MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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6.022J/2.792J/BEH.371J/HST542J: Quantitative Physiology: Organ Transport Systems

INTRODUCTION: THE FUNCTIONAL ANATOMY OF THE CARDIOVASCULAR SYSTEM

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A. FUNCTIONS OF THE CIRCULATION

(i) *Transport:* Supplies nutrients to various cellgroups. Removes wastes; distributes heat. Most important "nutrient" is oxgen (Figure 1). Other materials: CO_2, amino acids, glucose, fats, hormones, ions, urea, cells, etc.

(ii) *Communication:* Integrative communication via hormones

(iii) *Heat Exchanger:* Distributes heat to skin, lungs. Controls dissipation

(iv) *Protection:* Clotting mechanisms, transport of WBCs, antibodies.

B. COMPONENTS OF THE CARDIOVASCULAR SYSTEM

(i) *Major Components:* Two pumps in series; major conduits; exchange mechanisms between intravascular and extra-vascular fluid; reservoirs for fluid storage (Figure 2); fluid medium (blood). Physical characteristics of elastic arteries, collapsible veins, resistance vessels.

(ii) *Organization:* High pressure delivery system, low-pressure capacitance system (Figure 2). Parallel organization of supply routes (Figure 3).

(iii) *Some Numbers:* Typical Dimensions, velocities, normal values (Tables 1, 2).

(iv) Perfusion and O_2 Uptake of representative organs (Figure 4).

C. FUNCTlONAL ANATOMY OF THE HEART

(i) Anatomical Landmarks - to be discussed in Lecture. Use Textbooks for reference.

(ii) The Conduction System

(iii) The Cardiac Cycle (Figure 5) — Pressures, volumes, mechanical events, heart sounds.

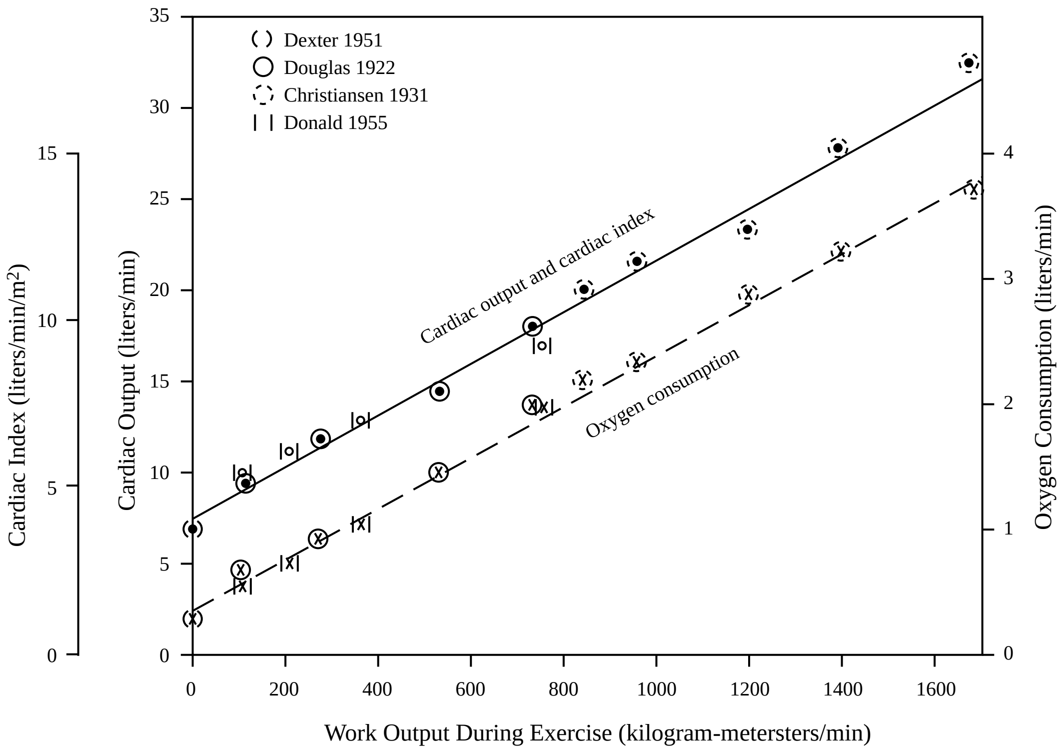

Figure 1: Relationship between cardiac output and work output (solid curve) and between oxygen consumption and work output (dashed curve) during exercise. [Data derived from studies by Douglas and Haldance (1922); Christensen and Mitteilung (1931); Dexter, Whittenberger, Haynes, Goodale, Gorlin, and Sawyer (1951); and Donald, Bishop, Cumming, and Wade (1955).] After Figure 1-1 in Guyton, A., C. Jones, and T. Coleman. *Circulatory Physiology: Cardiac Output and its Regulation*. 2nd ed. Philadelphia: W.B.Saunders, 1973.

