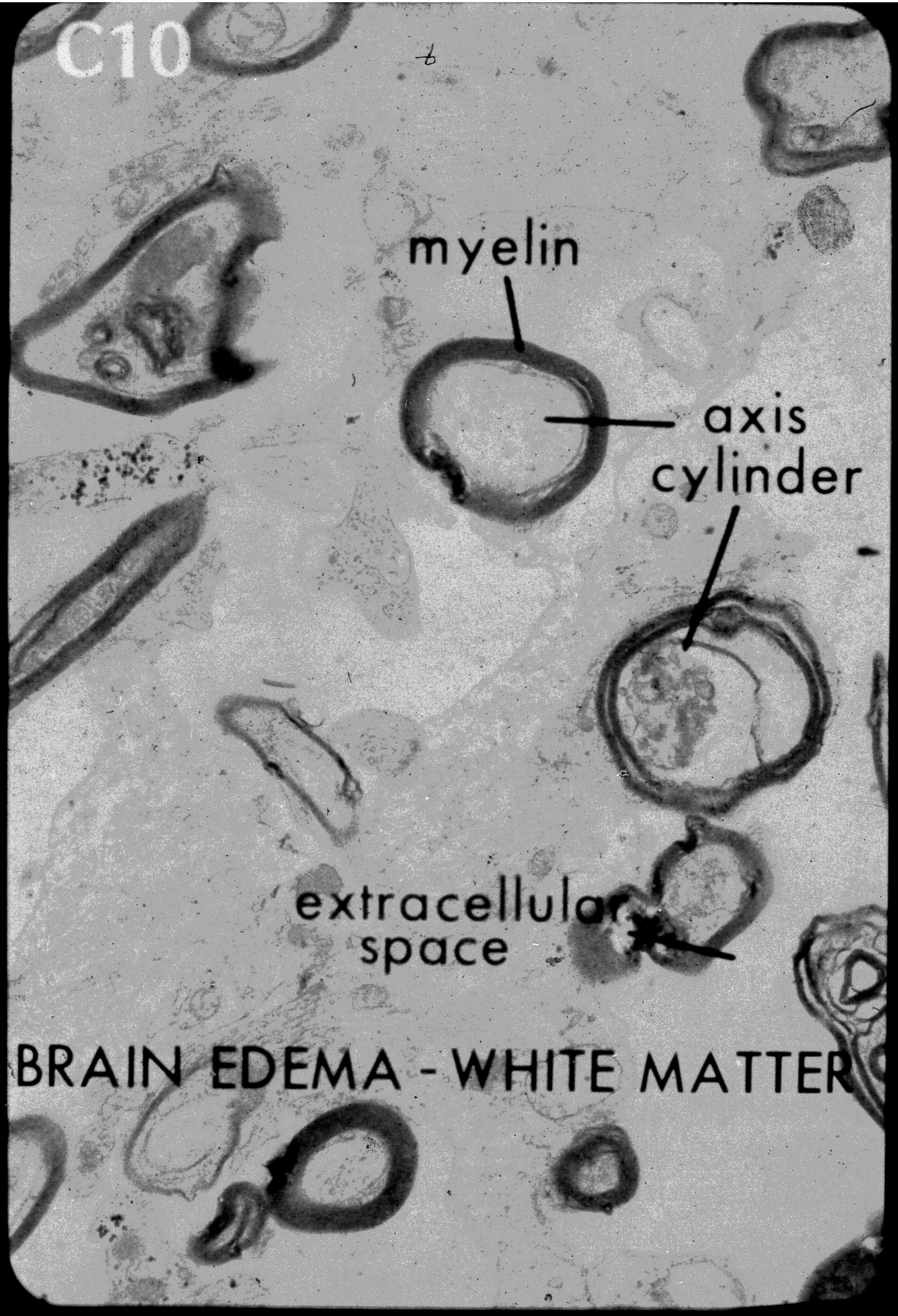


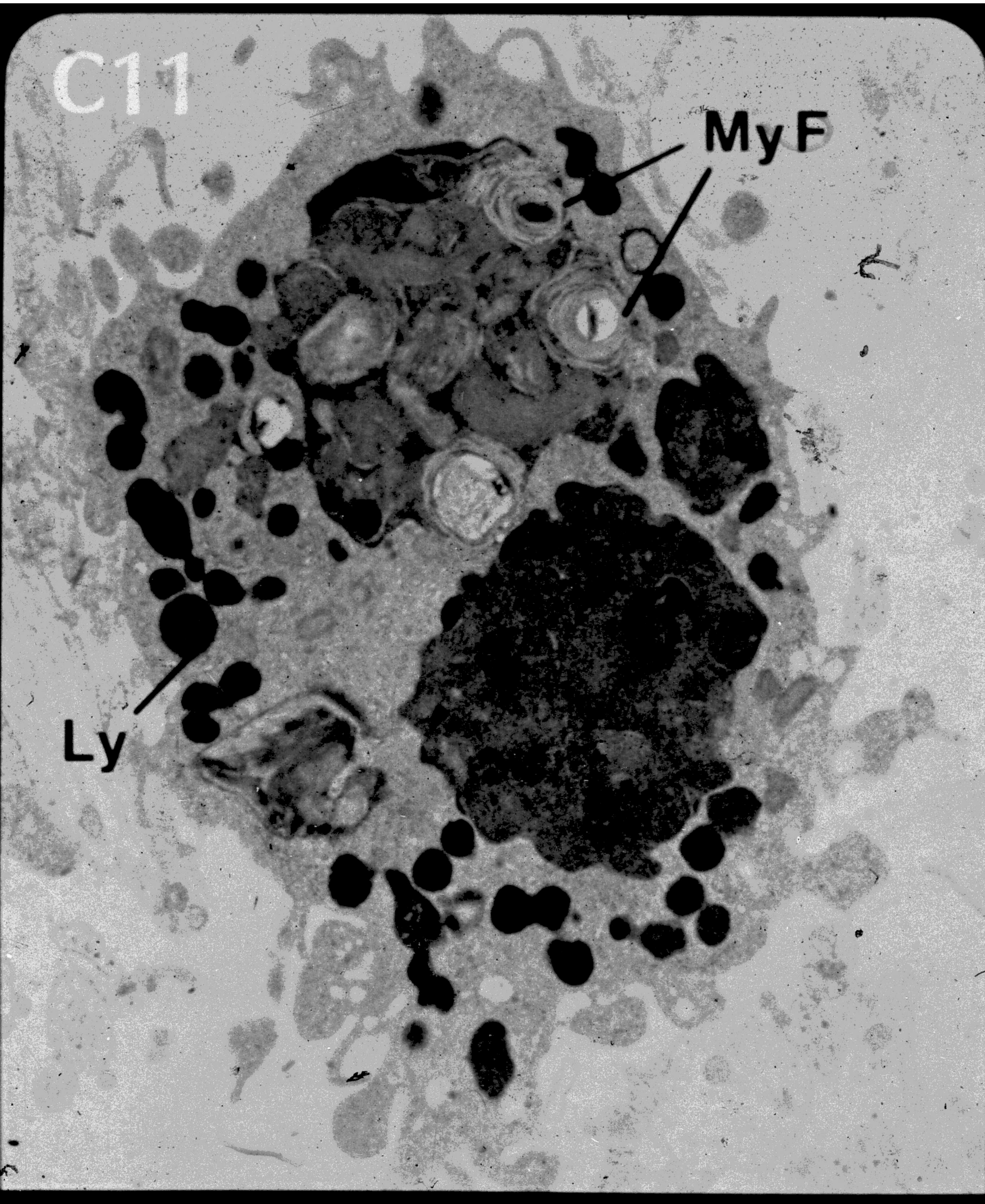
NEURON
CENTRAL CHROMATOLYSIS



DEGENERATING PERIPHERAL NERVE

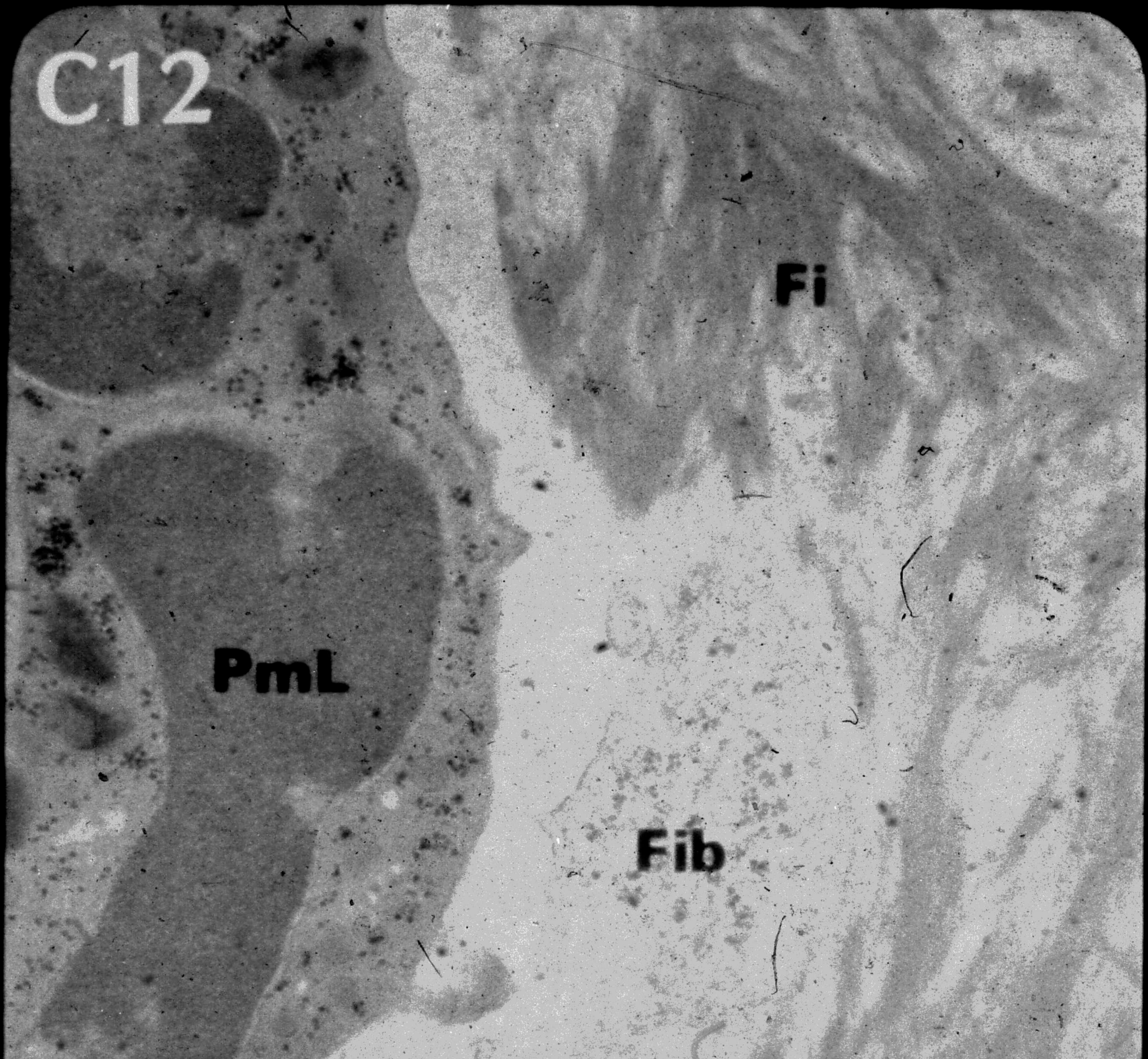

C9
BRAIN MACROPHAGES
(GITTER CELLS)
Ma


C10
myelin
axis cylinder
extracellular space
BRAIN EDEMA - WHITE MATTER



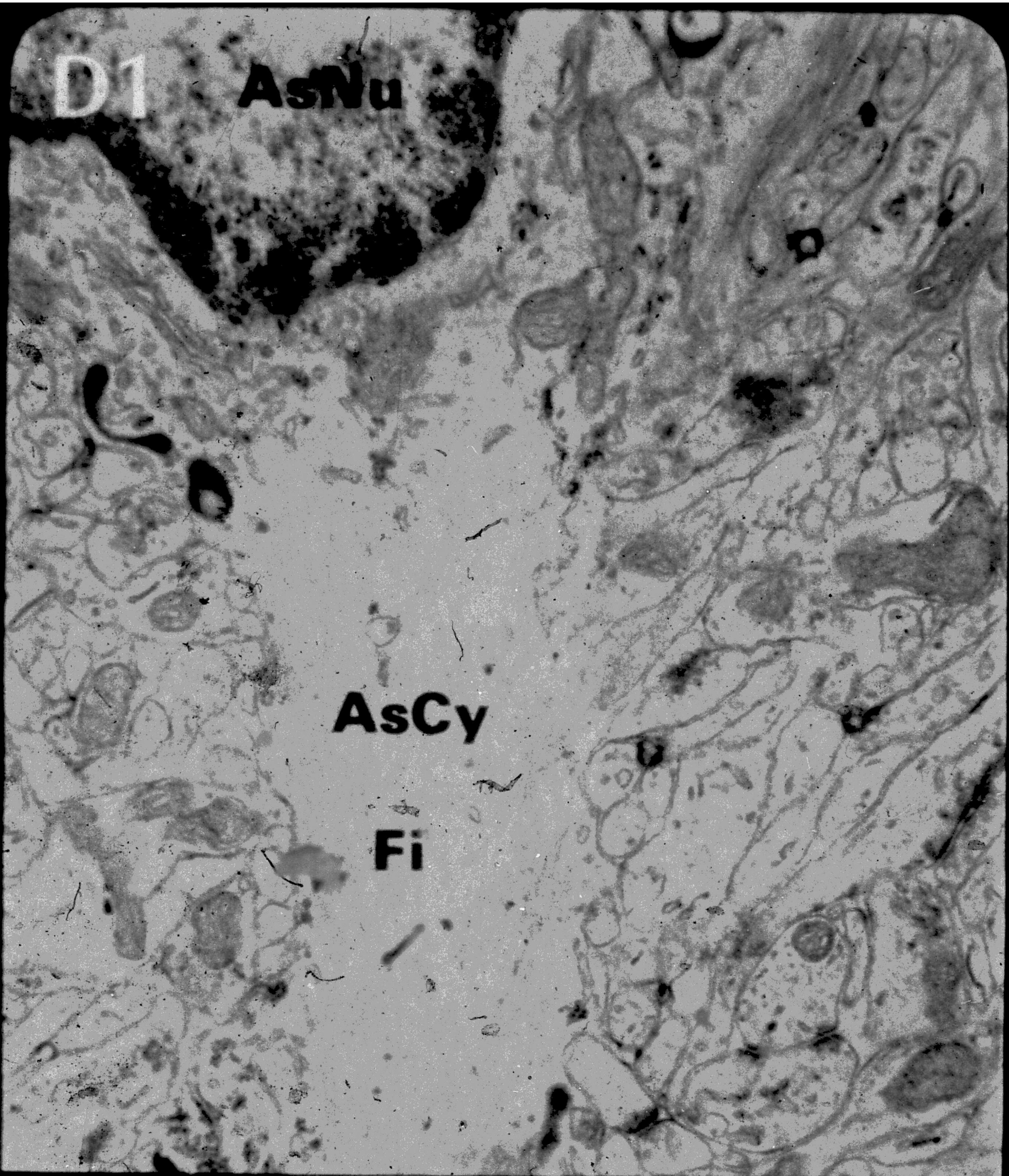
MACROPHAGE
(Gitter Cell)

