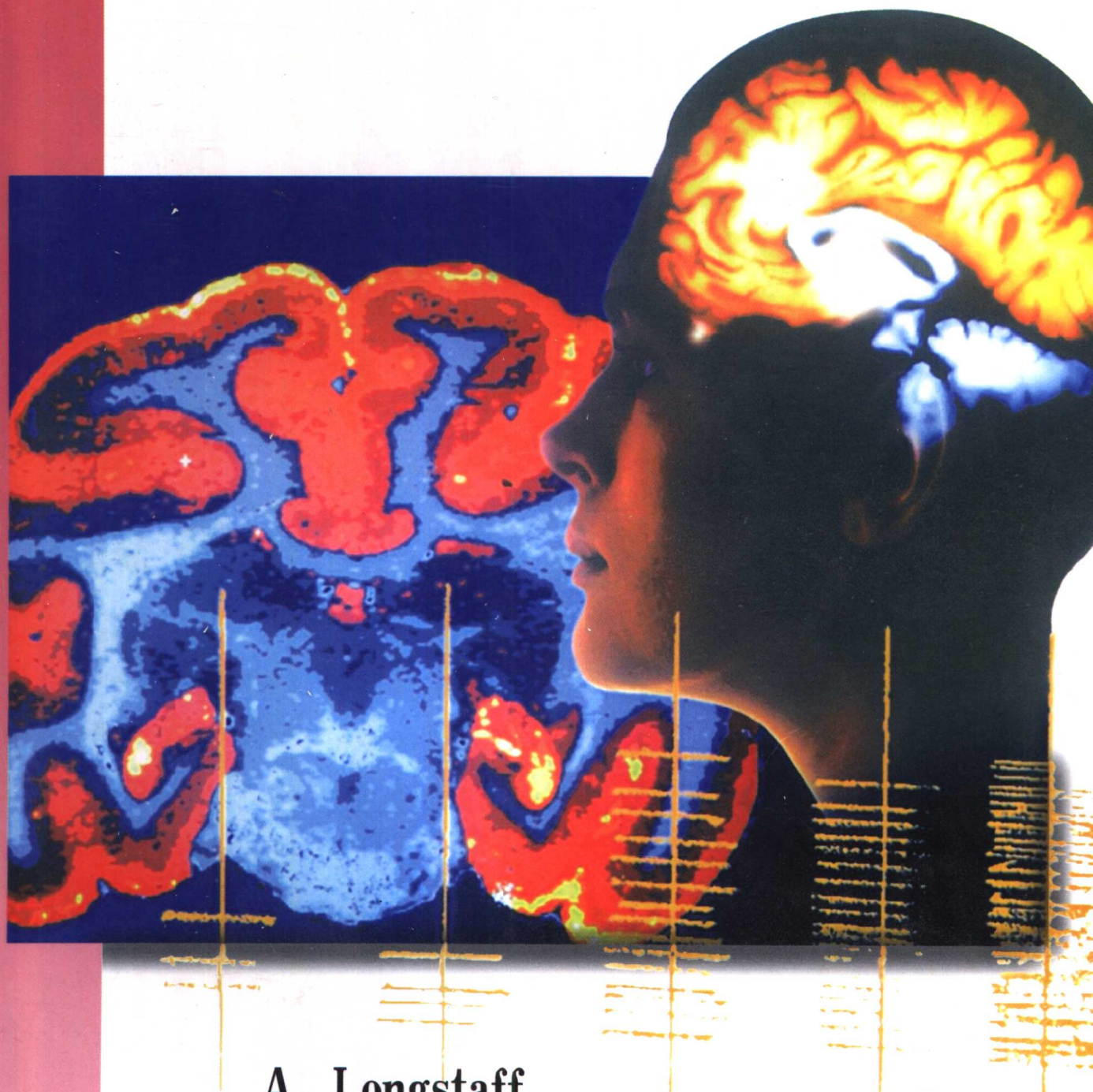
精要速览系列（影印版） Instant Notes

NEUROSCIENCE

神经科学



A. Longstaff

科学出版社

精要速览系列

Instant Notes

NEUROSCIENCE

神 经 科 学

（影印版）

A. Longstaff

Science writer and freelance lecturer in neuroscience

科 学 出 版 社

BIOS SCIENTIFIC PUBLISHERS LIMITED

2000

内 容 简 介

本书是国外优秀教材畅销榜的上榜教材，面向大学本科生，由著名的神经科学撰稿人 A. Longstaff 编写，英国著名大学具有丰富教学经验的一流教授审阅。它以一种风格独特的方式，全面、系统地概括了神经科学的核心内容和前沿动态，并以一种便于学习、利于复习的编写形式，使学生能快速、准确的掌握知识，很好地指导学习和考试。本书配有全新绘制和编写的插图与表格，非常有指导性，是其他教材无法比拟的。本书的简明和扼要也为大学教师备课提供了最好的参考。书中英文使用最为自然、易懂的语句，是提高专业外语的最佳用书。

A. Longstaff

Instant Notes in Neuroscience

Original edition published in the United Kingdom under the title of Instant Notes in Neuroscience

图字 01-2000-2683

科学出版社 出版

北京东黄城根北街 16 号

邮政编码：100717

北京双青印刷厂 印刷

科学出版社发行 各地新华书店经销

*

2000 年 9 月第 一 版 开本：787×1092 1/16

2000 年 9 月第一次印刷 印张：28

印数：1—3 000 字数：646 000

定 价：56.00 元

（如有印装质量问题，我社负责调换〈环伟〉）

精要速览系列影印版

已经推出：

Instant Notes in Biochemistry	《生物化学》
Instant Notes in Genetics	《遗传学》
Instant Notes in Molecular Biology	《分子生物学》
Instant Notes in Microbiology	《微生物学》
Instant Notes in Animal Biology	《动物生物学》
Instant Notes in Ecology	《生态学》
Instant Notes in Chemistry for Biologists	《生物学中的化学》
Instant Notes in Immunology	《免疫学》
Instant Notes in Neuronscience	《神经科学》
Instant Notes in Organic Chemistry	《有机化学》

即将推出：

Instant Notes in Developmental Biology	《发育生物学》
Instant Notes in Psycology	《心理学》
Instant Notes in Plant Biology	《植物生物学》
Instant Notes in Inorganic Chemistry	《无机化学》
Instant Notes in Physical Chemistry	《物理化学》
Instant Notes in Analytical Chemistry	《分析化学》

ABBREVIATIONS

ACh	acetylcholine
AChE	acetylcholinesterase
ACTH	adrenocorticotrophic hormone
AD	Alzheimer's disease
AII	angiotensin II
AMPA	α-amino-3-hydroxy-5-methyl-4-isoxazole-proprionic acid
ANS	autonomic nervous system
AP	action potential
apoE	apolipoprotein E
APP	amyloid precursor protein
APV	D-2-amino-5-phosphonovalerate
ATN	anterior thalamic nuclei
ATP	adenosine 5′-triphosphate
AVP	arginine vasopressin
