

Contents

<i>Foreword</i>	<i>page</i> xiii
<i>Preface to the First Edition</i>	xvii
<i>Acknowledgements</i>	xx
<i>Introduction to the Second Edition</i>	xxi
Part I Background mechanics	1
1 Particles and continuous materials	3
2 Particle mechanics	7
Position	7
Velocity	8
Acceleration	12
Newton's laws of motion: mass and force	14
Momentum	20
Work and energy	20
3 Units	24
The difference between units and dimensions	24
Mass, length, and time as fundamental units	25
The inconvenience of force as a fundamental unit	26
Energy and heat	27
The concept of substance	27
Dimensional homogeneity and consistency of units	27
The use of volume and flow rate in physiology	27
Système International (SI)	28
4 Basic ideas in fluid mechanics	31
Stress	31
Hydrostatic pressure	33
Stress in a moving fluid: viscosity	35
The equation of motion of a fluid	38

vi	<i>Contents</i>	
	Convective and local acceleration	40
	Conservation of mass	41
	Bernoulli's theorem	42
5	Flow in pipes and around objects	45
	Poiseuille flow in a tube	45
	Flow in the entrance region	50
	The idea of the boundary layer	52
	Reynolds number	55
	Turbulence in pipe flow	56
	Unsteady flow in a very long pipe	58
	Effects of constrictions on pipe flow characteristics	61
	Flow in curved pipes	66
	Flow past bodies	69
6	Dimensional analysis	80
	Similarity and the idea of scale models	81
	Some examples of scaling in biological systems	81
	A method of obtaining homogeneous relationships between variables	82
7	Solid mechanics and the properties of blood vessel walls	86
	Definitions of elastic properties	86
	The properties of blood vessel walls	91
	Statics of an elastic tube	100
8	Oscillations and waves	105
	Simple harmonic motion	105
	Simple waves	112
	Damping	116
	Wave reflections and resonance	120
	Linearity	123
	Fourier analysis	126
9	An introduction to mass transfer	128
	Diffusion	129
	The colloidal state	133
	Mass transfer coefficients	133
	Diffusion through pores and membranes	135
	Restricted diffusion	136
	Active transport	137
	Permeability	138
	Filtration through membranes	138
	Osmosis	139
	A simple mass transfer model	141

<i>Contents</i>		vii
	The interaction of bulk flow and diffusion	142
	The Schmidt number	145
	Part II Mechanics of the circulation	147
10	Blood	149
	Viscosity of fluids and suspensions	149
	Spherical particles	151
	Asymmetric particles	154
	Viscosity of plasma	155
	Osmotic pressure of plasma	156
	The suspended elements	157
	The blood cells	157
	Red cells	158
	White cells	165
	Platelets	165
	Blood coagulation	167
	Thrombosis	168
	Mechanical properties of whole blood	169
	Sedimentation of red cells	170
	Principles of measurement of blood viscosity	171
	Viscous properties of blood	174
11	The heart	178
	Anatomy of the heart	179
	The cardiac cycle	183
	Electrical events	183
	Mechanical events	184
	Properties of cardiac muscle	186
	Structure	186
	Static mechanical properties of cardiac muscle	189
	Dynamic mechanical properties of cardiac muscle	191
	Summary	201
	Mechanical behaviour of the intact heart	202
	Left ventricular shape and wall stresses	204
	Right ventricular shape	209
	The mechanics of the entire ventricle	210
	Summary	224
	Fluid mechanical aspects of cardiac function	225
	Right heart	225
	Left heart	227
	Sounds and murmurs in the heart	234