Ly-lysosome MyF-myelin figures



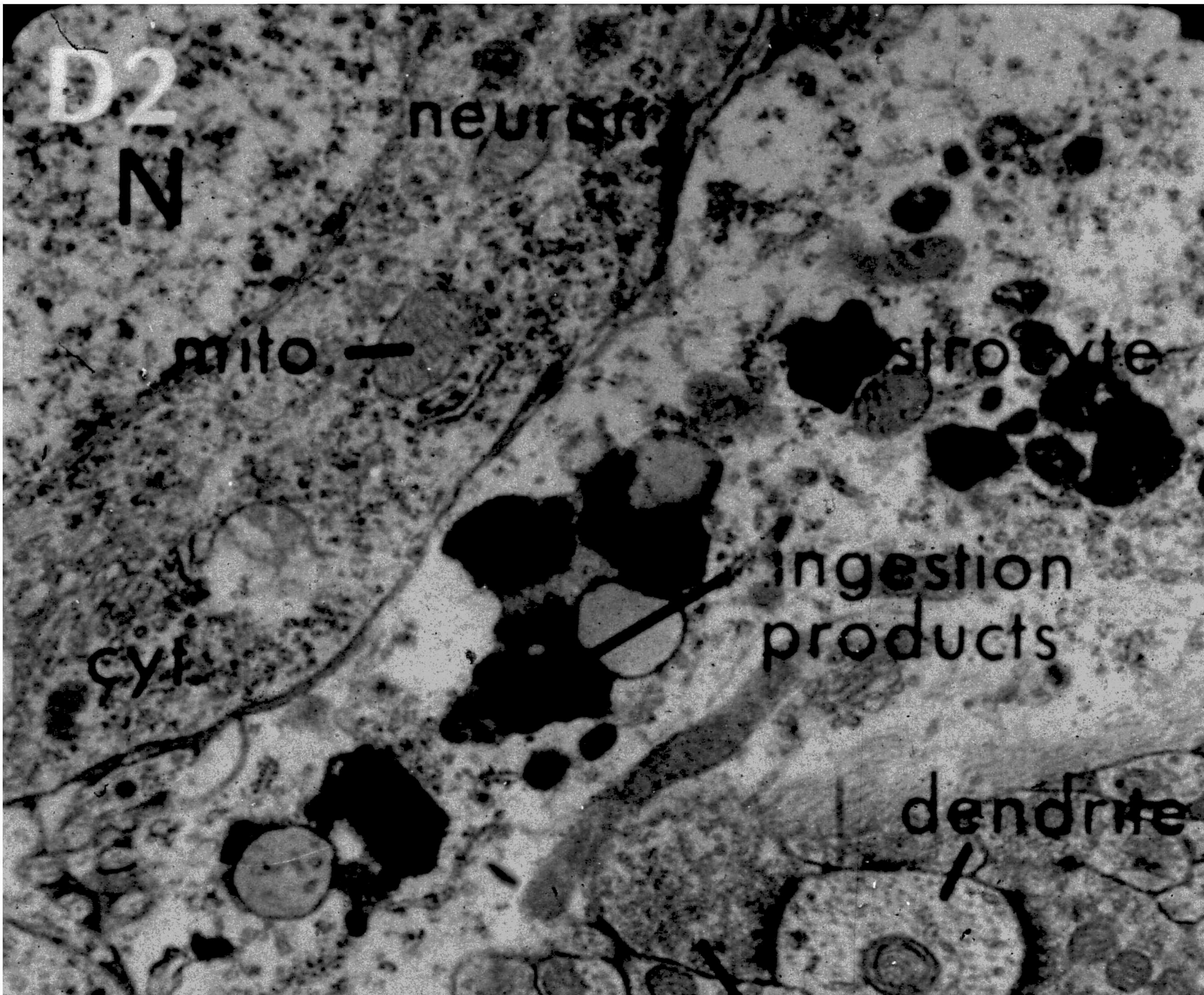
BRAIN
PERIVASCULAR SCAR FORMATION

PmL · Polymorphonuclear leukocyte
Fib · Fibroblast
Fi · Fibrils



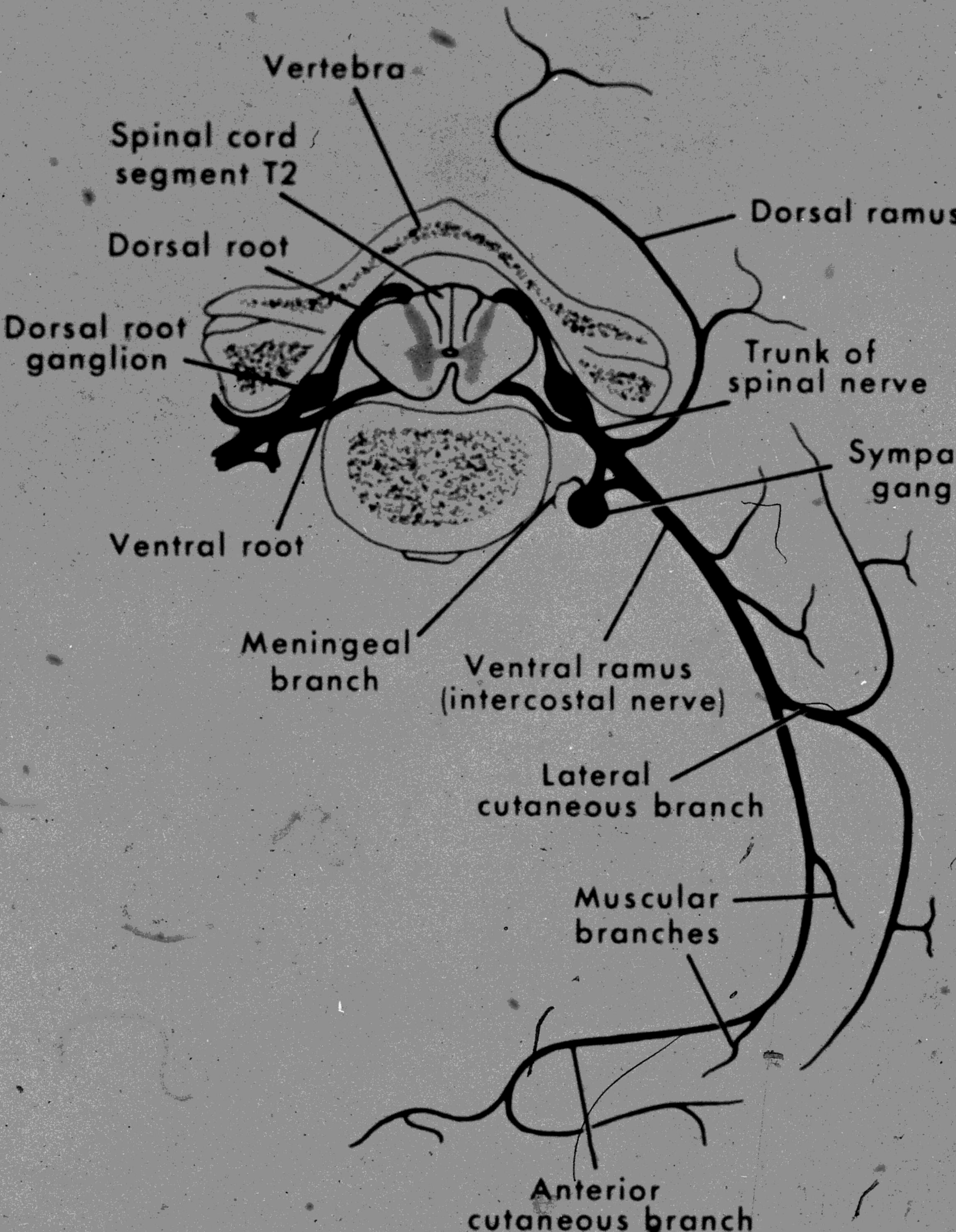
FIBRILLARY ASTROCYTE HYPERTROPHY

AsNu · Astrocyte nucleus
AsCy · Astrocyte cytoplasm
Fi · Fibrils



FINE-STRUCTURE NEUROPIL

D3



FORMATION OF PERIPHERAL NERVES

D4

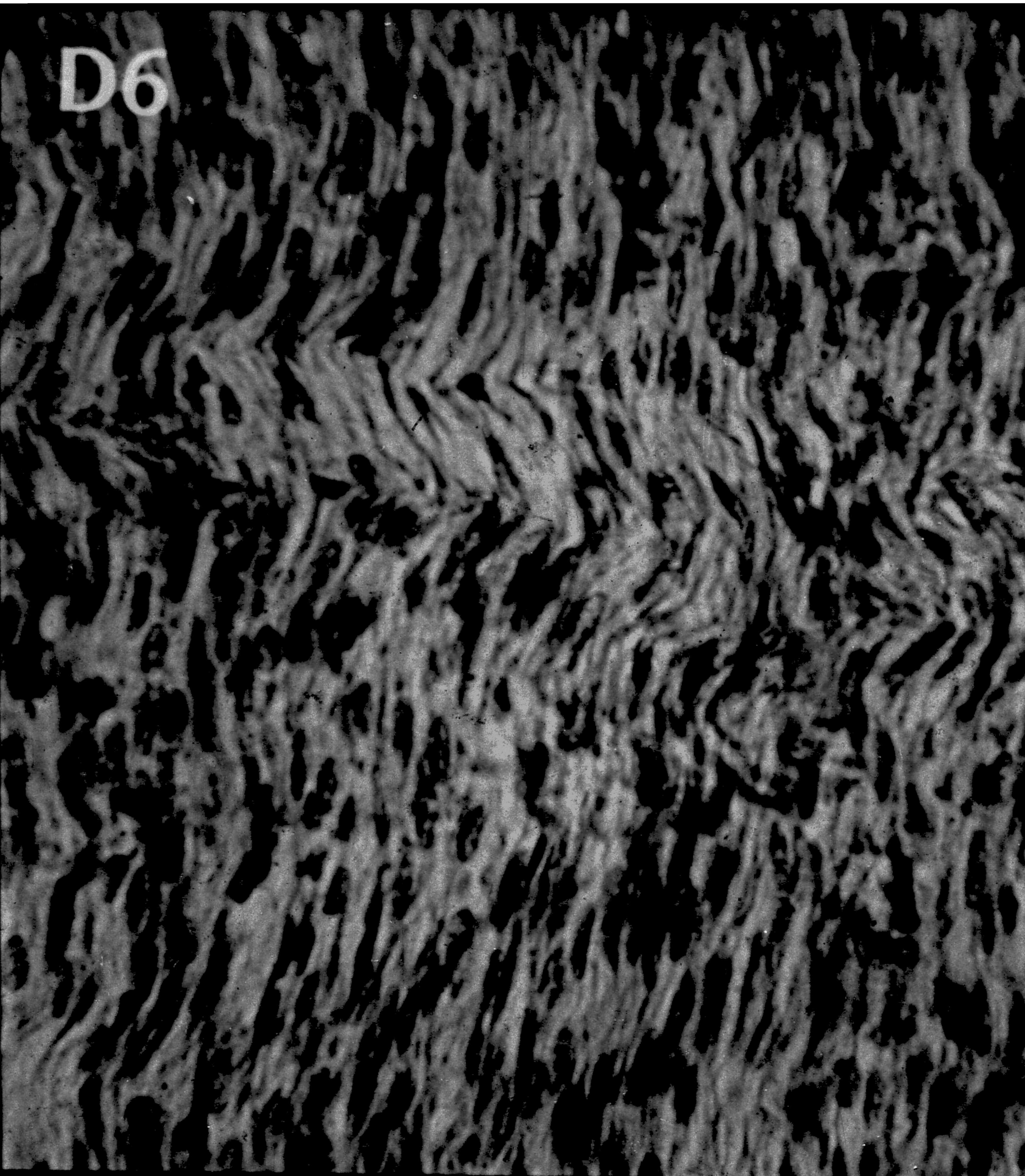