βA	β-amyloid
βAR	β adrenoceptors
BAT	brown adipose tissue
BDNF	brain derived neurotrophic factor
bl	basal lamina
BMP	bone morphogenetic protein
α-BTX	α-bungarotoxin
CA	cornu ammonis
CaM	calmodulin
CAM	cell adhesion molecule
CaMKII	calcium–calmodulin-dependent protein kinase II
cAMP	cyclic adenosine monophosphate
CAT	computer assisted tomography
cbf	cerebral blood flow
CC	cingulate cortex
CCK	cholecystokinin
CF	characteristic frequency
cGMP	3′,5′-cyclic guanosine monophosphate
ChAT	choline acetylesterase
CL	central laminar nucleus (of thalamus)
CNG	cyclic-nucleotide-gated channel
CNS	central nervous system
CoA	coenzyme A
CPG	central pattern generators
CRH	corticotrophin releasing hormone
CRO	cathode ray oscilloscope
CS	conditioned stimulus
CSF	cerebrospinal fluid
CVA	cerebrovascular accident
CVLM	caudal ventrolateral medulla
CVO	circumventricular organ
DAG	diacylglycerol
DBL	dorsal blastopore lip
DCML	dorsal column–medial lemniscal system
DCN	dorsal column nuclei
2-DG	2-deoxyglucose
DHC	dorsal horn cell
DI	diabetes insipidus
DLPN	dorsolateral pontine nucleus
DOPAC	dihydroxyphenyl acetic acid
DRG	dorsal root ganglion
DYN	dynorphin
ECT	electroconvulsive therapy
EEG	electroencephalography
EGF	epidermal growth factor
EGL	external granular layer
EMG	electromyography
ENK	encephalin
ENS	enteric nervous system
epp	endplate potential
epsp	excitatory postsynaptic potential
ER	endoplasmic reticulum
F-actin	filamentous actin
FEF	frontal eye field
FF	fast fatiguing
FM	frequency modulation
fMRI	functional magnetic resonance imaging
FR	fatigue resistant
FRA	flexor reflex afferents
FSH	follicle stimulating hormone
G_i	inhibitory G protein
G_q	G protein coupled to phospholipase
G_s	stimulatory G protein
GABA	γ-aminobutyrate
GC	guanylyl cyclase
GDP	guanosine 5′-diphosphate
GFAP	glial fibrillary acidic protein
GH	growth hormone
GHRH	growth hormone releasing hormone
GnRH	gonadotrophin releasing hormone
GPe	globus pallidus pars externa
GPi	globus pallidus pars interna

