

# CONTENTS

	<i>Preface</i>	xi
<b>1</b>	<b>Physiological introduction</b>	<b>1</b>
1.1	Anatomy, wall structure and mechanical properties	2
1.1.1	<i>The heart</i>	3
1.1.2	<i>The systemic arteries</i>	9
1.1.3	<i>The pulmonary arteries</i>	22
1.1.4	<i>The veins</i>	25
1.1.5	<i>The blood</i>	29
1.2	The physiological relevance of fluid mechanics	31
1.2.1	<i>Blood pressure and transmural pressure</i>	31
1.2.2	<i>Unsteady pressures</i>	33
1.2.3	<i>Velocity waveforms</i>	36
1.2.4	<i>Velocity profiles</i>	42
1.2.5	<i>Disturbed or turbulent flow</i>	48
1.2.6	<i>Wall shear stress and arterial disease</i>	51
1.2.7	<i>Korotkoff sounds</i>	55
1.3	Fluid mechanics of the left ventricle	57
1.3.1	<i>The mitral valve</i>	57
1.3.2	<i>The aortic valve</i>	60
1.3.3	<i>The dynamics of left ventricular ejection</i>	62
1.3.4	<i>The case of a spherical ventricle</i>	67
<b>2</b>	<b>Propagation of the pressure pulse</b>	<b>72</b>
2.1	One-dimensional theory, uniform tube, inviscid fluid	72
2.1.1	<i>Basic theory</i>	72
2.1.2	<i>Comparison with experiment</i>	74
2.1.3	<i>Attenuation</i>	77
2.1.4	<i>Non-linear effects</i>	79
2.2	Two-dimensional theory, uniform tube, viscous fluid	87
2.2.1	<i>Isotropic, elastic walls; no wall inertia, no initial stresses, no tethering</i>	93
2.2.2	<i>The effect of longitudinal tethering</i>	95
2.2.3	<i>The physiological pressure pulse (summary)</i>	98

2.2.4	<i>Flow-rate and wall shear</i>	99
2.3	Effects of taper and branchings (linear theory)	101
2.3.1	<i>Taper</i>	102
2.3.2	<i>Isolated wave reflections</i>	106
2.3.3	<i>Multiple wave reflections</i>	109
2.4	Non-linear models of a complete arterial pathway	114
<b>3</b>	<b>Flow patterns and wall shear stress in arteries</b>	
	<b>I Straight tubes</b>	126
3.1	The difficulty of measuring wall shear stress	126
3.1.1	<i>The need for a good frequency response</i>	126
3.1.2	<i>The limitations of the hot-film anemometer</i>	131
3.2	Entry flow in a straight tube	136
3.2.1	<i>Steady flow</i>	137
3.2.2	<i>Non-reversing unsteady flow</i>	139
3.2.3	<i>Reversing flow</i>	149
<b>4</b>	<b>Flow patterns and wall shear stress in arteries</b>	
	<b>II Curved tubes</b>	160
4.1	Fully developed steady flow, $\delta \ll 1$	163
4.1.1	<i>Small <math>D</math></i>	165
4.1.2	<i>Intermediate <math>D</math></i>	168
4.1.3	<i>Large <math>D</math></i>	172
4.2	Fully developed oscillatory flow, $\delta \ll 1$	177
4.2.1	<i>Zero mean pressure gradient</i>	178
4.2.2	<i>Non-zero mean pressure gradient</i>	183
4.3	Fully developed unsteady flow starting from rest	192
4.3.1	<i>Uniform curvature</i>	193
4.3.2	<i>Slowly varying curvature</i>	199
4.4	Entry flow with a flat entry profile	203
4.4.1	<i>Uniform curvature</i>	207
4.4.2	<i>Slowly varying curvature</i>	213
4.4.3	<i>Experiments</i>	218
4.5	Steady entry flow with a parabolic entry profile	224
<b>5</b>	<b>Flow patterns and wall shear stress in arteries</b>	
	<b>III Branched tubes and flow instability</b>	235
5.1	Flow in symmetric bifurcations	235
5.1.1	<i>Model experiments</i>	235
5.1.2	<i>Theory</i>	249
5.2	Flow in asymmetric bifurcations	260
5.2.1	<i>Model experiments</i>	260
5.2.2	<i>Effect of a weak branch on flow in the parent tube</i>	269

5.2.3	<i>Flow into a very small, very weak branch</i>	276
5.3	The instability of flow in the aorta	291
<b>6</b>	<b>Flow in collapsible tubes</b>	301
6.1	Physiological and experimental background	301
6.1.1	<i>Physiological phenomena</i>	301
6.1.2	<i>Model experiments</i>	302
6.1.3	<i>Mechanisms of Korotkoff sounds</i>	308
6.2	Viscous flow in slowly varying collapsible tubes	316
6.2.1	<i>Lubrication theory and the effect of inertia</i>	318
6.2.2	<i>Application to collapsible tubes</i>	324
6.3	A lumped-parameter model for self-excited oscillations	335
6.3.1	<i>Physical mechanisms</i>	335
6.3.2	<i>Mathematical formulation</i>	340
6.3.3	<i>Equilibrium states</i>	349
6.3.4	<i>Stability and oscillations</i>	354
6.4	Other mechanisms of instability	362
	<b>Appendix: Analysis of a hot-film anemometer</b>	369
A.1	Introduction	369
A.2	The steady boundary layer solution	375
A.3	The unsteady boundary layer with non-reversing shear	378
A.3.1	<i>Small <math>x_1</math></i>	378
A.3.2	<i>Large <math>x_1</math></i>	380
A.4	A hot-film in reversing flow	385
A.4.1	<i>The shear on the probe</i>	386
A.4.2	<i>The heat transfer from the film</i>	390
A.4.3	<i>Comparison with experiment</i>	396
A.5	Departures from boundary layer theory for a short hot-film	404
A.5.1	<i>The leading edge</i>	405
A.5.2	<i>The trailing edge</i>	412
A.6	Steady heat transfer from a very short hot-film	417
	<i>References</i>	423
	<i>Index</i>	439