DORSAL ROOT AND GANGLION

M = medulla C = cortex DR = dorsal root

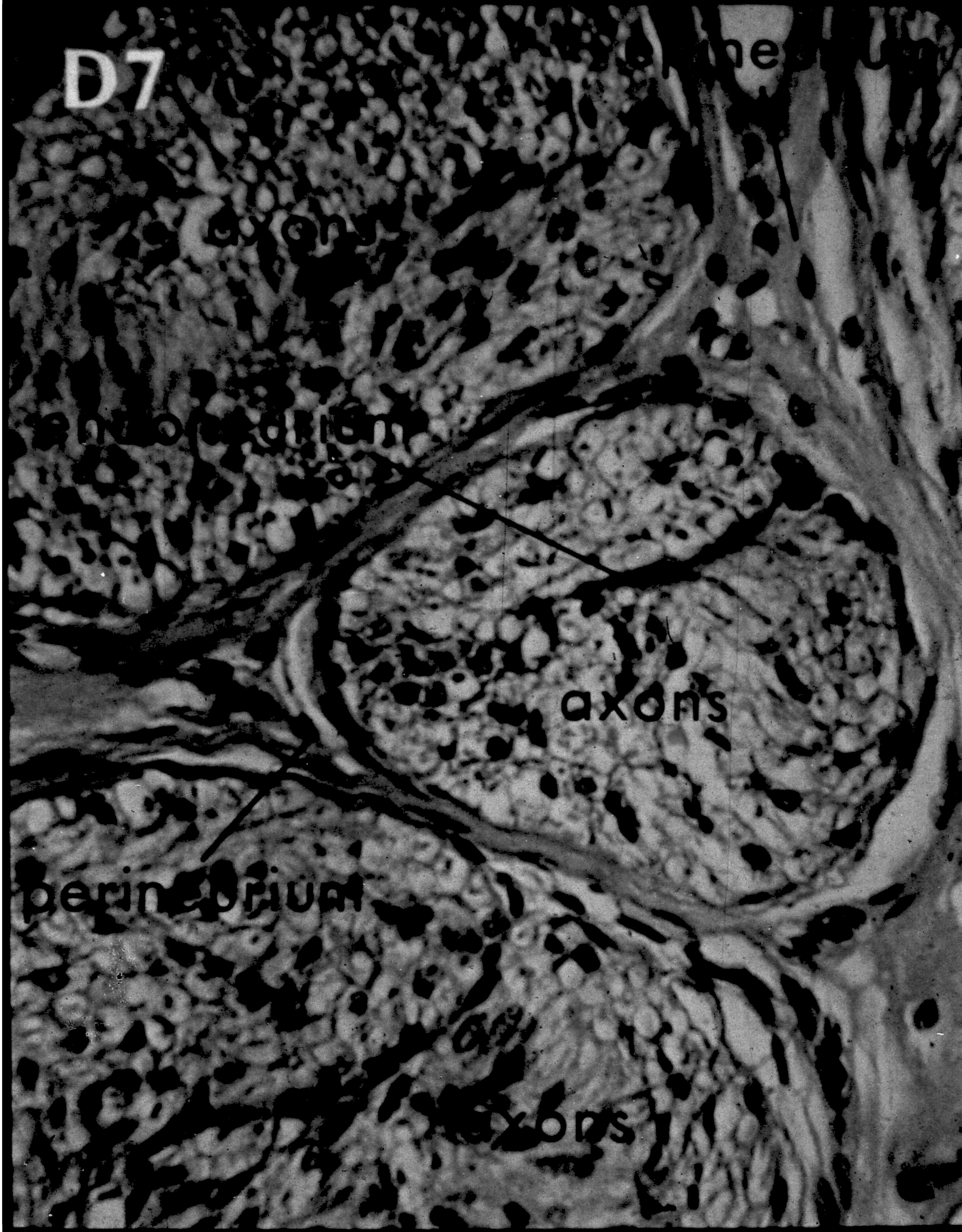
DRGC = dorsal root ganglion cells

DORSAL ROOT GANGLION CELL

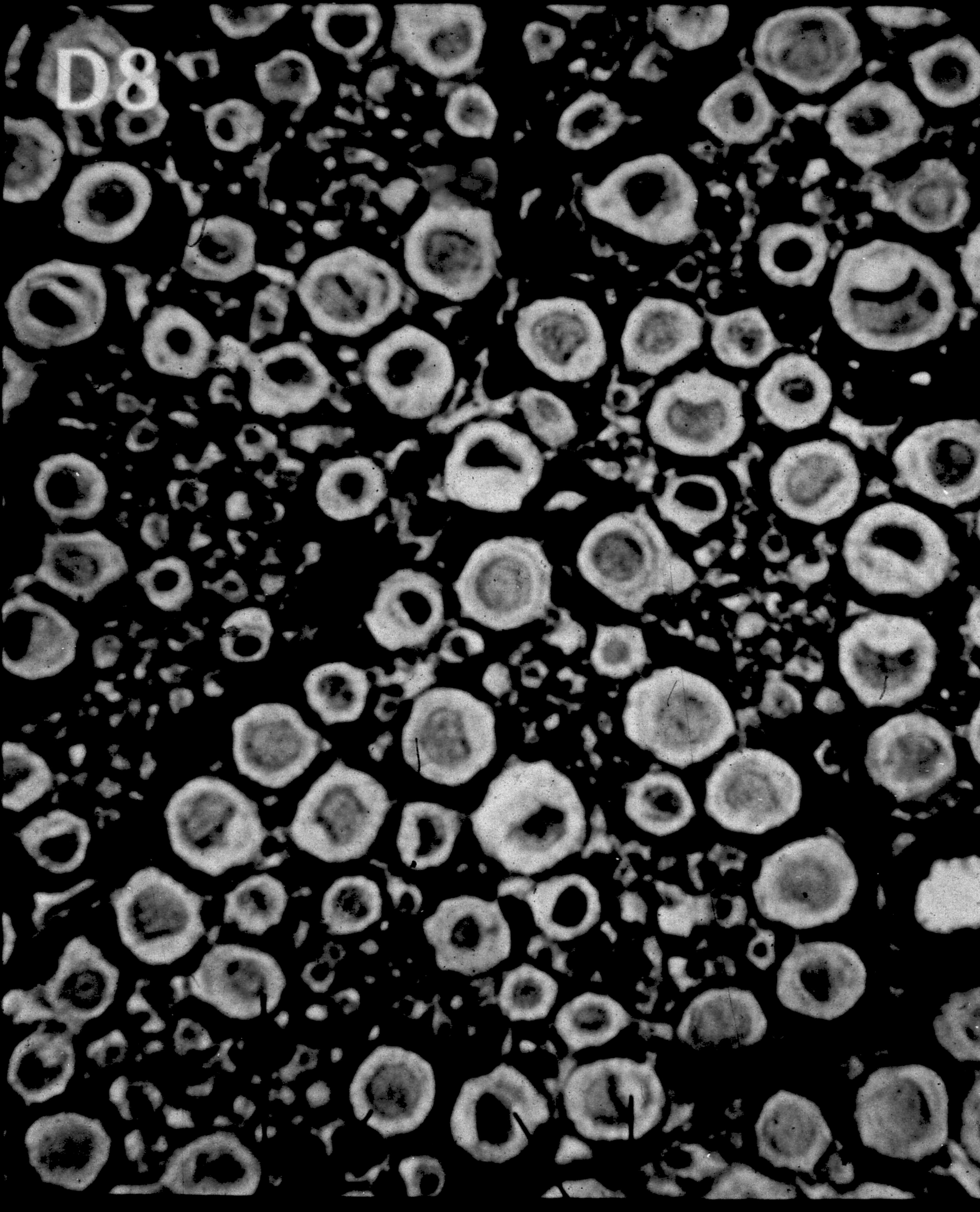
Cy Cytoplasm
Nu Nucleus
No Nucleolus
SC Satellite cells
SSC Schwann sheath cell



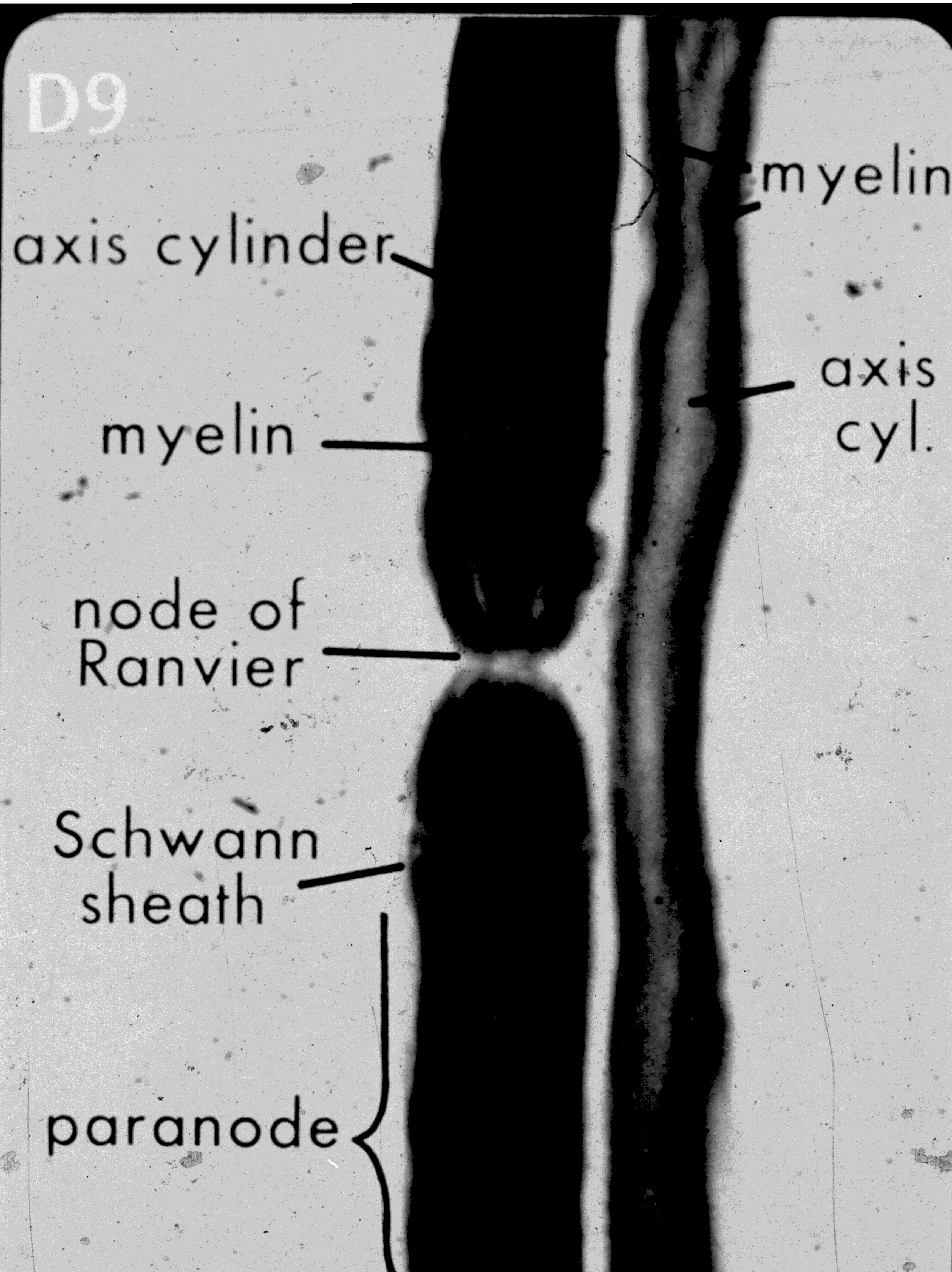
PERIPHERAL NERVE
LONGITUDINAL SECTION
AXONS



PERIPHERAL NERVE TRUNK
(FASCICLES)