GR	glucocorticoid receptor
GTO	Golgi tendon organs
GTP	guanosine 5'-triphosphate
5-HIAA	5-hydroxyindoleacetic acid
HPA	hypothalamic–pituitary–adrenal (axis)
HPG	hypothalamic–pituitary–gonadal (axis)
HPT	hypothalamic–pituitary–thyroid (axis)
HRP	horseradish peroxidase
5-HT	5-hydroxytryptamine (serotonin)
5-HTP	5-hydroxytryptophan
HVA	high voltage activated
IaIN	Ia inhibitory interneurons
IbIN	Ib inhibitory neurons
IC	inferior colliculus
ICSS	intracranial self-stimulation
Ig	immunoglobulin
IGF-1	insulin-like growth factor 1
IGL	internal granular layer
iGluR	ionotrophic glutamate receptor
ILD	interaural level differences
IP_3	inositol 1,4,5-trisphosphate
ipsps	inhibitory postsynaptic potential
IT	inferotemporal cortex
JGA	juxtoglomerular apparatus
L-DOPA	L-3,4-dihydroxyphenylalanine
LC	locus cerulus
LCN	lateral cervical nucleus
LDCV	large dense-core vesicle
LGN	lateral geniculate nucleus
LH	luteinizing hormone
LSO	lateral superior olivary nucleus
LTD	long-term depression
LTM	long-term memory
LTN	lateral tegmental nucleus
LTP	long-term potentiation
LVA	low voltage activated
M	magnocellular pathway
M/T	mitral/tufted cells
mAChR	muscarinic cholinergic receptor
MAO	monoamine oxidase
MAP	mean arterial (blood) pressure
MB	mammillary bodies
mepp	miniature endplate potential
MFB	medial forebrain bundle
MFS	mossy fiber sprouting
mGluR1	type 1 metabotropic glutamate receptor
MGN	medial geniculate nucleus
MI	primary motor cortex
MII	secondary motor cortex
MLCK	myosin light chain kinase
MLR	mesencephalic locomotor region
MOPEG	3-methoxy,4-hydroxy phenylglycol
MPOA	medial preoptic area
MPP^+	1-methyl-4-phenyl pyridinium
mpsp	miniature postsynaptic potential
MPTP	1-methyl-4-phenyl-1,2,3,6-tetrahydropyridin
MR	mineralocorticoid receptor
MRI	magnetic resonance imaging
MSO	medial superior olivary complex
MST	medial superior temporal cortex
NA	noradrenaline
nAChR	nicotinic cholinergic receptor
NGF	nerve growth factor
NMDA	*N*-methyl-D-aspartate
NMDAR	*N*-methyl-D-aspartate receptor
nmj	neuromuscular junction
NMR	nuclear magnetic resonance
NPY	neuropeptide Y
NREM	nonrapid eye movement sleep
NRM	nucleus raphe magnus
NST	nucleus of the solitary tract
NT3-6	neurotrophins 3-6
OC	olivocochlear
OCD	obsessive–compulsive disorder
OHC	outer hair cells
6-OHDA	6-hydroxydopamine
ORN	olfactory receptor neurons
OVLT	vascular organ of the lamina terminalis
P	parvocellular pathway
PAD	primary afferent depolarization
PAG	periaqueductal gray matter
Pc	Purkinje cells
PD	Parkinson's disease
PDE	phosphodiesterase
PDS	paroxysmal depolarizing shifts
PET	positron emission tomography
pf	parallel fibers
PFC	prefrontal cortex
PGO	pontine–geniculate–occipital spikes
PHF	paired helical filaments
PIP_2	phosphatidyl inositol-4,5-bisphosphate
PKA	protein kinase A
PM	premotor cortex

