
CONTENTS

<i>Preface</i>	xv
1 Introduction	1
<i>Some elementary haemodynamics</i>	2
<i>The Poiseuille equation</i>	3
<i>Viscosity</i>	3
<i>Total fluid energy</i>	4
<i>Resistance</i>	5
<i>Pressures on land and in water</i>	7
<i>Velocity and cross sectional area</i>	9
 2 The heart	 10
Introduction	10
The structure of cardiac muscle	11
<i>The dimensions of fish myocytes</i>	12
<i>Sarcoplasmic reticulum, caveolae and T tubules</i>	13
<i>Intercalated discs, fasciae adherentes and gap junctions</i>	14
<i>Specific granules</i>	14
<i>Pace-makers and pace-maker tissue</i>	15
<i>The atrioventricular and ventriculoconal delays</i>	17
<i>Fast conducting tracts</i>	18
Electrical properties of fish cardiac muscle	19
<i>The resting membrane potential and muscle action potential</i>	19
<i>The electrocardiogram (ECG)</i>	20
The events of the cardiac cycle	21
<i>The atrium</i>	21
<i>The ventricle</i>	22
<i>The pericardium and pericardial fluid</i>	24
<i>The bulbus arteriosus</i>	27

x	<i>Contents</i>	
	<i>The conus arteriosus</i>	29
	<i>The sinus venosus</i>	31
	The myocardium and its blood supply	31
	<i>The compact layer</i>	31
	<i>The coronary arteries; atherosclerosis and cardiac pathology</i>	32
	<i>The spongy layer</i>	34
	The output of the heart	36
	<i>Starling's law of the heart</i>	38
	<i>Homeometric regulation</i>	39
3	The peripheral circulation	41
	Introduction	41
	<i>Arteries</i>	41
	<i>Arterioles</i>	43
	<i>Capillaries</i>	44
	<i>Capillary beds, cross sectional area and velocity of flow</i>	46
	<i>Interchanges across the capillary wall; the Starling principle</i>	47
	<i>The two pathways through the capillary wall</i>	48
	<i>The effect of plasma proteins on permeability</i>	49
	<i>The fate of spilt plasma protein</i>	50
	<i>Veins</i>	51
	<i>Valves in veins</i>	52
	Blood pressure in fish	53
	Reactive hyperaemia	53
	The principal blood vessels of the fish circulatory system	55
4	The blood	58
	Haemoglobin	59
	<i>Blood oxygen capacity</i>	59
	<i>The oxygenation of haemoglobin</i>	61
	<i>Oxygen affinity, P_{50} and environmental P_{O_2}</i>	62
	<i>The Bohr effect</i>	64
	<i>The Root effect</i>	65
	<i>The effect of cell haemoglobin concentration</i>	66
	<i>The effect of temperature</i>	66
	<i>The effect of nucleoside triphosphates (NTP)</i>	67
	Acclimation and adaptation in haemoglobins	68
	<i>Multiple haemoglobins</i>	69
	The carriage of CO_2 in the blood	70
	The plasma proteins	71
	<i>Fibrinogen and the blood clotting factors</i>	73
	Blood viscosity	75
	<i>The relation of η to temperature</i>	75

<i>Contents</i>	xi
<i>The relation of η to haematocrit</i>	76
<i>The relation of η to shear rate</i>	76
The leucocytes	77
5 Haemopoiesis and phagocytosis – the mononuclear phagocytic system	80
The phagocytic cells of the MPS system	80
<i>Macrophages</i>	81
Haemopoietic and phagocytic organs and tissues	82
<i>The thymus</i>	82
<i>The spleen</i>	83
<i>The gut-associated tissue</i>	84
<i>The kidney</i>	85
<i>The organ of Leydig, the epigonal organ and the meninges</i>	85
<i>The cavernous bodies</i>	86
6 Circulation through special regions	89
I The microcirculation of the gill	89
<i>Introduction</i>	89
<i>The arterioarterial pathway</i>	90
<i>Blood pressure and blood flow through the secondary lamellae</i>	91
<i>The arteriovenous pathway</i>	92
II The secondary blood system	96
III The renal portal circulation	99
<i>The urophysis</i>	100
<i>The bladder veins</i>	100
<i>Connections with the posterior intestine and rectum</i>	101
<i>Afferent and efferent flows to the kidney</i>	102
IV Red and white muscle	103
7 Retial counter-current systems: flow–diffusion–concentration	106
Introduction	106
Retia that concentrate oxygen and nitrogen	107
<i>The retia of the swimbladder</i>	107
<i>The removal of gas from the bladder</i>	110
<i>The choroidal rete of the eye</i>	112
Retia that concentrate heat	114
<i>The responses of the circulatory system to temperature change in fish lacking retia</i>	114
<i>Acclimation to temperature</i>	114
<i>The muscle retia of tuna</i>	116
<i>Muscle retia in the mackerel sharks</i>	120
<i>Retia that concentrate heat in the digestive organs</i>	121
<i>Retia that concentrate heat in the brain and eye</i>	123