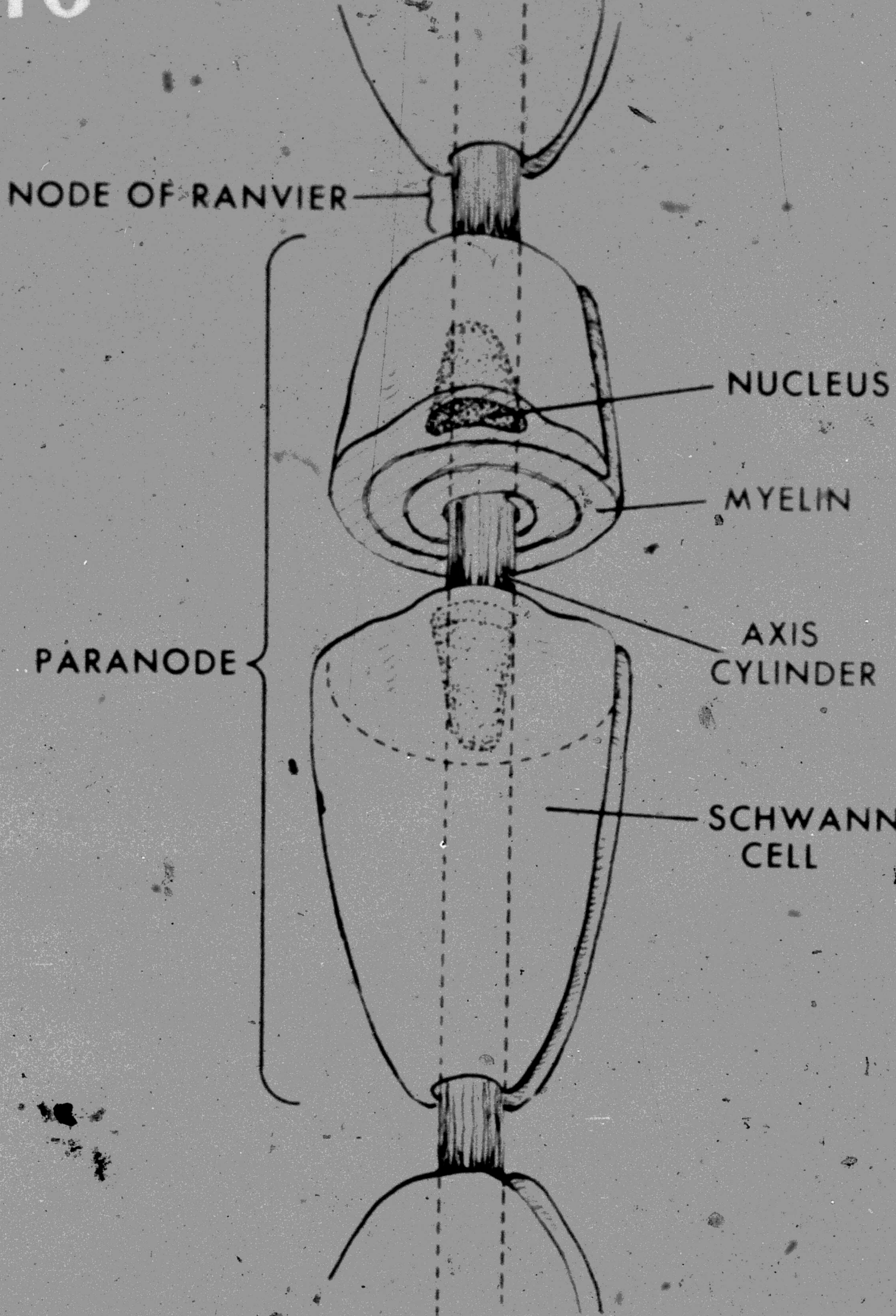


PERIPHERAL NERVE TRUNK
Large and Small Myelinated Axons



MYELINATED AXONS

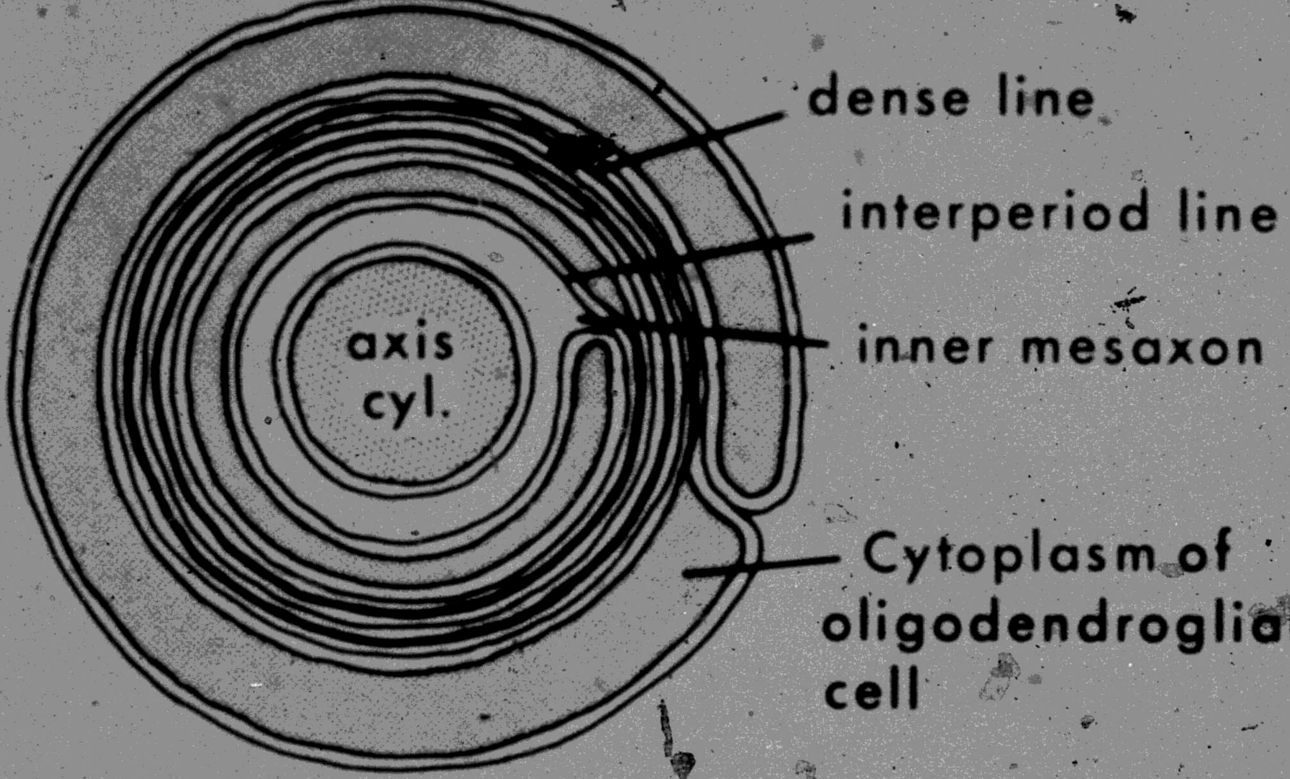
D10



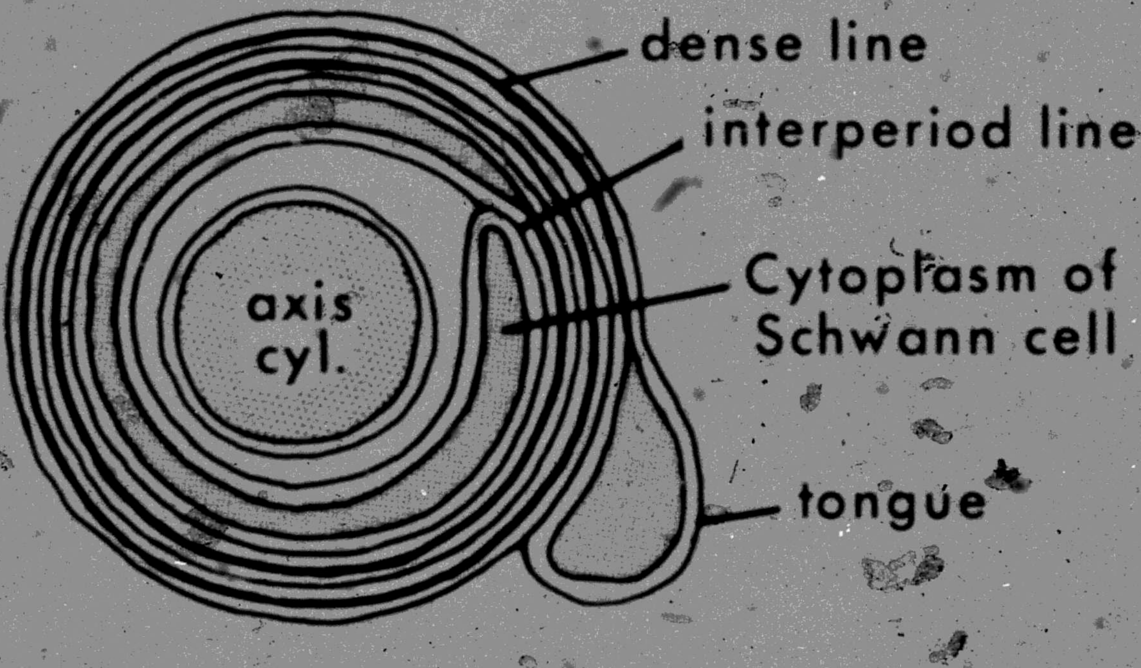
MYELINATED AXON

D11

CNS



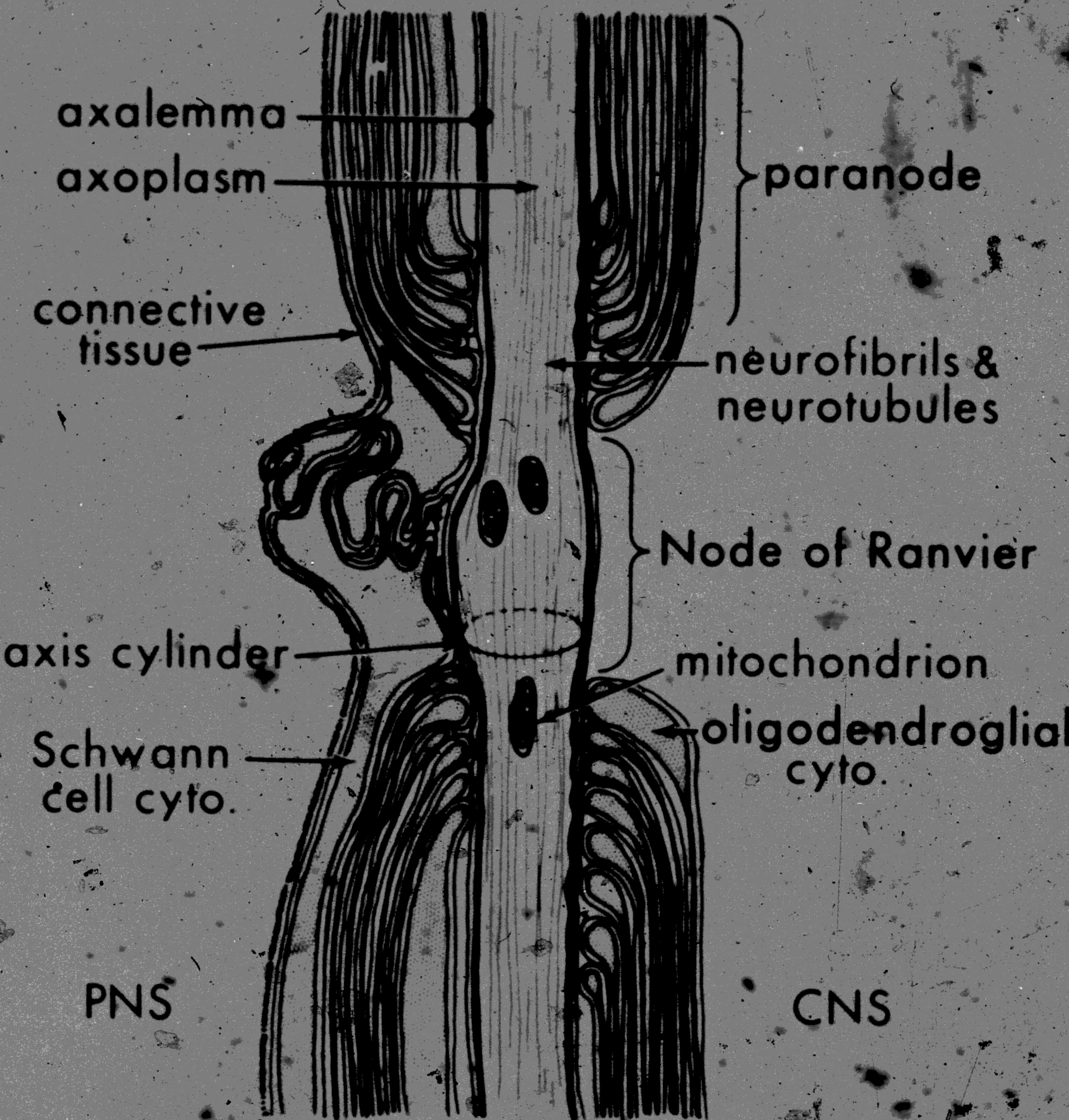
PNS



FINE-STRUCTURE MYELINATED AXONS

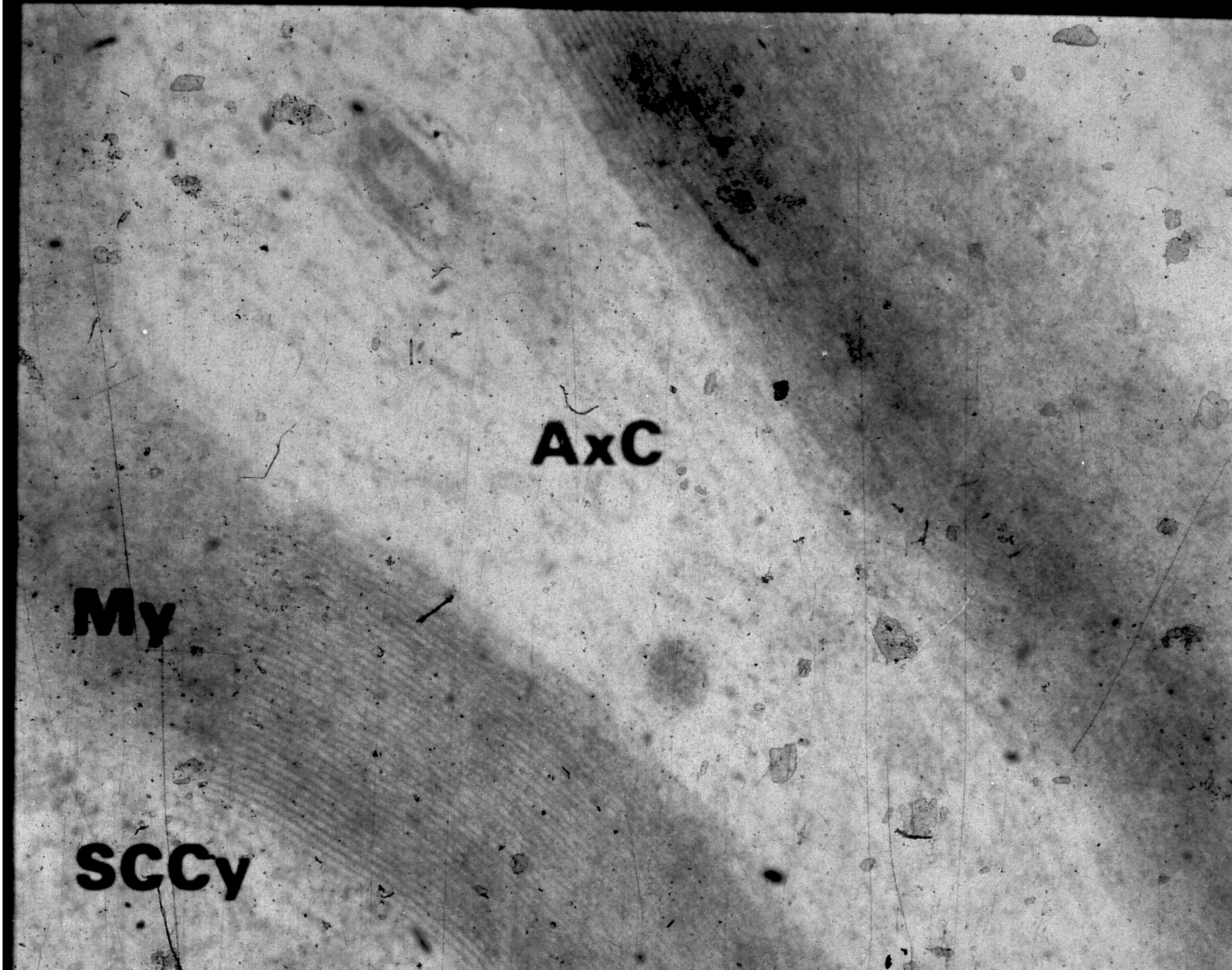
Cross-Section

D12



FINE-STRUCTURE NODE OF RANVIER
Longitudinal View
Myelinated Axon

E1



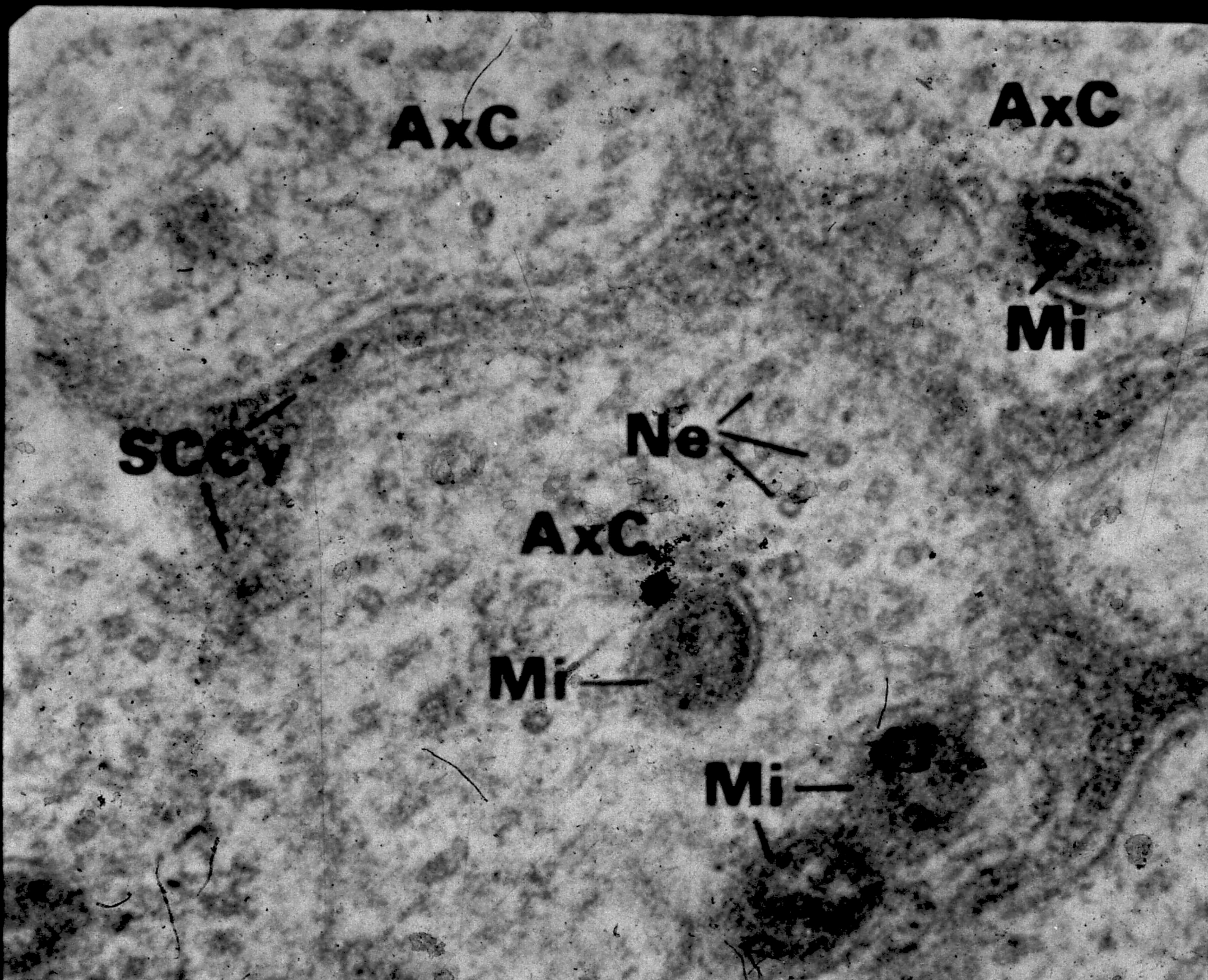