PNS	peripheral nervous system
POA	preoptic area
POM	posterior complex (medial nucleus) of thalamus
POMC	pro-opiomelanocortin
PP	posterior parietal complex
PRL	prolactin
PSNS	parasympathetic nervous system
psp	postsynaptic potential
PVN	paraventricular nucleus
RA	retinoic acid
REM	rapid eye movement sleep
RF	receptive field
RHT	retinohypothalamic tract
S	slow twitch fiber
SCG	superior cervical ganglion
SCN	suprachiasmatic nucleus
Sc	Schaffer collateral
SDN-POA	sexually dimorphic nucleus of the preoptic area
SER	smooth endoplasmic reticulum
SH2	src homology domain 2
SHH	sonic hedgehog protein
SMA	supplementary motor area
SNpc	substantia nigra pars compacta
SNzc	substantia nigra zona compacta
SNS	sympathetic nervous system
SON	supraoptic nucleus
SP	substance P
SPL	sound pressure level
SR	sarcoplasmic reticulum
SSRI	selective serotonin reuptake inhibitors
SSV	small clear synaptic vesicle
STM	short-term memory
STN	subthalamic nucleus
STT	spinothalamic tract
TB	trapezoid body
TCA	tricyclic antidepressants
TEA	tetraethylammonium
TENS	transcutaneous electrical nerve stimulation
TH	tyrosine hydroxylase
TM	transmembrane
TRH	thyrotropin releasing hormone
trk	tyrosine kinase receptors
TSH	thyroid releasing hormone
TTX	tetrodotoxin
UR	unconditioned response
US	unconditioned stimulus
VDCC	voltage-dependent calcium channel
VDKC	voltage-dependent potassium channel
VDSC	voltage-dependent sodium channel
VIP	vasoactive intestinal peptide
VLH	ventrolateral hypothalamus
VLPO	ventrolateral preoptic area
VMAT	vesicular monoamine transporter
VMH	ventromedial hypothalamus
VOR	vestibulo-ocular reflexes
VPL	ventroposterolateral nucleus (of thalamus)
VPM	ventroposteromedial nucleus (of thalamus)
VRG	ventral respiratory group
VST	ventral spinocerebellar tract
VZ	ventricular zone

PREFACE

Neuroscience is one of the most rapidly advancing areas of science and, as a consequence, spawns a literature which is growing dramatically. At one level it attempts to provide a mechanistic account of the most complex 'device' in the known Universe, the human brain. Moreover, neuroscience is multidisciplinary, having contributions from biochemistry and molecular biology, physiology, anatomy, psychology and clinical medicine, to name the most obvious. For these reasons, it is becoming increasingly difficult for lecturers and textbook authors to present neuroscience in a way that manages to be comprehensive, up-to-date and accessible, while still being sufficiently rigorous to prepare students to be successful explorers of the literature for themselves. *Instant Notes Neuroscience* is not intended as a replacement for lectures or the standard textbooks, but as an affordable text to supplement them, which is of a manageable size and in a format which aids learning.