Sounds	234
Murmurs	236
Further reading	237
12 The systemic arteries	238
Anatomy and structure	239
The anatomy of large blood vessels	239
Branching ratios and angles	241
The structure of the arterial wall	244
Arterial wall thickness	250
Changes in the arterial wall with age	251
Blood pressure and flow in systemic arteries	255
Transmural pressures	256
Unsteady pressure in large arteries	259
Flow	262
Terminology	265
Fourier analysis	266
Wave propagation in arteries	269
The Windkessel model	270
The propagation of the pressure wave	271
Determination of the wave speed	272
Comparison of theory with experiment	275
Further limitations of the simple elastic model	277
Reflection and transmission of the wave at junctions	278
Reflection at a single junction	278
The matching of impedances	281
Positive and negative reflection	283
Physiological evidence of wave reflections	285
Multiple reflections	288
Interpretation of observed pressure waveforms in large arteries	291
The effect of taper	294
The influence of nonlinearities	297
Viscous effects	299
Effect of blood viscosity on flow-rate waveform	299
Effect of viscosity on wave propagation	301
Effect of wall visco-elasticity	304
Other types of wave	304
Flow patterns in arteries	306
Velocity profiles in large arteries	306
Physical mechanisms underlying the velocity profiles	313
Stability and turbulence	321

	<i>Contents</i>	ix
Mixing and mass transport in arteries		328
Mixing in the heart and large blood vessels		328
Mass transport across artery walls		333
Appendix: Impedance		338
Further reading		341
13 The systemic microcirculation		343
The organization of a microvascular bed		344
The arteriolar system		344
The capillary system		346
The venular system		349
The lymphatic system		350
The structure of the vessels of the microcirculation		350
The arterioles		351
The capillaries		353
The venules		358
The lymphatics		360
The junctions between vascular endothelial cells		360
The pinocytic vesicles		363
The interstitial space		363
Static mechanical properties of the microcirculatory vessels		363
Elastic properties of the arterioles		364
Mechanical properties of the capillaries		366
Elastic properties of the venules		368
Pressure in the microcirculation		368
The distribution of pressure		368
The propagation of cardiac pressure oscillations		375
Pressure in the interstitial space		376
Flow in models and in the large vessels of the microcirculation		378
The motion of single particles at very low flow rates		378
The motion of single particles at high flow rates		381
The motion of single red blood cells in Poiseuille flow		381
The flow of concentrated suspensions of particles and red cells		384
The viscosity of whole blood		386
Radial dispersion of red cells		387
The cell-free layer		387
Velocity profiles in vessels		391
Blood flow in capillaries		392
Positive clearance		394
Negative clearance		396
Mass transport in the microcirculation		399

	Filtration and reabsorption of water within single capillaries	400
	Capillary pressure and filtration of water in whole organ preparations	405
	The dependence of plasma oncotic pressure on protein concentration	407
	Evidence for the existence of filtration pores in the capillary wall	407
	Diffusion across the capillary wall	408
	Methods of measuring permeability coefficients	410
	The diffusion pathway across the capillary wall	417
	The Pappenheimer equivalent pore theory	418
	The pathway for water transport across the capillary wall	419
	The transport of large molecules	420
	Further reading	424
14	The systemic veins	426
	Anatomy	427
	Transmural pressure and static elastic properties	429
	The resistance to bending of a tube wall	438
	Dynamics of blood flow in large veins	440
	Observed pressure and flow-rate waveforms	441
	Wave propagation in veins	443
	Flow patterns and velocity profiles in veins	450
	Flow in collapsible tubes	451
	Model experiments	452
	Mechanisms	456
	Physiological evidence: Korotkoff sounds	459
	Mechanics of venous beds	460
	Elevation of a venous bed above the level of the heart	461
	Contraction of skeletal muscle	461
	Respiratory manoeuvres	464
15	The pulmonary circulation	467
	Anatomy	468
	Pulmonary circulation	468
	Bronchial circulation	475
	Transmural pressure and static elastic properties of vessels	475
	Intravascular pressure	476
	Perivascular pressure	476
	Elastic properties	480
	Pulmonary blood volume	482
	Dynamics of blood flow in large pulmonary vessels	489
	Waveforms	489

	<i>Contents</i>	xi
Wave propagation		491
Flow patterns		494
Pulmonary vascular resistance		494
Flow in the alveolar sheet		494
Zonal distribution of blood flow		499
Effect of lung mechanics		501
Further reading		504
<i>Index</i>		507
<i>Table I</i>		524