MYELINATED AXON

AxC · Axis cylinder

My · Myelin

SCCy · Schwann cell cytoplasm

E2

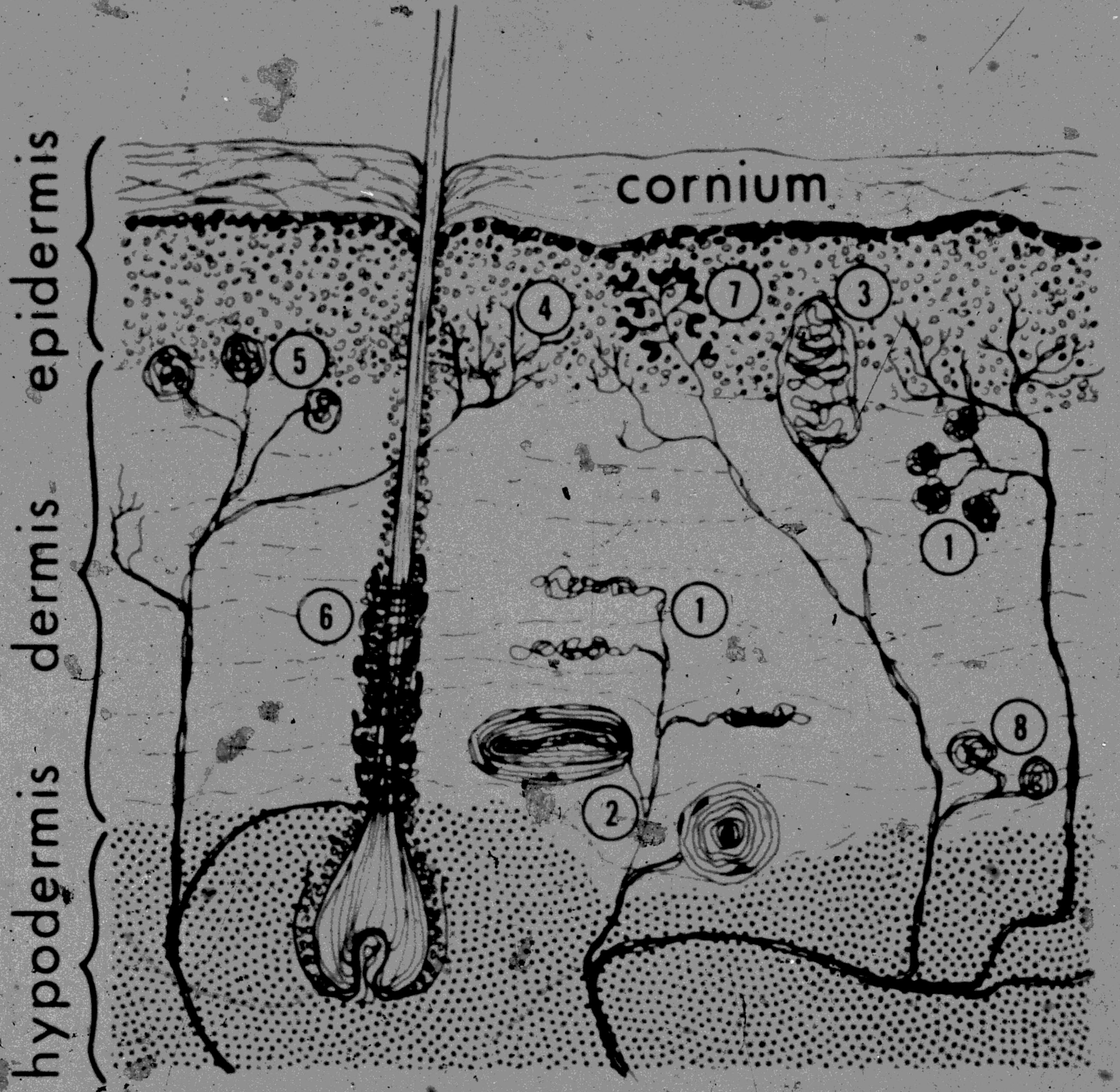


NON-MYELINATED AXONS

AxC · Axis cylinder
Mi – Mitochondria
Ne · Neurotubules
SCCy · Schwann cell cytoplasm

E3

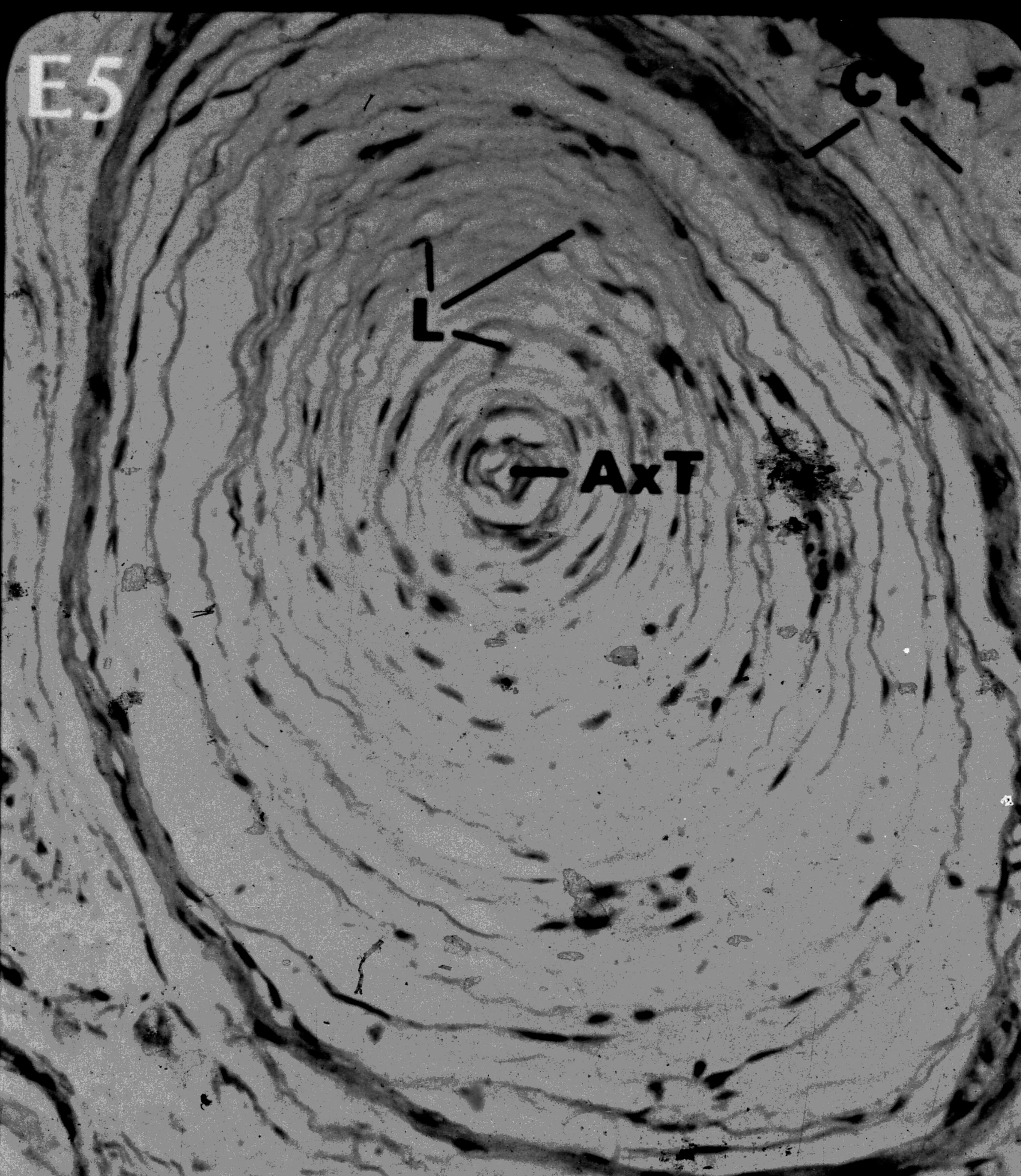
RECEPTORS IN SKIN



1. Ruffini's endings
2. Pacinian corpuscles
3. Meissner's corpuscles
4. "Free" nerve endings
5. Krause's end bulbs
6. Nerve fibers and endings on hair follicle
7. Merkel's discs
8. Golgi-Mazzoni endings