The text is designed to provide the core of the subject in 18 sections containing 93 topics. When coming to a new subject, it is my experience that students commonly express two concerns: first, how to sort out the important ideas and facts from the wealth of detail, and second, how to get to grips with the unfamiliar terminology. Lecturers, in addition, will want students (especially later in their studies) to be able to integrate their knowledge across the subject. *Instant Notes Neuroscience* attempts to address each of these issues. Each topic is supported by a 'Key Notes' panel which gives a concise summary of the crucial points. Whenever a term appears for the first time it is in bold and immediately followed by a definition or explanation. Extensive cross-references are provided between topics so that students can forge the links that are important for integration.

This is a much slimmer volume than most neuroscience texts, which can be dauntingly large. A number of features contribute to this. First, I have tried to minimize the amount of detail without compromising the need for a database for further study. Second, while many of the methods used by neuroscientists are included, *individual* experiments or items of evidence are included only where I thought it essential to illustrate a point, or on matters that would need some justification to be convincing. Third, with a few exceptions, I have restricted examples to those most appropriate to the human condition. In so doing I have always qualified the species, since species differences matter. If not, then rats and cats would behave as humans do, which clearly they do not!

Section A introduces the cells of the nervous system, showing how they are specialized for the functions they serve. The next three sections are essentially cellular neuroscience. Section B is concerned mostly with action potentials, Section C with synapses, while Section D deals with how nerve cells act as information processors. These sections provide an introduction to the electrophysiological techniques used to study nerve cells, and say something about the molecular biology of the ion channels and receptors that govern their behavior. Section E takes a broad view of neuroanatomy and summarizes techniques, such as brain imaging, used to investigate nervous system structure. How information is encoded by the firing and connectivity of neurons is considered in Section F. All the material thus far might reasonably be found in first-year courses.

The next seven sections (G–M) form the core of systems neuroscience. Section G reviews the body senses, touch, pain and balance. Sections H and I deal with vision and hearing, respectively, while Section J looks at the chemical senses, smell and taste. The properties of skeletal muscle, motor reflexes, and the cortical control of voluntary movement are the subject of Section K, while the involvement of the cerebellum (including proprioception) and the basal ganglia in movement is covered in Section L. Neuroendocrinology, and both peripheral and central aspects of the autonomic nervous system appear in Section M, which also (and unusually for standard neuroscience texts) includes the functions of smooth and cardiac muscle, and the enteric nervous system. A short Section N describes the essential features of amine transmission, the basis for much neuropharmacology, and paves the way for understanding aspects of behavior, such as motivation and sleep that are included in Section O. Section P is

an overview of how the embryonic nervous system develops, ranging from how the basic plan is genetically specified, to how differences between male and female brains might arise. Section Q addresses how the nervous system continues to rewire itself on the basis of experience (i.e., learning and memory). Finally, although quite a number of nervous system disorders are considered at appropriate places throughout the book, section R takes the four most common neuropathologies, stroke, epilepsy, Parkinson's disease and Alzheimer's dementia and looks in some detail at what has gone amiss and what current and future treatments may do. Space precluded the inclusion of topics on two major psychiatric disorders (schizophrenia and depression) in the text; it is intended that these topics will be made available on the BIOS website free of charge. At the end of the book is a reading list for those who wish to take their studies further.

As a student, how should you use this book? Restrict your reading only to the sections and topics covered by your current course. That said, Sections A–F are likely to appear in, or be required knowledge for, just about any neuroscience program; you will probably need to work through these first. Later sections can be dipped into in any order. Read the main sections thoroughly first, making sure that you *understand* the ideas, and use the 'Related topics' to make links, just as you would if you were surfing the internet. Where appropriate, reference is made to areas that are covered in more detail in the companion volumes, *Instant Notes in Biochemistry*, 2nd edn, and *Instant Notes in Molecular Biology*, 2nd edn. At this stage you can incorporate additional material from lectures or other textbooks in the gaps at the end of topics, or highlight things which seem to be particularly important for your course. Studying *Instant Notes Neuroscience* 'little but often' is a good strategy. The information density in the text is high, so many short, concentrated, bursts are much more effective than a few eight-hour stints. The more times you work through a topic, the better your understanding, and the more likely you will be to remember it clearly. When it comes to revision, use the 'Key Notes' as a prompt. In addition, you should aim to be able to write, from memory, a few sentences about each of the terms that appears in bold in the main text. Being able to reproduce the simpler diagrams is also an effective way of getting your point across in an exam. Neuroscience is an extraordinary endeavor because it aims to reveal what, in essence, it is to be human; how we behave, think and feel as we do. At the moment we are a long way from being able to give a coherent account of any of these faculties; that there is so much still to be done is one reason that this science is so exciting. This book is an account of the remarkable progress made so far. I hope you find that it serves your needs well and that, like me, you enjoy discovering neuroscience.

