

Peter Böck

The Paraganglia

With 61 Figures



Springer-Verlag Berlin Heidelberg New York 1982

Contents

A. Introduction	1
I. Alfred Kohn and the Concept of Paraganglionic Cells and Tissues	1
II. Max Watzka's Review on Paraganglia	2
III. Notes on Terminology	2
IV. Paraganglia and the APUD Cell Concept	5
V. Paraganglia and the Concept of Paraneurons	6
B. Morphological and Histochemical Methods for the Study of Paraganglionic Cells	8
I. Fine Structural Morphology and Electron Microscopic Cytochemistry of Catecholamines	8
1. Primary Fixation with Metal Salts	8
2. Primary Fixation with Aldehydes	8
a) Glutaraldehyde/Dichromate	10
b) Glutaraldehyde/Osmium Tetroxide	11
3. Uranaffin Reaction	11
4. Staining of Ultrathin Sections	12
a) Lead Citrate	12
b) Argentaffin Reaction	12
II. Light Microscopic Methods for the Study of Paraganglionic Cells	12
1. Chromaffin Reaction	12
2. Argentaffin Reaction	14
3. Iodate Oxidation	15
4. Schmorl's Ferric Ferricyanide Reaction	16
5. Other Staining Methods	16
6. Fluorescence Methods	18
a) Fixation in Aqueous Solutions	18
b) Freeze-Dried Tissue	20
c) Combination with Other Methods	24
III. Immunocytochemistry of Enzymes Involved in Catecholamine Synthesis	24
IV. Staining Methods for Proteins	25
1. Lead Haematoxylin	25
2. Masked Metachromasia	25
3. Coriophosphine O	25

V. Quinacrine Fluorescence	26
C. General Morphology of Paraganglionic Cells and Tissues	27
I. The Chromaffin (Paraganglionic) Cell	27
1. Terminology	27
2. Cytology	29
a) Nucleus	29
b) Perikaryon and Cell Organelles	30
c) Cilia	32
d) Morphology of the Specific Granules	34
α) Large Granules	34
β) Small (Cored) Vesicles	36
e) Origin and Fate of Specific Granules	37
f) Shape of Paraganglionic Cells	41
g) Synaptic Connections of Paraganglionic Cells	42
α) Efferent Synapses	42
β) Afferent Synapses	44
γ) Reciprocal Synapses	44
δ) Inhibitory Synapses?	47
ϵ) Special Axon Terminals	47
h) Contact Regions Between Paraganglionic Cells	50
i) Mitoses	51
3. Catecholamines in Paraganglionic Cells	53
a) Chromaffin Reaction	53
b) Argentaffin Reaction	53
c) Fluorescence Histochemistry	53
d) Enzymes Synthesizing Catecholamines	55
e) Chemical Determinations	56
4. Adenine Nucleotides of Paraganglionic Cells	57
5. Composition of the Specific Granules	59
II. Sustentacular Cells	60
1. Terminology	60
2. Cytology	61
a) Nucleus	61
b) Perikaryon and Cell Organelles	61
c) Shape of Sustentacular Cells	63
III. Composition of Paraganglionic Tissue	64
1. Basal Lamina	64
2. Vascularization	64
a) Supplying Arteries	64
b) Capillaries	65
c) Venous Drainage	66
d) Lymphatics	67
3. Connective Tissue	67
4. Relationship to the Perineurium of the Supporting Nerves	67
5. Distribution of Tracer Material	67

