

Contents

Acknowledgments

About the Author

1	Introduction	1
	The Emergence of Sensory Science	2
	Animals Discussed in This Book	4
	Organization of the Book	5
	Do Animals Have Conscious Experience?	5
2	Vision in Vertebrates	7
	The Vertebrate Eye	7
	How the Retinal Image Is Formed	7
	Cells of the Retina	10
	Adaptations for Vision in Bright and Dim Light	11
	Rods and Cones	12
	Vision and the Brain	15
	From Retina to Brain	16
	Visual Cortex	16
	Optic Tectum	20
	Superior Colliculus	22
	Central Visual Processing in Birds	23
	Perceptual Organization in Animals	24
	Figure and Ground	24
	Amodal Completion	26
	Effects of Artificial Light at Night	27
	Summary	29
3	Vision in Invertebrates	31
	Arthropods	31
	Simple and Compound Eyes	31
	The Arthropod Brain	36
	Molluscs	37
	Evolution of Mollusc Eyes	37
	Molluscan Visual Receptors	40
	Vision in the Octopus	41
	Light Sensitivity in the Skin	44
	The Octopus Brain	44
	Camouflage in Cuttlefish	46
	Summary	47
4	Color Vision	49
	Color Vision in Mammals	50
	Dogs, Cats, and Other Nonprimates	50
	Humans	51
	Other Primates	53

Color Vision in Nonmammalian Vertebrates	54
Fish	54
Amphibians	56
Reptiles	56
Birds	57
Color Vision in Arthropods	58
Insects	58
Crustaceans	61
Do Molluscs Have Color Vision?	62
Color Changes in Cephalopods	62
How Cephalopods Change Color	63
The Case for Colorblindness	63
Summary	64
5 Visual Space Perception	65
Perceiving Egocentric Direction	65
Depth Perception	66
Motion Parallax	66
Pictorial Depth Cues	68
Binocular Disparity	70
Visual Navigation	72
Landmarks	73
The Sun Compass	74
A Star Compass	75
Polarized Light	75
ALAN and Navigation	80
Summary	81
6 Touch	83
The Human Sense of Touch	83
Receptor Cells in the Skin	83
Mechanoreceptors	84
Central Pathways	86
Touch and Haptics	86
Touch in Other Vertebrates	87
Mammals	87
Birds, Reptiles, and Amphibians	90
Fish	91
Touch in Arthropods	92
Insects	92
Scorpions	93
Spiders	93
Crustaceans	94
Touch in Molluscs	94
Somatosensation and Emotion	95
Beneficial Touch	95
Nociception and Pain	96
Pain in Humans	97
Pain in Fish	97
Pain in Invertebrates	98
Summary	100



7	Hearing	101
	Human Hearing	101
	Structure of the Ear	101
	How the Cochlea Works	103
	Pitch Perception	103
	Localizing Sounds	106
	Auditory Cortex	106
	Hearing in Fish	107
	The Origin of Ears	107
	Auditory Sensitivity	107
	Pitch Perception	108
	Lateral Lines and Hearing	109
	Hearing in Amphibians	110
	Hearing in Reptiles	111
	Hearing in Birds	112
	Cowbirds	112
	Barn Owl	114
	Hearing in Mammals	115
	Elephants	115
	Bats	117
	Cetaceans	120
	Hearing in Arthropods	122
	Insects	123
	Spiders	124
	Hearing in Molluscs	125
	Summary	127
8	Taste	129
	Taste in Humans	130
	The Anatomy of Taste	130
	Basic Tastes	130
	The Physiology of Taste	132
	Receptor Cells and Receptor Molecules	132
	Taste Coding: Labeled Line or Patterning?	134
	Variations in Taste among Mammals	136
	Taste in Other Vertebrates	137
	Fish	137
	Amphibians and Reptiles	138
	Birds	139
	Taste in Invertebrates	139
	Insects	139
	Molluscs	140
	Summary	142
9	Smell	145
	The Human Sense of Smell	145
	Anatomy	145
	Perception	146
	Biological Basis of Vertebrate Olfaction	147
	The Main Olfactory System	147
	The Vomeronasal System	149

Olfaction in Mammals	149
Dogs	150
Mouse Pheromones	154
Olfaction in Birds	155
Pigeons	156
Seabirds	157
Olfaction in Reptiles	158
Turtles	158
Chemical Crypsis in a Snake	159
Olfaction in Amphibians	159
Olfaction in Fish	161
The Olfactory Mucosa	161
Central Olfactory Pathways	162
Plasticity	163
Effects of Ocean Acidification	164
Olfaction in Arthropods	166
The Fruit Fly	166
The Honeybee	168
Bolas Spiders	170
Hermit Crabs	170
Olfaction in Molluscs	171
Behavior	171
Olfactory System	172
Summary	173
10 Senses We Don't Have	175
Magnetic Sense	175
Magnetoreception in Vertebrates	175
Magnetoreception in Arthropods	186
Magnetoreception in Molluscs	188
Magnetoreception: A Summary	189
Electrical Sense	189
Passive Electrosense	189
Electric Fish	191
Bees	195
Infrared Sense	195
Pit Vipers	195
Vampire Bats	198
Summary	198
11 Final Thoughts	201
Information and Life	201
The Evolution of Senses	201
Theoretical Limits of Sensitivity	202
The Anthropocene Epoch	203
The Value of Sensory Science	203
Widening the Lens	204
References	207
Author Index	235
Subject Index	243