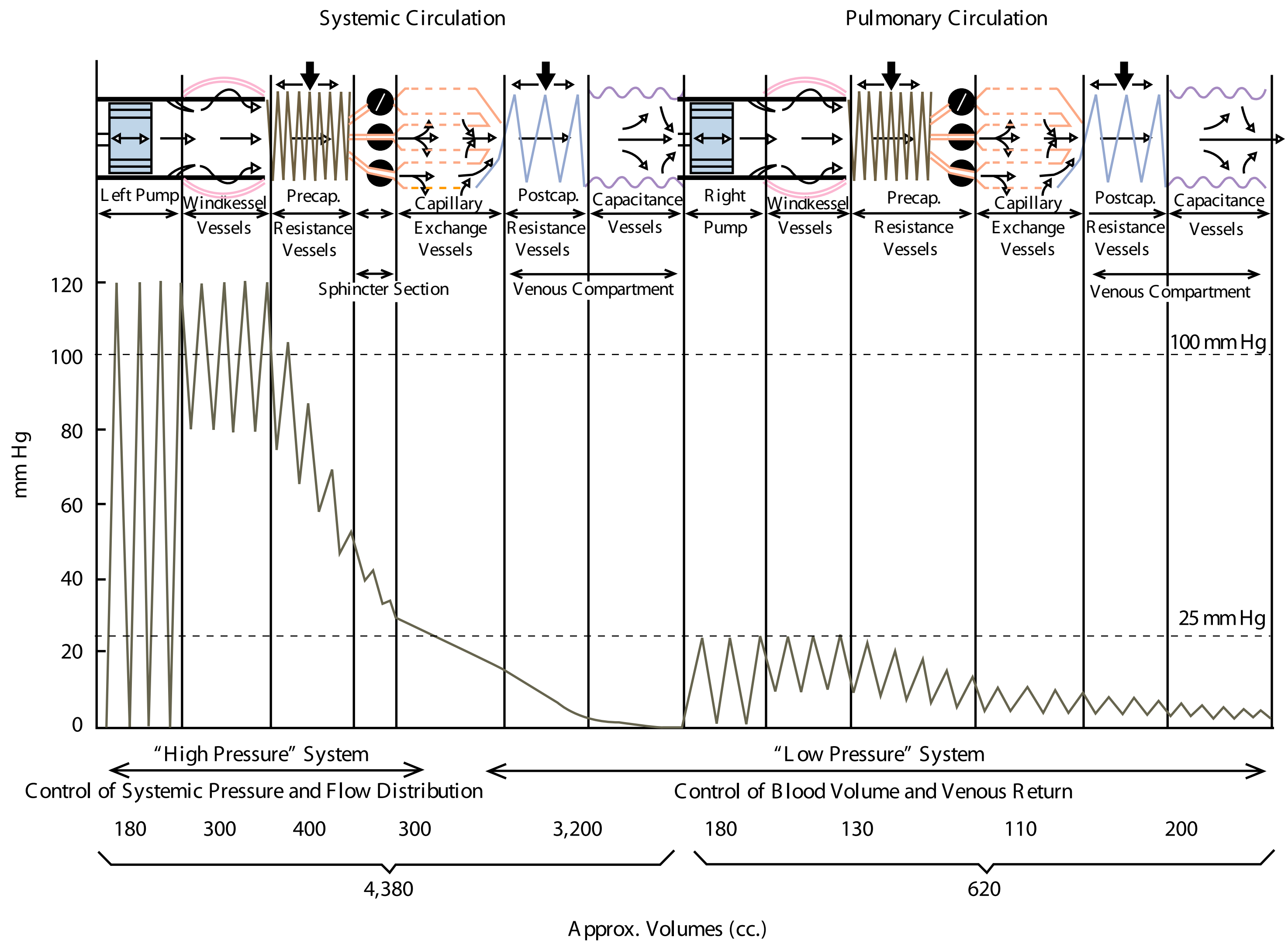

Figure 2

Figure by MIT OCW. After B. Folkow and E. Neil, *Circulation*. Oxford University Press, 1971, pp. 6-7.