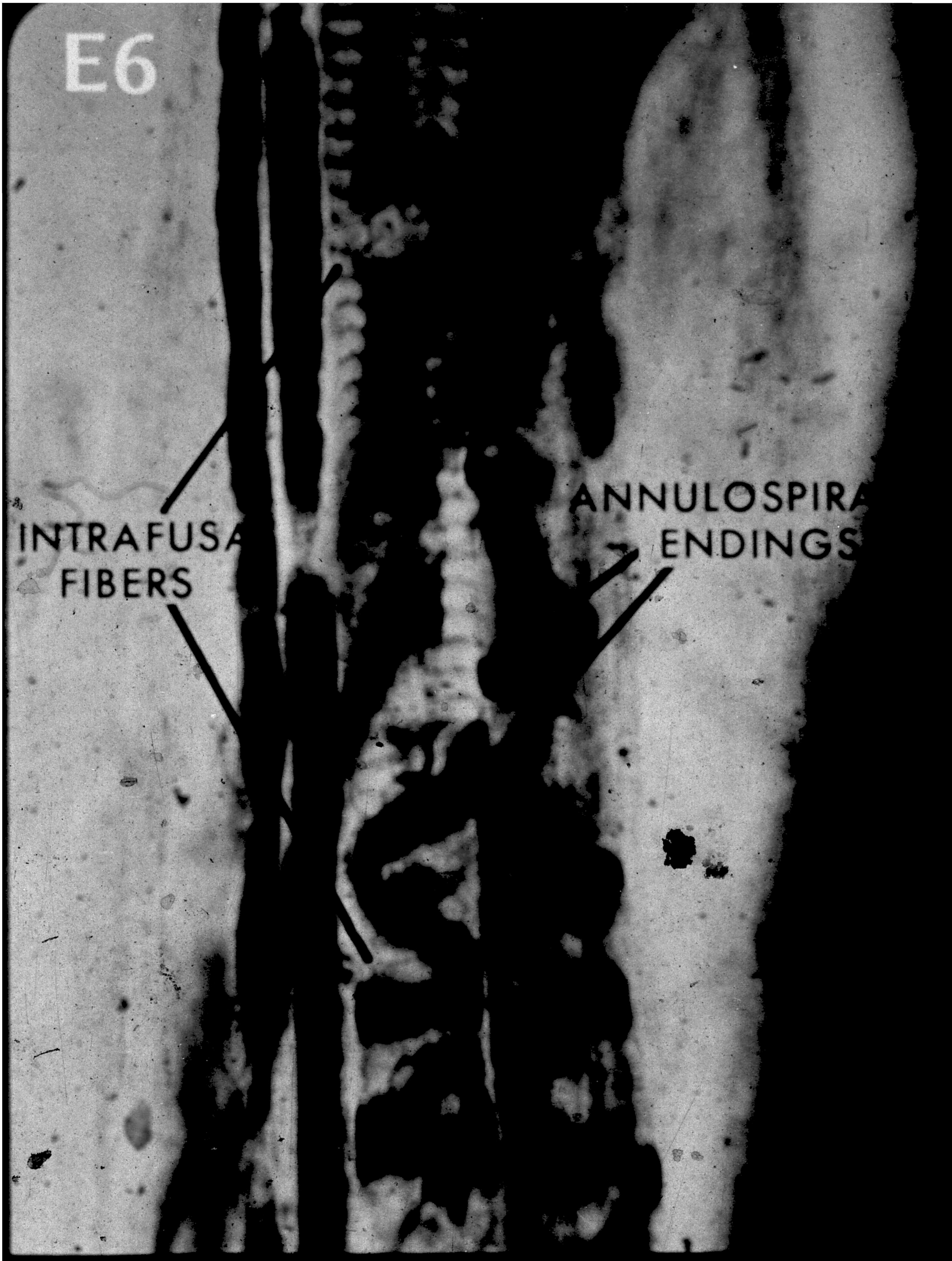
MEISSNER'S CORPUSCLE
SKIN

dermis ⬇ | ⬆ epidermis

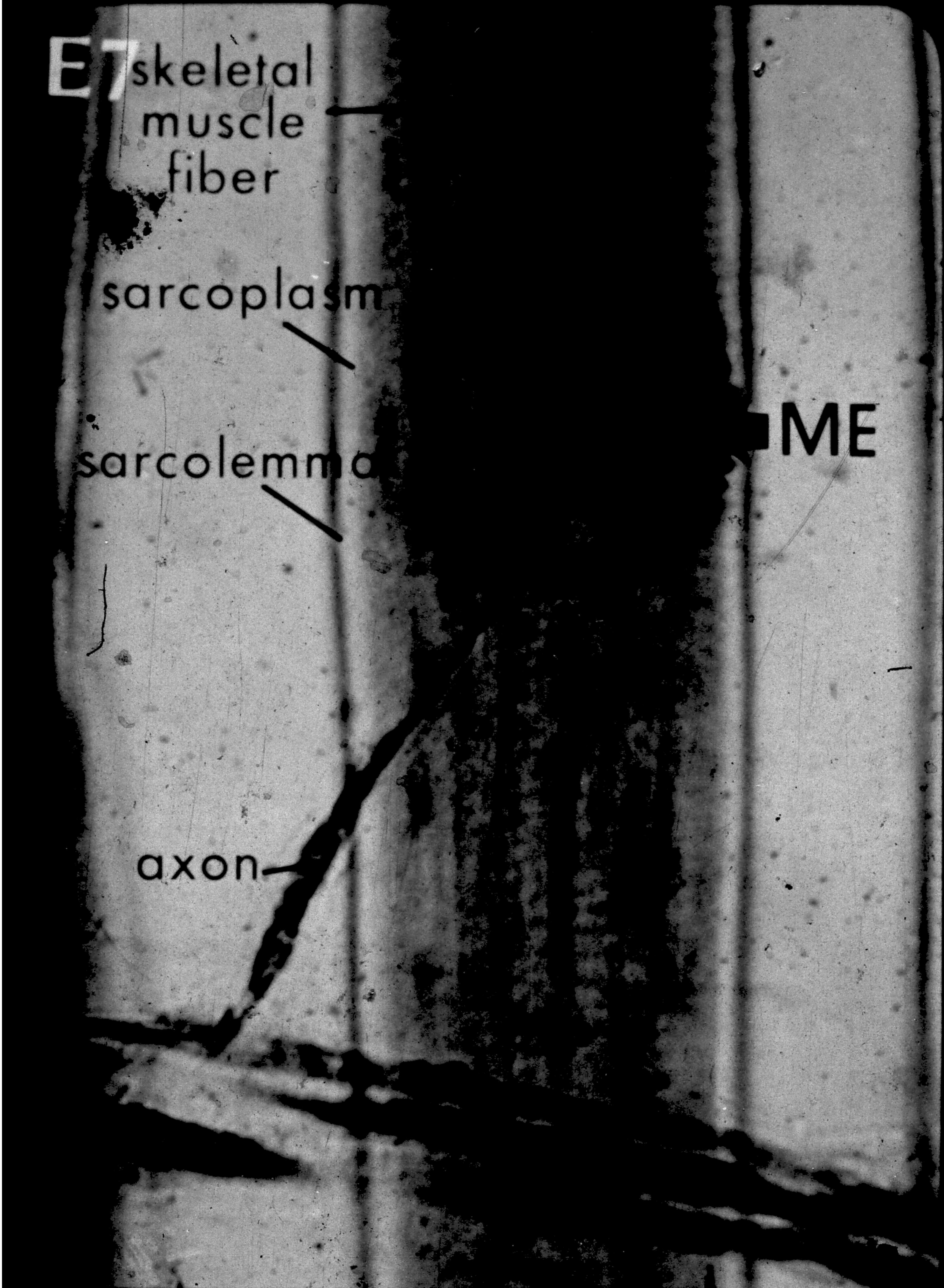


PACINIAN CORPUSCLE

AxT · Axon terminal
L · Lamellae
CT · Connective tissue

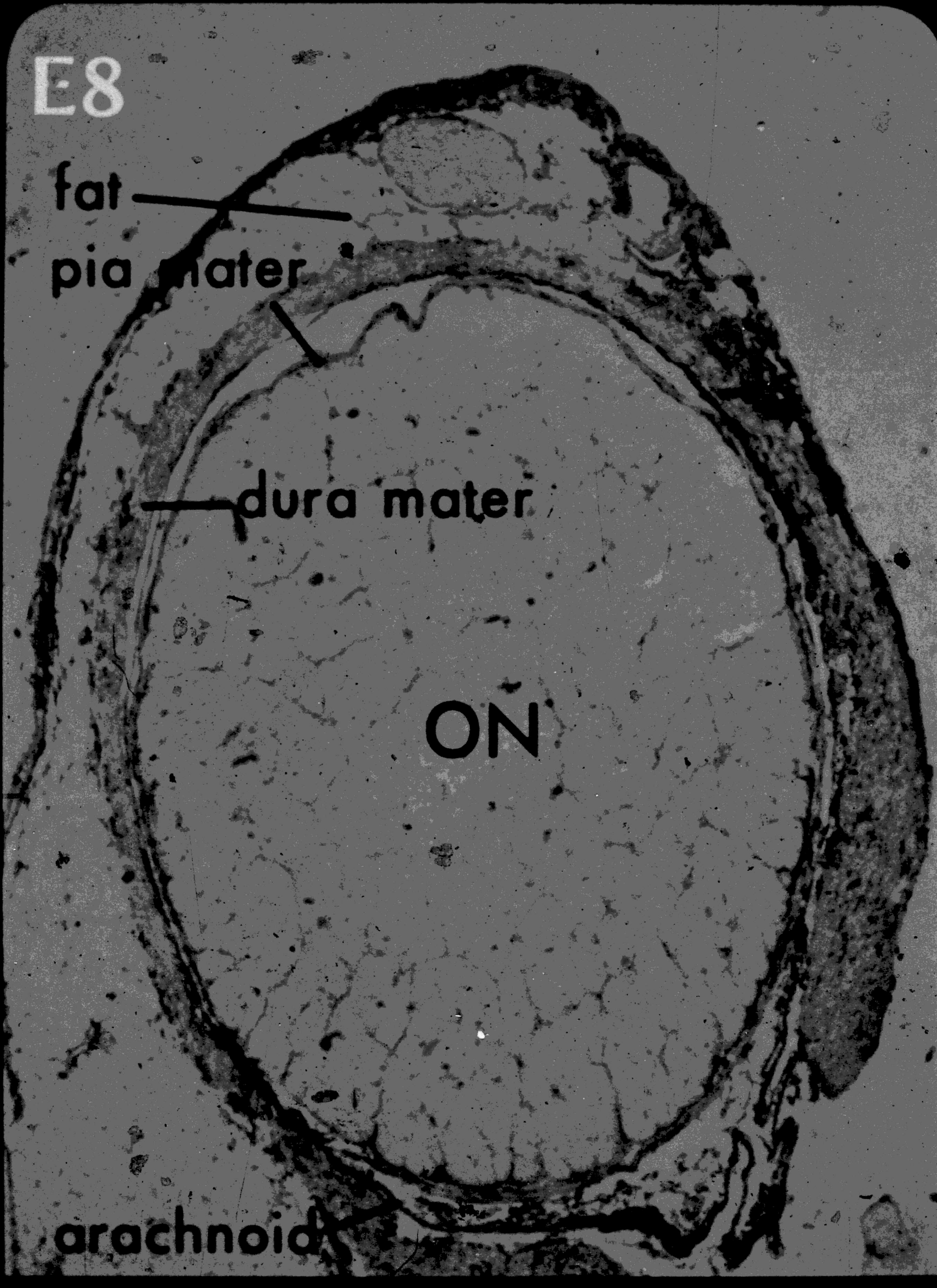


SOMATIC MUSCLE

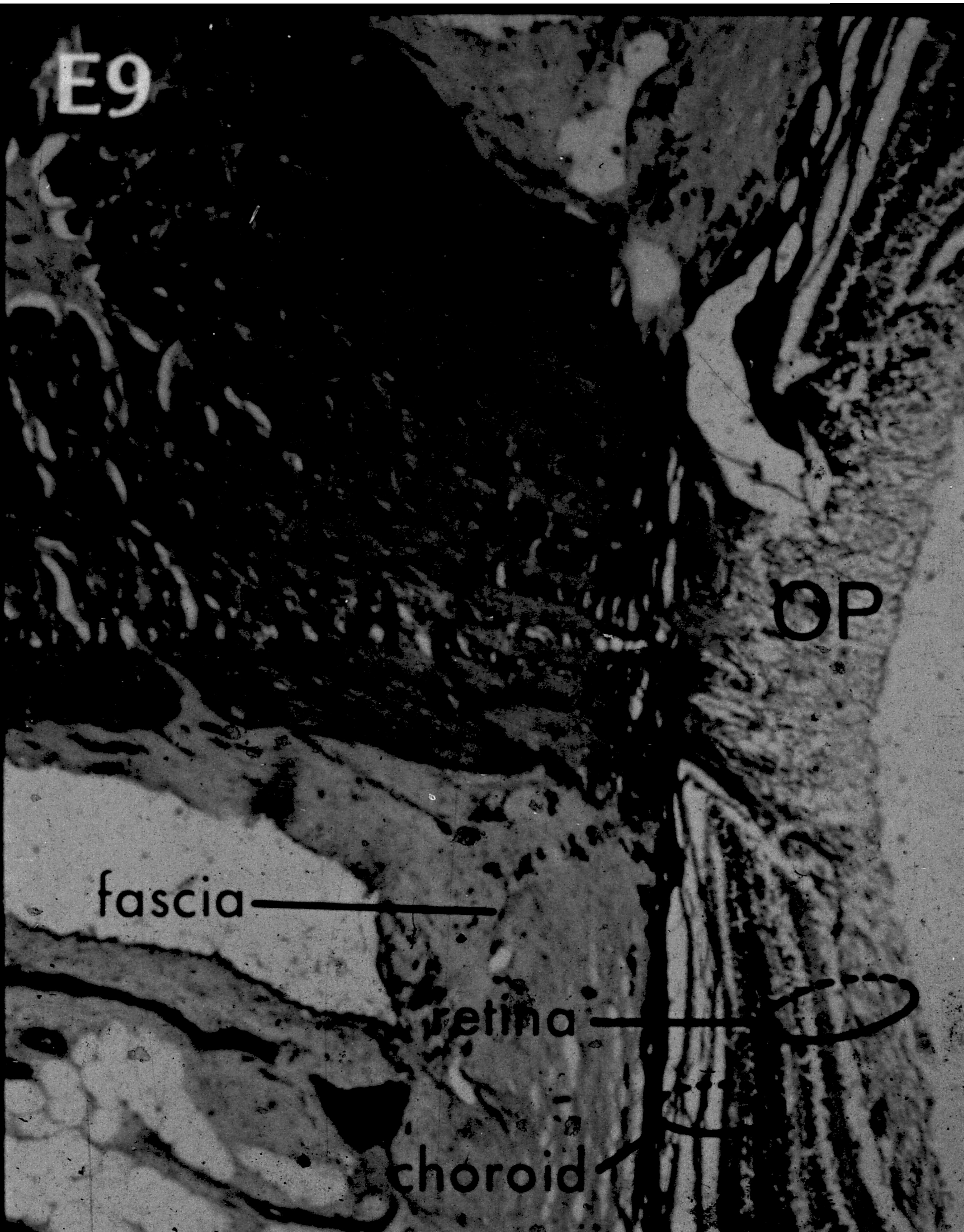


MYONEURAL JUNCTION

ME - motor endplate



OPTIC NERVE

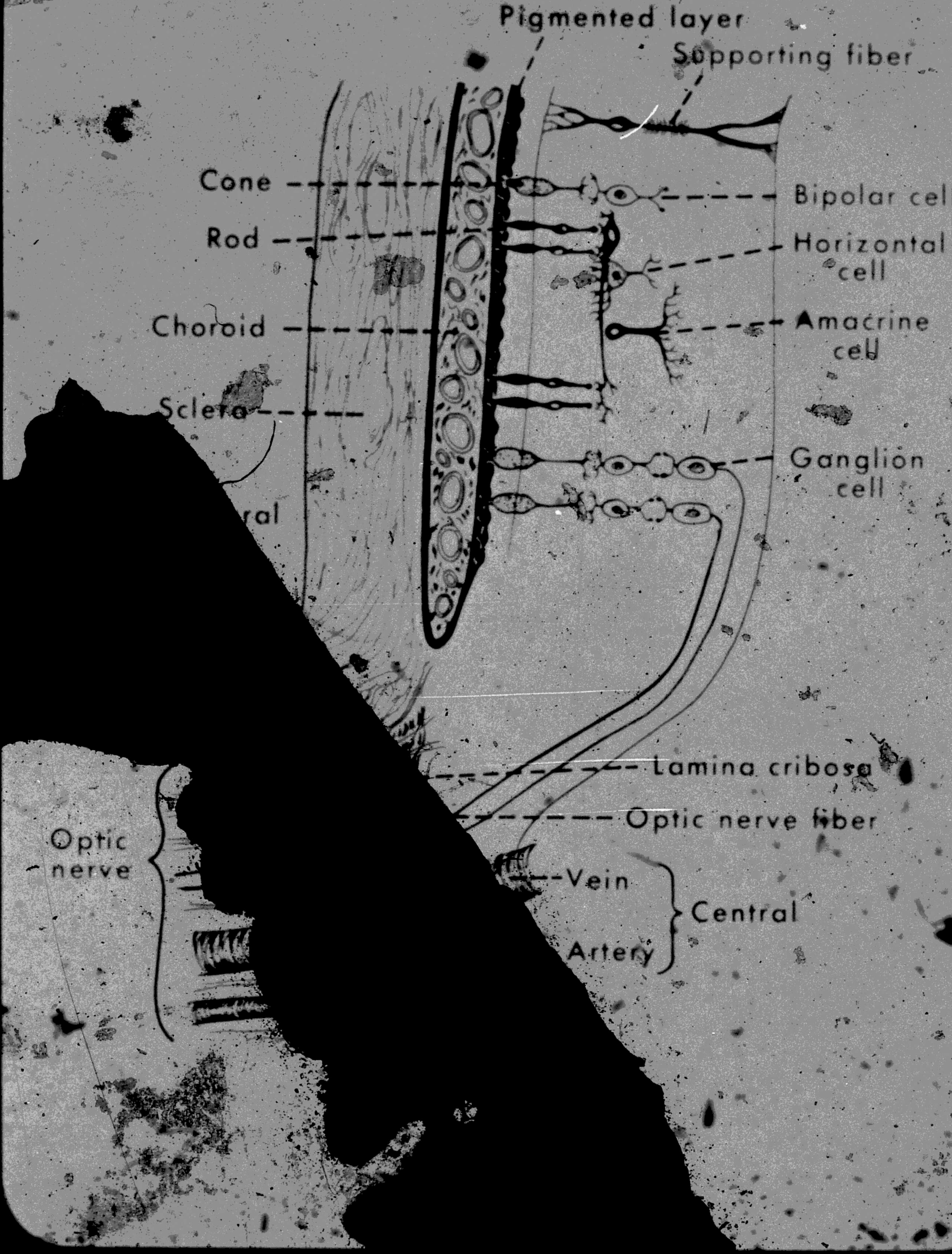


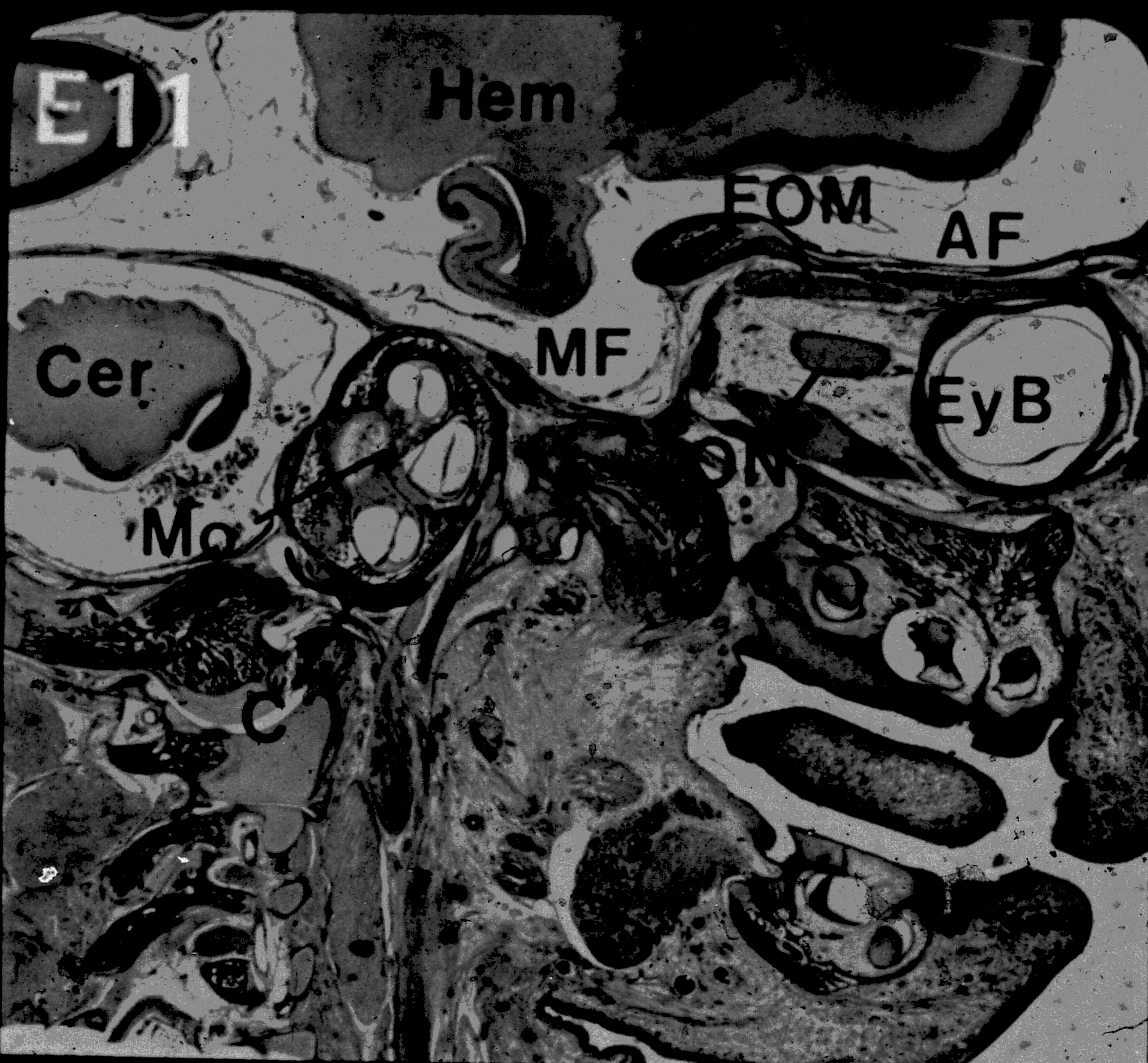
OPTIC PAPILLA

ON optic nerve OP optic papilla

E10

RELATIONSHIP OF OPTIC NERVE AND RETINAL LAYERS



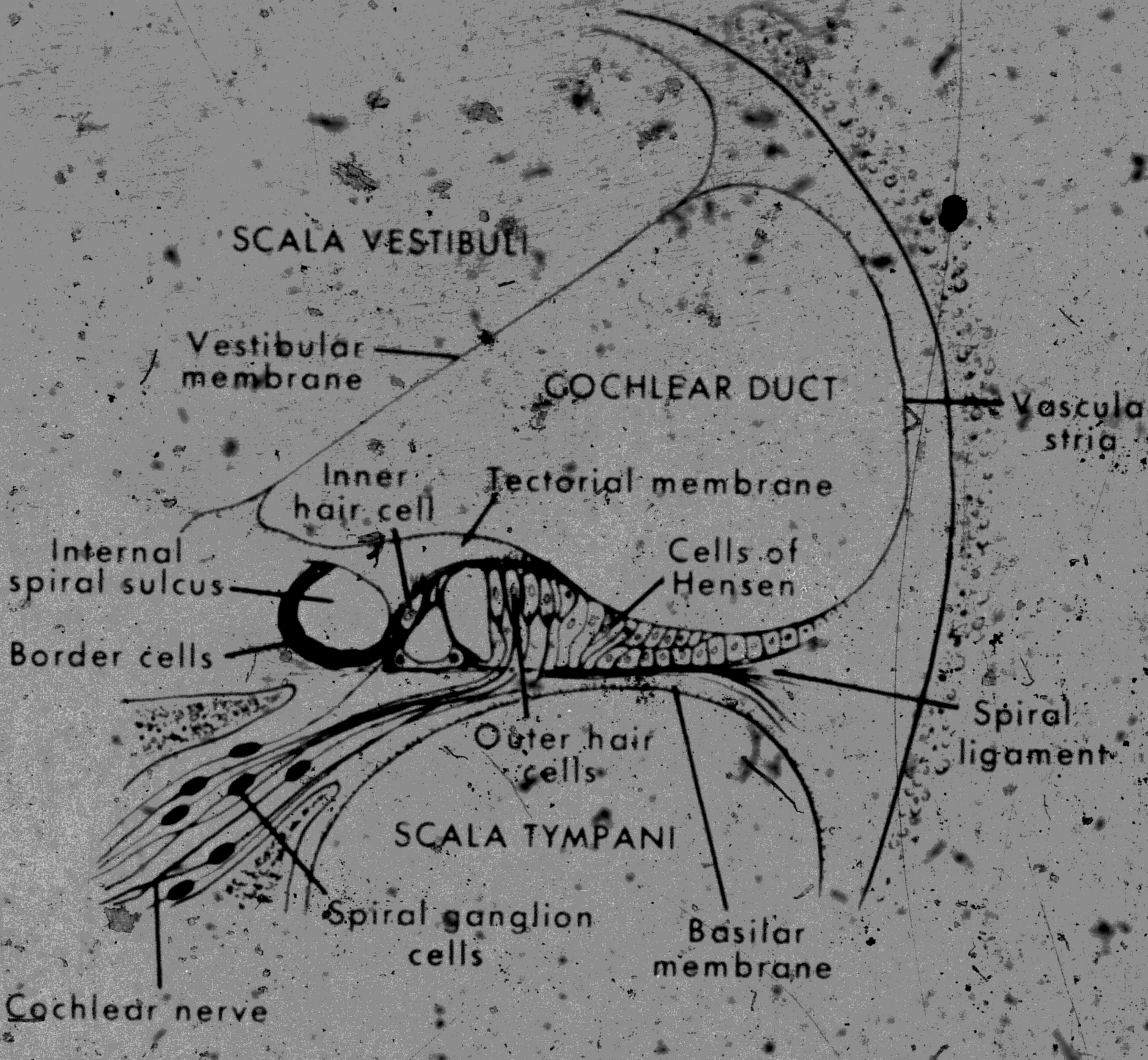


PARASAGITTAL SECTION OF FETAL HEAD

AF - anterior fossa
MF - middle fossa
Mo - modiolus
C - cochlea
EyB - eyeball (globe)
EOM - extraocular muscle
ON - optic nerve
Hem - hemisphere
Cer - cerebellum

F12

COCHLEA - CROSS SECTION ORGAN OF CORTI



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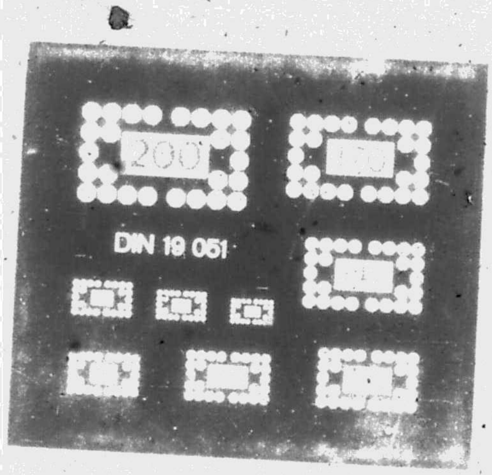

For instance, the omission of education levels as an endogenous component of poverty leads to the absence of some important feedbacks.

There are several reasons for the limitations of the model in this regard. In a number of cases, the problem is to define suitable variables, corresponding to the aspect of poverty concerned. This is true of say, status, and also of security. In other cases, such as mortality and health, the variables may be relatively easy to define, but their measurement poses problems. And dynamic problems affect a third class of variables. A case in point is the fertility (number of children) function. We may wish to explain the number of children because of its role as a component of security - but the current number of children depends on past, not current decisions. All the "stock", as opposed to "flow" variables present similar problems, a point to which we return below.

The problem, in deciding what and how many components of poverty to include in a model, is to keep the model focussed rather than diffuse, but without neglecting major aspects of poverty. The use of clustering or principal components techniques appears to provide a partial solution. This apart, the main decision rules would appear to be: (i) select elements in the poverty vector which overlap with each other as little as possible - i.e., identify a restricted number of major dimensions; but (ii) include in the poverty vector those components of poverty which have significant effects on other variables in the system of relationships, and which therefore also have an important role in the generation of poverty.

Fourthly, the model endogenises certain variables involved in the generation of poverty but not in its definition. The choice of such variables depends on the over-all theoretical perspective, but once again an important criterion is the strength of the feedbacks involved. In other words, it is desirable to endogenise those variables which have the strongest and most pervasive effects. This criterion must of course be tempered by theoretical consideration of whether the element concerned is determined by the variables included in the system, and if so whether or not a behavioural relationship can be readily specified and estimated. In terms of the relationships shown in Figure 3, we may infer that the education of the household head, which is exogenous in the model, should be given higher priority for endogenisation than water supply, which is endogenous. Moreover it is not difficult, in the light of discussion earlier in this paper to identify other variables which should be endogenous but which are exogenous or absent from the model, mostly because of data problems.

It is worth noting that frequently variables take different forms, and refer to different time periods, when included as dependent and independent variables. In the demographic relationships, for instance, it is usually household size and age structure which is the independent variable - but this structure is governed by variables such as fertility, marriage and mortality. There is therefore a need for transformation functions which relate the two sets of variables to each other, and these are absent from the model as presented. For an individual household, this is a question of accounting in an exact relationship. For whole populations, on the other hand, unless every household is included separately, it will be necessary to specify a corresponding functional relationship to close the system.

2. The structure of the system

An examination of Figure 3 indicates that there are relatively few feedbacks in the model estimated in the last section. If we track chains of relationships (continuous lines in the figure), we find that most are blocked at some point in the system. In particular, calorie intake affects only health, which affects only calorie intake; education is exogenous; income affects only calorie intake and water supply, and the latter in turn only affects health. Labour supply affects only income. These weak links in the system are not compensated by the somewhat denser relationships surrounding household size and structure, assets and occupation. Nor does this imbalance in the system adequately represent reality. The dotted lines added to Figure 3 represent a few of the relationships which might plausibly be expected to exist in practice, but which are not included in the model. Some of these were tried and proved insignificant - for instance the effect of health on labour supply. But we have reason to suppose that with improved measurement of health, a significant relationship would be observed. Similar comments on data or model specification can be made in other cases. Certain relationships were omitted because the dependent and independent variables referred to different time periods, or because there were important intervening variables on which data were missing. An example of the latter is the relationship between income and labour supply, which requires better specification of labour market variables.

