

Contents

	Preface	xi
1.	Form and Function	1
	The Relation of Form and Function	5
	Adaptation of Function as a Design Principle	8
	Integration of Function as a Design Principle	11
	Economy as a Design Principle	12
	The Principle of Symmorphosis	18
2.	Cells and Tissues: Oxidative Metabolism in Muscle	24
	Energy Supply and Mitochondria	29
	Is Mitochondrial Structure Matched to the Demand for Oxidative Energy?	35
	Testing for a Quantitative Match of Form and Function in Muscle Mitochondria	41
	Is \dot{V}_{O_2} max Related to $V(\text{mi})$ in Exercising Muscle Cells?	45
	Natural Variation in Energy Demand and Mitochondria	47
	Are Muscle Capillaries Adjusted to Mitochondrial Oxygen Needs?	52
	Symmorphosis in the O_2 Pathway in Muscle	56
3.	Muscle: Supplying Fuel and Oxygen to Mitochondria	60
	Differences between Oxygen and Fuel Supply	61
	Variations in Fuel Supply to Mitochondria in Working Muscle Cells	66
	Partitioning of Fuel Consumption between Glucose and Fatty Acids	68
	Estimating the Capillary Supply of Substrates	69
	Revising the Model for Capillary Oxygen and Substrate Supply	71

	Fuel Supply from Capillaries versus Intracellular Stores	74
	Conclusions on Form and Function in Muscle Cells and Tissue	77
4.	Organ Design: Building the Lung as a Gas Exchanger	80
	Modeling Gas Exchange in the Lung	85
	A Large Surface and a Thin Barrier Determine the Gas Exchange Capacity of the Lung	90
	The Diffusing Capacity of the Human Lung	95
	How Much Lung Diffusing Capacity Do We Really Need?	101
	The Gas Exchanger of the Athletic Pronghorn	105
	The Effect of Reducing the Gas Exchanger	107
	Conclusion	109
5.	Problems with Lung Design: Keeping the Surface Large and the Barrier Thin	110
	A Fiber Continuum Supports Parenchymal Structures	111
	Controlled Surface Tension Determines Parenchymal Mechanics	116
	Keeping the Barrier Dry and Thin	124
	Conclusion	130
6.	Airways and Blood Vessels: Ventilating and Perfusing a Large Surface	131
	Morphogenesis of Airways, Vessels, and Gas Exchanger	132
	Designing the Airway Tree for Efficient Ventilation	135
	Are Airways Designed as Fractal Trees?	145
	Conclusion	149
7.	The Pathway for Oxygen: From Lung to Mitochondria	150
	Testing the Hypothesis of Symmorphosis	152
	The Strategy: Exploiting Comparative Physiology	154
	The Model and Predictions	158
	Testing the Respiratory System for Symmorphosis	162
	Does Symmorphosis Prevail in the Respiratory System?	178

8.	Adding Complexity in Form and Function: The Combined Pathways for Oxygen and Fuels	181
	Strategies for Oxygen and Fuel Supply	183
	Design of the Fuel Supply Pathway	184
	Design of Nutrient Uptake Systems	185
	The Substrate Pathways for Fueling Muscle Work	195
	The Test of Symmorphosis	197
	On Symmorphosis in Complex Pathways	206
9.	Symmorphosis in Form and Function: Concepts, Facts, and Open Questions	210
	How to Perform a Test of Symmorphosis:	
	Future Prospects	213
	Conclusions	218
	References and Further Reading	231
	Credits	255
	Index	259