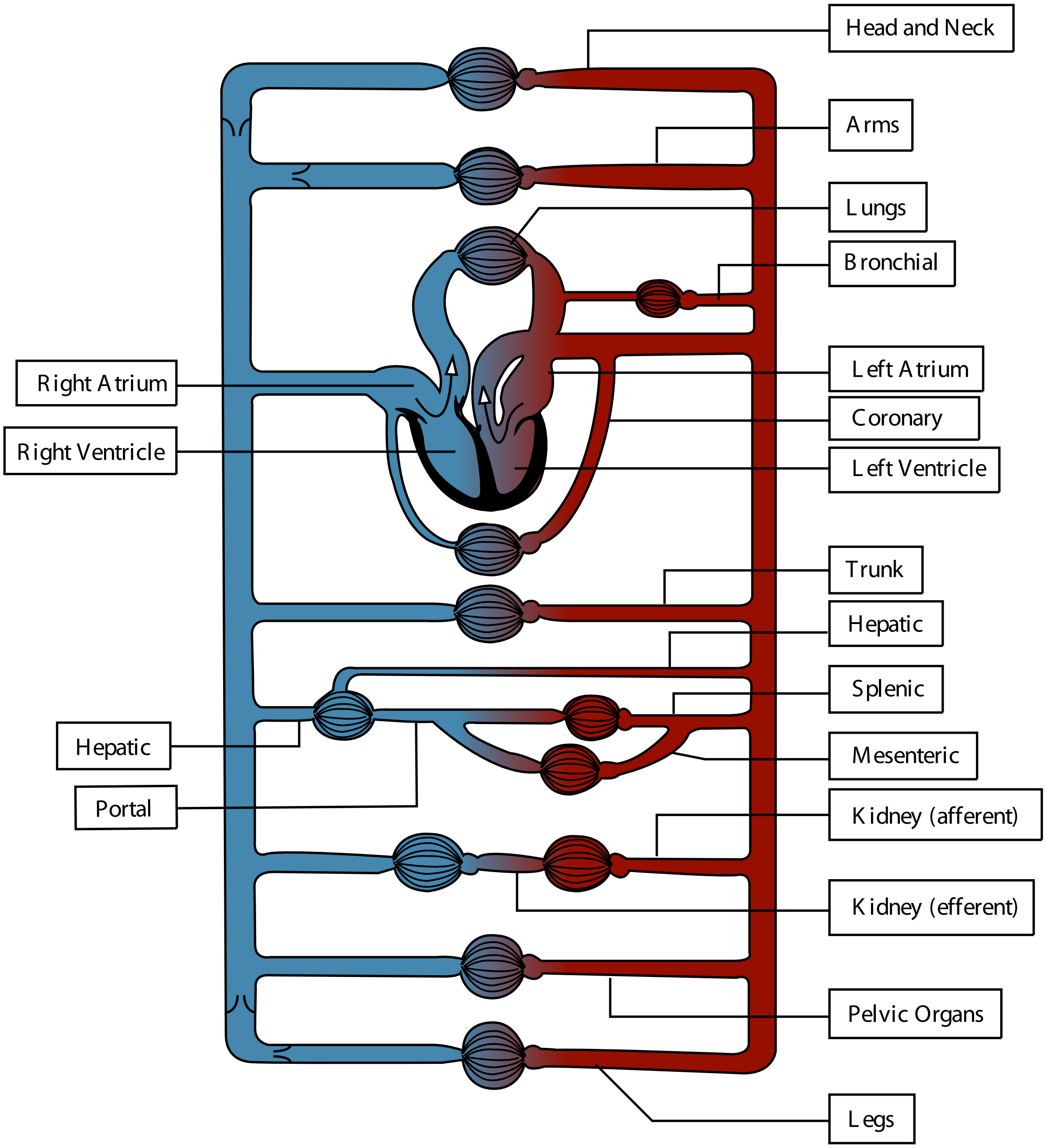

Figure by MIT OCW. After Green, H.D. "Circulation: Physical Principles." in Glasser, O.[ed.], *Medical Physics.* Vol. 1. Chicago: The Year Book Publishers, 1949.