xii	<i>Contents</i>	
8	Venous return and venous pumps	126
	<i>Venous pressure</i>	126
	<i>The haemal arch pump</i>	126
	<i>The branchial pump</i>	130
	<i>The 'cardinal heart' of the myxinooids</i>	130
	<i>The caudal pump</i>	131
	<i>The caudal heart of the carpet shark</i>	133
	<i>The caudal heart of the eel</i>	135
	<i>The caudal heart of the hagfish</i>	137
	<i>The portal heart of the hagfish</i>	139
9	The autonomic nervous system	141
	Introduction	141
	The parasympathetic and sympatho-adrenal systems	142
	<i>Adrenergic and cholinergic receptors</i>	145
	<i>Antagonism and alliance in the autonomic system</i>	147
	Atrial natriuretic peptide (ANP)	149
	Vascular receptors	150
	<i>Pressure or baroreceptors</i>	150
	<i>Hypoxia receptors</i>	152
	<i>Gill nociceptors</i>	153
10	The response to exercise	158
	Introduction	158
	The response of the heart	159
	<i>The extent of the increase in cardiac output</i>	159
	<i>The intrinsic mechanism: the Starling response</i>	160
	<i>The role of the cardiac vagus</i>	160
	<i>The role of circulating catecholamines</i>	161
	<i>The role of cardioaccelerator nerves</i>	162
	The response of the gill vasculature	163
	<i>Intrinsic dilation of gill vessels</i>	163
	<i>Parasympathetic nerve fibres to the gills</i>	163
	<i>The response of the gill vessels to branchial efferent adrenergic fibre stimulation</i>	164
	<i>The response of the gill vessels to centrally liberated catecholamines</i>	165
	The response of the peripheral vessels	166
	<i>Intrinsic responses</i>	166
	<i>The response to circulating catecholamines</i>	167
	<i>The role of the autonomic vasomotor nerves</i>	167
	<i>In summary</i>	168
11	The response to hypoxia	170
	Introduction	170

<i>Contents</i>	xiii
I Reflex responses (A) The heart	171
<i>The bradycardia of hypoxia</i>	171
<i>Cardiorespiratory synchrony</i>	172
<i>Changes in coronary blood flow</i>	173
I Reflex responses (B) The peripheral circulation	173
II The intrinsic responses of the gill vessels	173
III The central liberation of catecholamines	175
<i>The defence of the acidotic myocardium</i>	175
<i>Catecholamines and the increase in the oxygen diffusive conductance of the gill</i>	176
<i>The role of catecholamines in regulating oxygen uptake by erythrocytes</i>	177
<i>Effects on the efflux of H⁺ from the gill</i>	179
<i>Effects on carbohydrate metabolism</i>	180
<i>In summary</i>	181
12 Myxine, a speculative conclusion	183
Introduction	183
The heart	185
<i>The performance of the myxinoid heart</i>	185
<i>The gross anatomy of the myxinoid heart</i>	185
<i>Some features of the myxinoid cardiac cycle</i>	186
The blood	188
The peripheral circulation	189
<i>The arterial system</i>	189
<i>The venous system</i>	190
<i>The sinus system and the subcutaneous sinus</i>	190
<i>Pathways into the sinus system</i>	191
<i>Pathways out of the subcutaneous sinus</i>	191
<i>The haematocrit and volume of sinus blood</i>	192
<i>What is the role of the subcutaneous sinus?</i>	193
<i>Can the subcutaneous sinus be related to other subdermal vascular spaces?</i>	194
Some final speculations	195
 <i>References</i>	198
 <i>Appendix of popular and scientific names</i>	227
 <i>Index</i>	233