Thus the absence of feedbacks is not characteristic of relationships in the generation of poverty, but in fact reflects a weakness in the system specified here. Moreover, if additional dependent variables are introduced, along the lines of the discussion above, the strength of these feedbacks would in fact be increased.

In addition to shortcomings in individual relationships between variables, there are a number of critical sets of relationships which are totally omitted from this system. One such set, referred to briefly above, concerns the labour market and production process. Labour supply, employment, occupational distribution and assets, and the incomes which are generated by the interaction of these variables, cannot be fully understood from a micro-model of this type. A macro-model of the labour market, of wage determination, and of income opportunities needs to be linked in to this part of the model. A first step would be to specify an aggregate model of labour demand and wage determination in different segments of the labour market, relating this to the aggregation of labour supply decisions.

Another set of relationships which is not captured in the model centres on the concepts of power and control. These variables are not likely to be easily incorporated in a model of this sort, since they face both conceptual and measurement problems. However, in their absence some of the major causes and effects of the asset-labour-income relationships will be missing.

A third set of relationships not adequately included here are most of the detailed demographic decisions (fertility, migration, marriage, etc.), which generate households by size, structure, location and life cycle phase, as well as education enrolment. These can however be incorporated relatively easily, using the techniques developed for the BACHUE models, provided an appropriate data base exists

A fourth set of relationships, underlying some aspects of the model, but not explicitly included, involves the determination of social norms. Norms need to be included in the model for the interpretation of outcomes in terms of deprivation; but they also contribute substantially to the explanation of behaviour, and to its changes over time. It would of course be desirable to endogenise changes in norms, but this is unlikely to be feasible.

There is little point in extending this list indefinitely. Major developments of the system of relationships represented in Figure 3 are required if it is adequately to capture the determination of poverty. It is not clear that this can be handled within a conventional econometric framework. The model estimated above already ignores certain econometric deficiencies. These could perhaps be overcome, but an extension of the model to cover issues as broad as those proposed here poses serious econometric difficulties. The model is heterogeneous, and different components have to be constructed separately. But probably the problem which it is most urgent to overcome is that posed by the time dimension. Many relationships incorporate lags, to a greater or lesser degree, which already raises problems in the use of cross-sectional data. Thus a fertility decision leads to a birth after a lag which may be as short as nine months, or which may be indefinitely long. Low calorie intake has an effect on health over time through increased susceptibility to illness. In addition to these lagged relationships between "flow" variables, "stock" variables exist which cumulate over time, linking together decisions and outcomes separated by many years. Assets, children, education, the age of individuals all cumulate as a function of current variables and of their previous values. Analogous patterns characterise the formation of social norms.

In order to adequately depict the process of poverty generation, a time dimension must therefore be included. This time dimension may also be methodologically helpful for the integration of micro- and macro-phenomena, since micro-phenomena in the current period can be aggregated into macro-outcomes, which then affect micro-behaviour in their turn, but with a lag, avoiding the complex solution procedures of simultaneous models. The need for techniques of this type points to simulation models as a framework for analysing poverty. Models small enough to provide analytical solutions are likely to be useful for certain purposes - mainly for looking at one specific issue at a time. But because such models are necessarily restricted in scope, there are strong arguments for studying the evolution of poverty by applying simulation techniques to dynamic quantitative relationships.

3. Some final comments