IV. Histochemistry of Paraganglionic Tissue	68
1. Immunocytochemistry of Enzymes Synthesizing Catecholamines	68
2. Enzyme Histochemistry of Paraganglionic Tissue	70
3. Chemical Measurements of Enzyme Activities and O ₂ Consumption	76
V. Autoradiographic Studies on Paraganglionic Cells	78
1. Distribution of Radioactivity Derived from Labelled Precursors of Biogenic Amines	78
2. Distribution of ³ H-Leucine-Derived Radioactivity	79
3. Distribution of ³ H-ATP-Derived Radioactivity	80
4. Distribution of ³ H-Choline-Derived Radioactivity	80
VI. Hormones in Paraganglionic Cells	81
D. Description of Anatomically Defined Paraganglia	83
I. Paraganglia in Man and Mammals	83
1. Distribution and General Considerations	83
a) Distribution and Terminology	83
b) Paraganglia as a System	87
2. Carotid Body	88
a) Microscopic Anatomy	88
b) Cytology	96
c) Innervation of Chromaffin Cells	102
d) The Carotid Body as Chemoreceptor	104
e) Efferent Innervation	111
f) Morphological and Biochemical Findings After Stimulation of the Chemoreceptor	111
g) Secretions Other than Catecholamines in the Chromaffin Cells of the Carotid Body	113
h) The Carotid Body of the Wobbler Mutant Mouse	114
3. Subclavian Bodies	114
a) Microscopic Anatomy	114
b) Cytology	117
c) Subclavian Bodies as Chemoreceptors	118
4. Aorticopulmonary Bodies	118
a) Microscopic Anatomy and Cytology	118
b) Aorticopulmonary Bodies as Chemoreceptors	124
5. Tympanojugular Glomera	125
a) Microscopic Anatomy and Cytology	125
b) Functional Significance	128
6. Vagal (Intravagal), and Juxtavagal Paraganglia	128
a) Microscopic Anatomy	128
b) Cytology	129
7. Laryngeal Paraganglia	129
8. Zuckerkandl's Organ	131
9. Retroperitoneal Paraganglia	132
10. Paraganglia Related to Pelvic Viscera	136

11. Peribronchial Microparaganglia	140
12. Cardiac Paraganglia	141
II. Development of Paraganglionic Tissue	144
1. Cytodifferentiation	144
2. Development of the Carotid Body	148
3. Development of Subclavian Bodies	151
4. Development of Aorticopulmonary Bodies	153
5. Development of Tympanojugular Glomera	154
6. Development of Vagal Paraganglia	155
7. Development of Retroperitoneal Paraganglia	155
III. Postnatal Fate of Extra-Adrenal Paraganglionic Tissue	155
IV. Comparative Anatomy of Paraganglia in Non-Mammalian Vertebrates	158
1. Cyclostomes and Fish	159
2. Amphibians	161
3. Reptiles	166
4. Birds	168
5. Small Granule-Containing Cells (SGC Cells) in the Mammalian Adrenomedullary Tissue	171
E. Paraganglionic Cells in Sympathetic Ganglia (SIF Cells, SGC Cells)	174
I. Introduction	174
II. Morphology	175
III. Functional Considerations	189
F. Paraganglionic Cells Under Experimental Conditions	194
I. Tissue Culture	194
1. Methods and Control Preparations	194
2. Effects of Corticosteroids and Drugs on Cultured SIF Cells	197
3. Effect of Varying Concentrations of Oxygen and Carbon Dioxide on Cultured Chromaffin Cells of the Carotid Body	199
II. Transplantation of Paraganglionic Cells	199
III. In Vivo Effects of Hormones and Drugs	200
1. Corticosteroids	200
a) SIF Cells (SGC Cells)	200
b) Paraganglia	201
2. Neurotoxins (False Transmitters)	202
a) SIF Cells (SGC Cells)	202
b) Paraganglia	203
3. Drugs Which Influence Catecholamine Turnover	204
a) SIF Cells (SGC Cells)	204
b) Paraganglia	207
4. Stimulation of Secretion	207
5. Miscellaneous Compounds and Experimental Designs	210
IV. Hypoxia	211

G. Pathology	213
Appendix 1: A. Kohn, 1867–1959 Life History and His Papers on Paraganglia	218
Appendix 2: G. Muratori, 1909–1971 Life History and His Papers on Paraganglia	219
References	223
Author Index	277
Subject Index	301