Acknowledgements

A number of colleagues – Barry Hunt, Vasanta Raman and John Wilkinson, all at the University of Hertfordshire – kindly read through some individual topics and made very helpful suggestions. David Hames (University of Leeds, UK), Kevin Alloway (Penn State University, USA), and Patricia Revest (Queen Mary and Westfield College, London University, UK), were each brave enough to read through the entire text and their thought-provoking comments have been important in shaping the final version. I am very grateful to all of these people for their time and expertise. Finally, I thank Jonathan Ray, Rachel Offord, Will Sansom and Fran Kingston at BIOS Scientific Publishers for their encouragement and patience.

Alan Longstaff

A1 NEURON STRUCTURE

Key Notes

Cell body

The neuron cell body contains all the subcellular organelles found in a typical animal cell but it is specialized to maintain high rates of protein synthesis, as shown by the ribosome-packed Nissl bodies.

Neurites

Neurites are long projections from the cell body. There are two types of neurite, dendrites and axons. Dendrites are large extensions of the cell body and receive most of the synaptic inputs impinging onto the cell. Neurons may have one or many dendrites. Neurons have a single axon arising from the axon hillock. Axon terminals form the presynaptic components of synapses.

Axon or dendrite?

The two neurites can be distinguished on structural grounds. Dendrites contain many organelles and are capable of protein synthesis. By contrast, axons cannot synthesize protein, so axonal proteins are derived from the cell body. Axons and dendrites both have mitochondria. Organelles are transported into neurites via microtubules.

Related topic Morphology of chemical synapses (A3)

Cell body

The cell body (**soma** and **perikaryon** are synonyms) of a neuron (see *Fig. 1*) contains the nucleus, Golgi apparatus, ribosomes and other subcellular organelles, and is responsible for most of its routine metabolic 'housekeeping' functions. The neuronal perikaryon is not so different from non neuronal cells although structurally it is specialized to maintain high levels of biosynthetic activity. The rough endoplasmic reticulum, for example, is so densely packed as to produce distinct structures called **Nissl bodies** which are extremely rich in ribosomes. This reflects the high rates of protein synthesis of which neurons are capable.

Because there is a great variety of types of neurons, their cell bodies vary in size considerably. The smallest are some 5–8 μm in diameter, the largest 120 μm across.

Neurites

Neurons are distinguished from other cells by **neurites**, long (relative to the cell body) cylindrical processes that come in two varieties, dendrites and axons. **Dendrites** are highly branched extensions of the cell body, may be up to 1 mm in length and account for up to 90% of the surface area of many neurons. Dendrites on some neurons are covered with hundreds of tiny projections termed **dendritic spines** on which synapses (see below) are made. Nerve cells with spines are sometimes called **spiny neurons**, those lacking them **aspiny neurons**. A neuron may have one or many dendrites, arranged in a pattern which is cell typical and collectively referred to as the **dendritic tree.** The majority of synaptic inputs from other neurons are made on dendrites.

CONTENTS

A1 NEURON STRUCTURE

Key Notes

Cell body

The neuron cell body contains all the subcellular organelles found in a typical animal cell but it is specialized to maintain high rates of protein synthesis, as shown by the ribosome-packed Nissl bodies.

Neurites

Neurites are long projections from the cell body. There are two types of neurite, dendrites and axons. Dendrites are large extensions of the cell body and receive most of the synaptic inputs impinging onto the cell. Neurons may have one or many dendrites. Neurons have a single axon arising from the axon hillock. Axon terminals form the presynaptic components of synapses.