Figure 3: Arrangement of the parallel routes by which the circulation passes from the aorta to the vena cava. Representatives of the different categories of route discussed in the text are indicated. The Xs indicate the location of control points where arterioles may control the flow. *RA*, right atrium; *LA*, left atrium; *RV*, right ventricle; *LV*, left ventricle; *PV*, portal vein. (from Green, H.D.: Circulation: Physical Principles, in Glasser, O. [ed.]: *Medical Physics*, Vol. 1 [Chicago: The Year Book Publishers, Inc., 1949], p. 210. Original illustration kindly furnished by H.D. Green.)

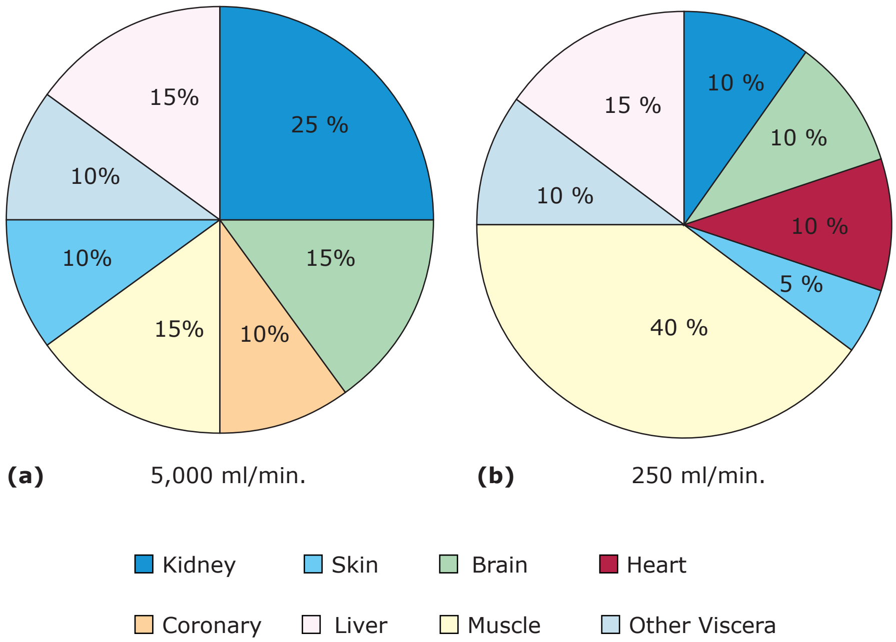

Figure by MIT OCW.

Figure 4: Estimated distributions of cardiac output (A) and oxygen consumption (B) to different organs of the body in a man at rest. The estimates are very rough, from data taken from many sources and not very consistent. The kidney is greatly overperfused; the muscles, underperfused. In exercise the proportion of blood flow to muscle increases enormously, as it does for skin in hot environments.

Table 1: Geometry of Mesenteric Vascular Bed of the Dog*

Kind of Vessel	Diameter (mm)	Number	Total Cross-sectional Area (cm^2)	Length (cm)	Total Volume (cm^3)	
Aorta	10	1	0.8	40	30	
Large arteries	3	40	3.0	20	60	
Main artery branches	1	600	5.0	10	50	
Terminal branches	0.6	1,800	5.0	1	25	
Arterioles	0.02	40,000,000	125	0.2	25	
Capillaries	0.008	1,200,000,000	600	0.1	60	}
Venules	0.03	80,000,000	570	0.2	110	}
Terminal veins	1	1,800	30	1	30	} 740
Main venous branches	2	600	27	10	270	}
Large veins	6	40	11	20	220	}
Vena cava	12	1	1..2	40	50	}
					930	

* Data of F. Mall.

