

Biology of Sensory Systems



C.U.M. Smith

WILEY

CONTENTS

Preface	ix	3.9 Conclusion	34
PART I: PRELIMINARIES		Box 3.1 Hermann von Helmholtz..	28
Chapter 1 Elements	1	Chapter 4 Evolution and Classification of Organisms	35
1.1 Allosteric effectors	3	4.1 Systematics	35
1.2 Membranes	4	4.2 Classification into six kingdoms	36
1.3 Receptor molecules	5	4.3 Unicellularity	36
1.4 Membrane signalling systems	9	4.4 Multicellularity	37
1.4.1 G-proteins	10	4.5 Protostomes and deuterostomes	37
1.4.2 Effectors and second messengers	10	4.6 Classification of the metazoa	39
1.5 Channels and gates	12	4.7 Conclusion	43
1.5.1 Ligand-gated ion channels (LGICs)	13	Self-assessment	44
1.5.2 Voltage-gated ion channels (VGICs)	13	Notes and Bibliography	47
1.6 Conclusion	15		
Chapter 2 Membrane and Action Potentials	16	PART II: MECHANOSENSITIVITY	51
2.1 The measurement of resting potentials	17	Chapter 5 Mechanosensitivity of Cell	
2.2 The ionic bases of resting potentials	17	Membranes	53
2.3 Electrotonic potentials and cable conduction	20	5.1 Mechanosensitive channels in <i>E. coli</i>	53
2.4 Receptor and generator potentials	21	5.2 Detection of osmotic swelling by hypothalamic cells in mammals	57
2.5 Sensory adaptation	22	5.3 Conclusion	60
2.6 Action potentials	23	Chapter 6 Kinaesthesia	61
2.7 Conclusion	25	6.1 Kinaesthetic mechanisms in arthropods	61
Chapter 3 General Features of Sensory Systems	26	6.1.1 Stretch receptors in crustacean muscle	62
3.1 Classification of the senses	27	6.1.2 Insect sensilla	63
3.2 Modality	27	6.1.3 Maintenance of equilibrium in flight	68
3.3 Intensity	29	6.2 Kinaesthetic mechanisms in mammals	68
3.4 Adaptation	31	6.2.1 Intrafusal spindle endings	69
3.5 Receptive fields	31	6.2.2 Golgi tendon organs	72
3.6 Maps of sensory surfaces	32	6.2.3 Joint receptors	74
3.7 Hierarchical and parallel design	33	6.3 Conclusion	75
3.8 Feature extraction and trigger stimuli	33		

CONTENTS

Chapter 7 Touch	76	11.2 Structure	160
7.1 Mechanoreception in <i>Caenorhabditis elegans</i>	76	11.3 Physiology	160
7.2 Insects	80	11.4 Biochemistry	161
7.2.1 Acoustic sensilla and tympanic organs	80	11.5 Conclusion	162
7.3 Tactile receptors in mammalian skin	84	Chapter 12 Gustation	164
7.3.1 Fast adapting receptors	84	12.1 Gustation in insects	165
7.3.2 Slow adapting receptors	86	12.2 Gustation in mammals	167
7.4 Cerebral analysis of touch	86	12.2.1 Taste buds	168
7.5 Plasticity of the somaesthetic cortex	90	12.2.2 Central projections	174
7.6 Conclusion	92	12.3 Labelled lines or population profile?	175
Chapter 8 Equilibrium and Hearing: the Uses of Hair Cells	93	12.4 Conclusion	175
8.1 Anatomy and physiology of hair cells	93	Chapter 13 Olfaction	177
8.2 Lateral line canals	97	13.1 Insect olfactory systems	177
8.3 Evolution of the vertebrate ear	99	13.1.1 Hygroreceptors	178
8.3.1 Equilibrium	99	13.1.2 Olfactory sensilla and pheromones	179
8.3.2 Phonoreception	101	13.2 Vertebrate olfactory systems	180
8.3.3 Bat sonar	112	13.2.1 Olfactory epithelium of the nasal cavity	180
8.4 Conclusion	113	13.2.2 Olfactory receptor cells	182
Box 8.1 Biophysics of cochlear hair cells	109	13.2.3 Molecular biology	182
Chapter 9 Cerebral Analysis	114	13.2.4 Central processing	185
9.1 Vestibular pathway and reflexes	115	13.3 The vertebrate vomeronasal organ and pheromones	187
9.2 Auditory pathway	117	13.4 Conclusion	188
9.3 Mapping auditory space: the barn owl	120	Self-assessment	189
9.4 Auditory cortex	123	Notes and Bibliography	191
9.5 Bat auditory system and echolocation	125		
9.6 Human auditory cortex and language	129		
9.7 Lateralisation and the neuroanatomy of language	133	PART IV: PHOTORECEPTIVITY	195
9.8 Callosectomy and after	134		
9.9 Conclusion	137	Box 14.1: Bacteriorhodopsin	199
Box 9.1 Broca and Wernicke	135	Chapter 14 Invertebrate Vision	203
Self-assessment	138	14.1 Designs of invertebrate eyes	203
Notes and Bibliography	143	14.1.1 Evolution of the vesicular eye	207
PART III: CHEMOSENSITIVITY	149	14.1.2 Evolution of the compound eye	207
Chapter 10 Chemosensitivity in Prokaryocytes	151	14.1.3 Scanning eyes	210
10.1 Chemosensitivity in <i>E. coli</i>	151	14.2 Examples of invertebrate eyes	211
10.1.1 Molecular genetics	153	14.2.1 Eyespots of the protista	212
10.2 Conclusion	156	14.2.2 The pinhole eye of <i>Nautilus pompilius</i>	216
Chapter 11 Mammalian Chemo-enteroreceptors	157	14.2.3 The mirror eye of <i>Pecten</i> (the scallop)	216
11.1 Location of mammalian chemo-receptors for PaO_2 and PaCO_2	158	14.2.4 The vesicular eye of <i>Octopus</i>	218
		14.2.5 The lateral eyes of <i>Limulus</i> , the King or Horseshoe 'Crab'	222
		14.2.6 The advanced compound eye	225