Axon or dendrite?

The two neurites can be distinguished on structural grounds. Dendrites contain many organelles and are capable of protein synthesis. By contrast, axons cannot synthesize protein, so axonal proteins are derived from the cell body. Axons and dendrites both have mitochondria. Organelles are transported into neurites via microtubules.

Related topic Morphology of chemical synapses (A3)

Cell body

The cell body (**soma** and **perikaryon** are synonyms) of a neuron (see *Fig. 1*) contains the nucleus, Golgi apparatus, ribosomes and other subcellular organelles, and is responsible for most of its routine metabolic 'housekeeping' functions. The neuronal perikaryon is not so different from non neuronal cells although structurally it is specialized to maintain high levels of biosynthetic activity. The rough endoplasmic reticulum, for example, is so densely packed as to produce distinct structures called **Nissl bodies** which are extremely rich in ribosomes. This reflects the high rates of protein synthesis of which neurons are capable.

Because there is a great variety of types of neurons, their cell bodies vary in size considerably. The smallest are some 5–8 μm in diameter, the largest 120 μm across.

Neurites

Neurons are distinguished from other cells by **neurites**, long (relative to the cell body) cylindrical processes that come in two varieties, dendrites and axons. **Dendrites** are highly branched extensions of the cell body, may be up to 1 mm in length and account for up to 90% of the surface area of many neurons. Dendrites on some neurons are covered with hundreds of tiny projections termed **dendritic spines** on which synapses (see below) are made. Nerve cells with spines are sometimes called **spiny neurons**, those lacking them **aspiny neurons**. A neuron may have one or many dendrites, arranged in a pattern which is cell typical and collectively referred to as the **dendritic tree.** The majority of synaptic inputs from other neurons are made on dendrites.

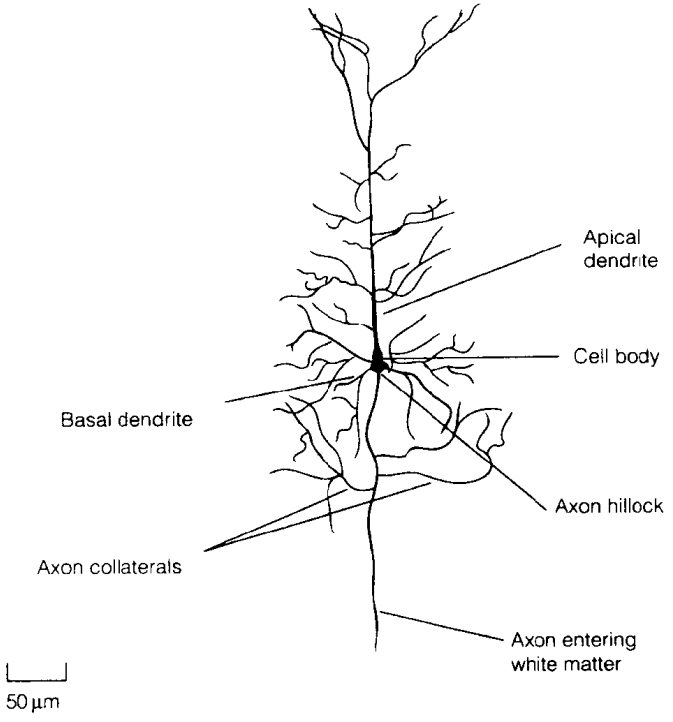


Fig. 1. Key features of a neuron. A drawing of a pyramidal cell showing the distribution of neurites (dendrites and axon).

Nerve cells usually have only one **axon** which arises typically from the cell body but may emerge from a proximal dendrite (the end of a dendrite closest to the soma). In either case, the site of origin is termed the **axon hillock**. Axons have diameters ranging from 0.2 to 20 µm in humans (though axons of invertebrates can reach 1 mm) and vary in length from a few µm to over a meter. They may be encapsulated in a **myelin sheath**. Axons usually branch, particularly at their distal end (furthest from the soma). These branches are referred to as **axon collaterals.** The ends of an axon are swollen **terminals** (or **boutons**) and usually contain mitochondria and vesicles. Some axons have a tuft of branches (a **terminal arbor**) at their tip, each with its terminal bouton, some have boutons along their length where they are described as **varicosities**. Axon terminals form the presynaptic component of chemical synapses.