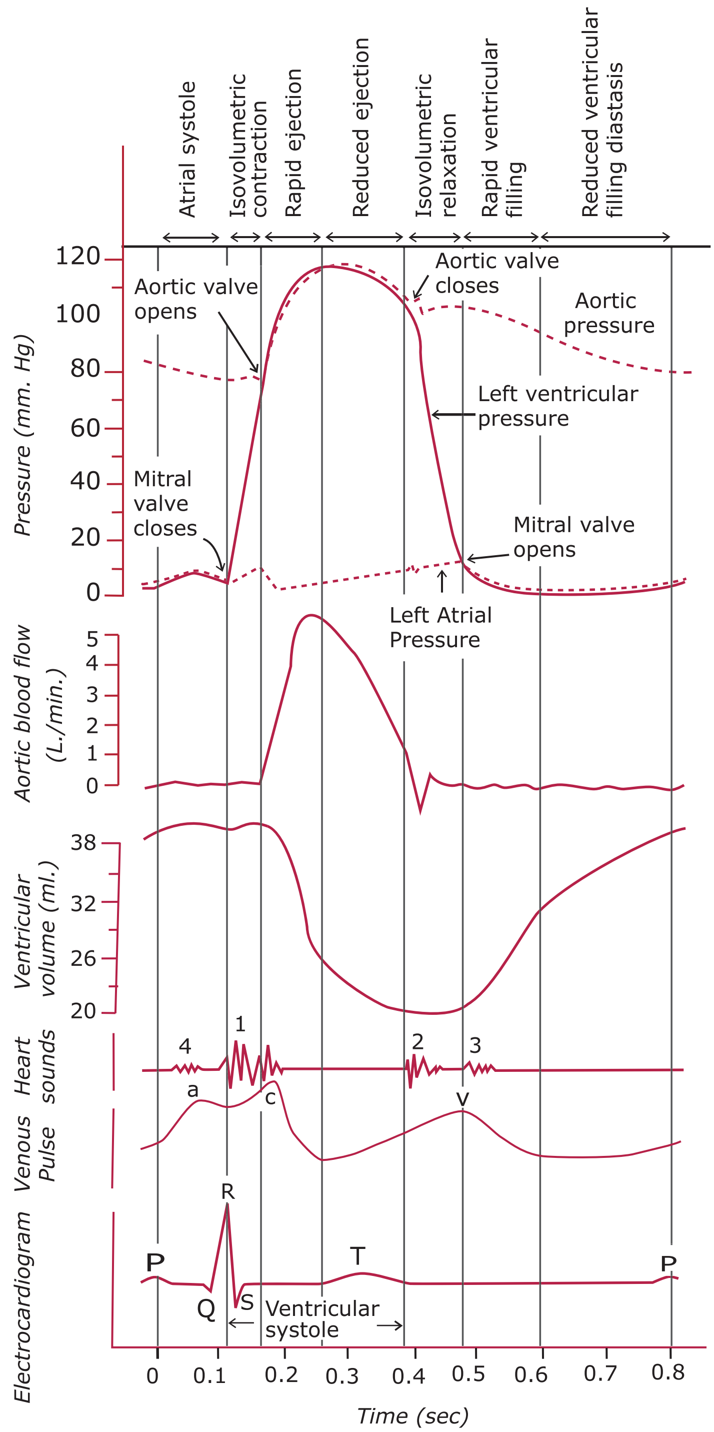

Figure by MIT OCW. After Fig. 4-14 in Berne and Levy, *Cardiovascular Physiology*. 3rd ed. St. Louis, MO: The C.V. Mosby Co., 1977.

Figure 5: Left atrial, aortic, and left ventricular pressure pulses correlated in time with aortic flow, ventricular volume, heart sounds, venous pulse, and electrocardiogram for complete cardiac cycle in the dog. [from R. M. Berne and M. N. Levy, *Cardiovascular Physiology* (4th edition). The C. V. Mosby Company, 1998.]

Table 2: Representative Values for Human Circulation

Cardiac Output:	5 liters/min. (resting)	
	15-25 liters/min. (exercise)	
Heart Rate:	60–80 beats/min. (resting)	
	120–160 beats/min. (exercise)	
Stroke Volume:	70 cc. (resting)	
	160 cc. (exercise)	
Pressures:	Aortic Phasic	120/80 mmHg
	Mean	100 mmHg
	Pulmonary Artery	25/10
	Mean	15
	Venous Mean	5
	Intrathoracic	–5
	1 mmHg = 1330 dynes/cm^2	
Dimensions (diameters):	Aorta	2.5 cm
	Medium Artery	0.5 cm
	Arteriole	30–60 m
	Capillary	8 m
	Vein (medium)	0.5 cm
	Vena Cava	3.0 cm
	Red Blood Cell	7 m
Velocities (approximate):	100 cm/sec. *peak* in aorta	
	0.5–1 mm/sec. in capillaries	
	20 cm/sec. in vena cava	
Viscosities:	Water	1.0 centipoise
	Plasma	1.5 centipoise
	Whole blood	4.0 centipoise
	(1 centipoise = 10^{-2} dyne-sec./cm^2)	
Resistance:	Total Pulmonary	150 dyne-sec. cm^{-5}
	Systemic	1500 dyne-sec. cm^{-5}