80	14.3 Conclusion	227	Chapter 18 Other Vertebrate Visual Systems	319
90	Box 14.1 The evolution of opsins	204	18.1 Visual pigments	319
01	Box 14.2 Early genetics of eyes	213	18.2 Photoreceptors	320
11			18.3 Tapeta	324
21			18.4 Retinae	325
31	Chapter 15 The Human Eye	229	18.4.1 Deep sea fish	325
41	15.1 Anatomy	230	18.4.2 Frog	325
51	15.1.1 Eyeball	230	18.4.3 Areae centrales of mammals and birds	326
61	15.1.2 Adnexa	231	18.5 Dioptric apparatus	328
71	15.2 Embryology	234	18.6 Median eyes	332
81	15.3 Detailed anatomy and physiology	239	18.7 Visual pathways	334
91	15.3.1 Cornea	239	18.8 Visual centres in the brain	334
101	15.3.2 Sclera	244	18.9 Conclusion	337
111	15.3.3 Lens	245	Self-assessment	338
121	15.3.4 Uveal tract	250	Notes and Bibliography	344
131	15.3.5 Iris	255		
141	15.3.6 Vitreous humour	258		
151	15.4 Movements of the eyeball	258		
161	15.5 Conclusion	261		
171	Box 15.1 Genetics of cataract	249		
Chapter 16 The Retina	262	PART V: OTHER SENSES	353	
16.1 Retinal pigment epithelium (RPE)	263	Chapter 19 Thermosensitivity	355	
16.2 Retina	265	19.1 Molecular biology	356	
16.2.1 Photoreceptor cells	266	19.2 Poikilotherms	357	
16.2.2 Horizontal cells	278	19.3 Homeotherms	357	
16.2.3 Bipolar cells	279	19.3.1 Thermoreceptors in the skin	358	
16.2.4 Müller cells	282	19.3.2 Deep thermoreceptors	359	
16.2.5 Interplexiform cells	282	19.3.3 Hypothalamic thermoreceptors	360	
16.2.6 Amacrine cells	283	19.4 Conclusion	360	
16.2.7 Ganglion cells	283	Chapter 20 Minority Senses	361	
16.2.8 Wiring diagrams	284	20.1 Infra-red radiation	362	
16.2.9 Colour	288	20.2 Polarised light	363	
16.3 Conclusion	290	20.3 Electric fields	366	
16.3.1 Box 16.1 Retinitis pigmentosa	287	20.4 Magnetic fields	370	
Chapter 17 Visual Pathways and Cortices	292	20.5 Conclusion	372	
17.1 Visual pathways into the brain	293	Chapter 21 Pain	373	
17.1.1 The retino-tectal pathway	293	21.1 The biological significance of pain	374	
17.1.2 The retino-geniculo-striate (RGS) pathway	294	21.2 Neurophysiology of pain	376	
17.2 Primary visual cortex	297	21.2.1 Peripheral nociceptors	376	
17.2.1 Structure	297	21.2.2 Central pathways	378	
17.2.2 Functioning	297	21.3 Neuropharmacology of pain pathways	381	
17.2.3 Plasticity	307	21.4 Referred pain	382	
17.3 Extrastriate cortices	311	21.5 Gate theory	383	
17.4 Face recognition	313	21.6 Conclusion	384	
17.5 Prosopagnosia	314	Self-assessment	386	
17.6 Conclusion	317	Notes and Bibliography	389	
17.6.1 Box 17.1 Blindsight	312			

CONTENTS

PART VI: CODA.		
	393	23.2 Qualia.....
		23.3 <i>Tabulae rasa?</i>
	395	23.4 Epigenetic epistemology
Chapter 22 Recurring Themes.....	396	23.5 Evolutionary epistemology
22.1 Molecular themes.....	399	23.6 Beyond Descartes.....
22.2 Cellular themes	400	23.7 Conclusion
22.3 Sense organs	401	Box 23.1: Sensory substitution.....
22.4 Central analysers	403	Self-assessment.....
22.5 Homeostasis	404	Notes and Bibliography
22.6 Different sensory worlds.....	405	<i>Appendix: Some techniques</i>
22.7 From abiotic to biotic: communication	406	<i>List of Acronyms</i>
22.8 Conclusion	407	<i>Glossary</i>
Chapter 23 Philosophical Postscript.....	407	<i>Index</i>
23.1 Descartes.....	407	