Axon or dendrite? Axons can be distinguished from dendrites on structural grounds. Axons tend to be long, untapered, less highly branched, never spiny and may have a myelin sheath, whereas dendrites are shorter, tapered, highly branched and may bear spines. Dendrites are extensions of the cell body in that they contain Golgi apparatus, rough endoplasmic reticulum and ribosomes – organelles not seen in axons. By contrast both axons and dendrites have mitochondria. Since axons do not possess protein synthetic machinery, proteins in axons must be made in the cell body and subsequently moved into and along the axon by a mechanism called axoplasmic transport. Axon terminals are often rich in mitochondria which indicates their high requirement for metabolic energy.

Differences in organelle composition are thought to result from the differing arrangements of **microtubules** in the two types of neurite. Microtubules are long protein polymers that are part of the internal scaffolding of cells called the **cytoskeleton**. Microtubules act as 'tramlines' along which organelles are moved within the cell. The two ends of a microtubule are different, designated + and – ; thus microtubules have a distinct polarity which means that organelles move along them in a specific direction. Mitochondria move in the – to + direction whereas other organelles move in the + to – direction. Both dendrites and axons have microtubules, but whereas dendrites have them orientated in either direction, those in axons are always arranged with their + ends away from the cell body. Thus axonal microtubules can transport mitochondria out of the cell body into the axon but cannot transport other organelles. Because microtubules are orientated in both directions in dendrites, all organelles are transported into these neurites.

When a neuron develops, it first grows a number of processes which are indistinguishable. It is not yet known how one of these is subsequently selected to differentiate into an axon. The first sign that a process will become an axon is that it grows at a much faster rate than those which are destined to be dendrites.

A2 CLASSES AND NUMBERS OF NEURONS

Key Notes

Neuron classification

Neurons may be classified by their morphology, function or by the neurotransmitter they secrete. Cells with one, two or three or more neurites are classed as unipolar, bipolar or multipolar respectively. The shape of the dendritic tree, or whether the dendrites have dendritic spines and the length of the axon have proved useful in categorizing neurons. Functional classification distinguishes between sensory neurons which respond directly to physiological stimuli and motor neurons which synapse with effectors.

Neuron numbers

The human nervous system may contain 300–500 billion neurons. Neuron density is quite constant across the cerebral cortex and between cerebral cortices of different mammals. Smaller brains have fewer neurons.

Related topics

Organization of the peripheral nervous system (E1)
Organization of the central nervous system (E2)

Neuron classification

There is no such thing as a 'typical' neuron. Nerve cells come in a wide variety of shapes and sizes with widely differing numbers and patterns of synaptic contacts using distinct neurotransmitters. Hence neurons are classified either according to morphology, function or by their neurotransmitters, and the assumption is that all neurons falling into a single class have similar functions.

Structural considerations to classifying a given cell include the size of the cell body, the number of neurites it has, the pattern of its dendritic tree, axon length and the nature of the connections it makes. A neuron with a single neurite is **unipolar**, one with two neurites is **bipolar** while a neuron with three or more neurites is said to be **multipolar** (*Fig. 1*). The majority of neurons in the vertebrate nervous system are multipolar but there are important exceptions. For example, a population of neurons in the retina which synapse with photoreceptors are bipolar and sensory neurons in the dorsal root ganglion are described as **pseudounipolar**; technically they are bipolar because they start life with two processes but these subsequently fuse. Invertebrate nervous systems are dominated by unipolar neurons.

Dendrites are used to classify neurons on the basis of whether or not they have dendritic spines and the overall pattern of their dendritic tree. The shape of any dendritic tree helps to determine the efficacy of its synaptic connections and so to the functioning of the cell. **Pyramidal** cells, so-called because of the shape of their cell bodies, comprise some 60% of neurons in the cerebral cortex and have dendrites which extend to fill a pyramidal space. A second population of cortical cells are termed stellate cells because of the star-like appearance of