No final conclusions on the shape of a model of poverty generation emerge from this paper, nor was this the intention. The precise specification of a model depends on its immediate purposes and its empirical context. The general considerations discussed here are intended to help in this specification, but cannot finalise it. Several general points about ~~research~~ strategy are nevertheless worth making in lieu of a conclusion.

First, it has been argued that simulation models of the generation of poverty are worth developing. These should be broader-based than the empirically estimated model presented in section VI of this paper. They should include an endogenous vector measuring a number of key components of poverty; should explicitly show and explain deprivation; and should attempt to explain those accessible and quantifiable economic, demographic and social factors which themselves are significant in the generation of poverty. Many of these relationships can best be observed at the micro-level, but models would benefit from the inclusion of several key macro-level relationships, particularly the aggregate processes of production and distribution, but more generally relationships describing the formation and interaction of socio-economic groups, those in which the aggregation or distribution across society of individual behaviour has an independent influence on the generation of poverty, and those involving the constraints imposed by the institutional framework. It is particularly important that such models reflect the dynamic aspects of poverty - notably asset accumulation or decumulation, intra- or inter-generational mobility, cumulative demographic change, and a variety of shorter term lagged processes.

However, although a model of this type is useful, indeed may be the core of the analysis, it cannot pretend to be comprehensive. There are a number of subjects which are important to the analysis of poverty, but which, realistically, can only be incorporated in a simulation model in a very crude way, if at all. Thus specific, complementary analyses are required of sets of relationships such as obligation networks and their functions, the conditions under which they can be called on and their rôle in relieving extreme poverty. The determinants, components and consequences of security is another integrated theme for research. Similarly, work could usefully be done on the nature and impact of power, and on the determinants of social norms relevant to the definition and causation of poverty. And an important area for research is subjective deprivation, in terms of the aspirations and objectives of the poor, and of the degree of their under-achievement. It would be particularly useful to study the relationships between subjective and objective deprivation. In some of these cases the outcome of qualitative research may be quantitative inputs to modelling, but this is not necessarily the objective - each of these areas is valid as a topic for research in its own right.

This dichotomous approach to analysis has some implications for information requirements. It is clear that the data available from conventional household surveys will in general be seriously deficient, because such surveys are rarely specifically designed for the analysis of poverty. A three-fold approach to data seems to be indicated. Firstly, information on the macro, structural social framework is required - information on labour markets, production relations, power structures, normative behaviour patterns and the like. Secondly, conventional large-scale sample survey data are required, because of the considerable advantages of such data in the quantitative testing of behavioural relationships. However the surveys need to be tailored to the requirements of poverty analysis. They should focus on some of the more important variables in poverty systems, especially on variables which, while measurable in principle, are subject to considerable error, such as measures of health and assets. Survey questions need to be carefully designed so that the exact variables required by a poverty model are available. And given the importance of dynamic relationships, longitudinal data would be particularly useful. Information collected should, if possible, include not only the conventional issues of income, expenditure, labour allocation, assets, household structure, health, education, demographic variables and so on, but also unconventional variables relevant to the analysis of poverty such as deprivation, obligations and interpersonal transfers, political participation and influence, group solidarity and organisation.

But there is a limit to how far the less conventional issues can be tackled with large-scale survey instruments, and this brings us to the third level of data collection, through informal, less structured techniques. At this level, in-depth interviews can provide much useful information about life styles and obligations, about felt economic or cultural deprivation, about powerlessness and the perception of insecurity, about class consciousness and the potential for organisation. Such data may or may not contribute to the design of simulation models, but they are likely to contribute significantly to understanding certain of the qualitative aspects of poverty, which underlie or interact with such relationships as can be built into quantitative models.

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