VORLESUNG 1

Vorlesung
Humboldt-Universität zu Berlin
Institut für Physik

Biologische Physik

Die Dynamik biologischer Prozesse im menschlichen Körper

Richard Weinkamer

Max Planck Institute of Colloids and Interfaces
Department of Biomaterials
Potsdam

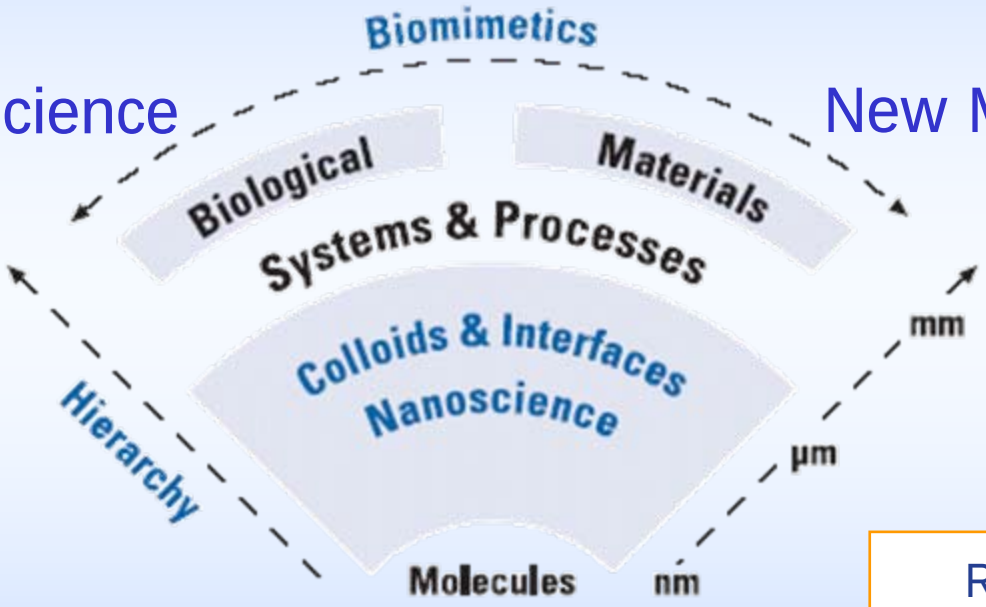
richard.weinkamer@mpikg.mpg.de

Max Planck Institute
of Colloids and Interfaces

Max Planck Institut für Kolloid- und Grenzflächenforschung

Max Planck Institute of Colloids and Interfaces

Kolloide: Strukturen im Nano- und Mikrometerbereich mit “viel Grenzfläche”



Colloid Science

Recognize construction principles of Nature and make them useful for technical applications

interdisziplinär: Chemie, Physik, Biologie, Materialwissenschaft, ...

Outlook

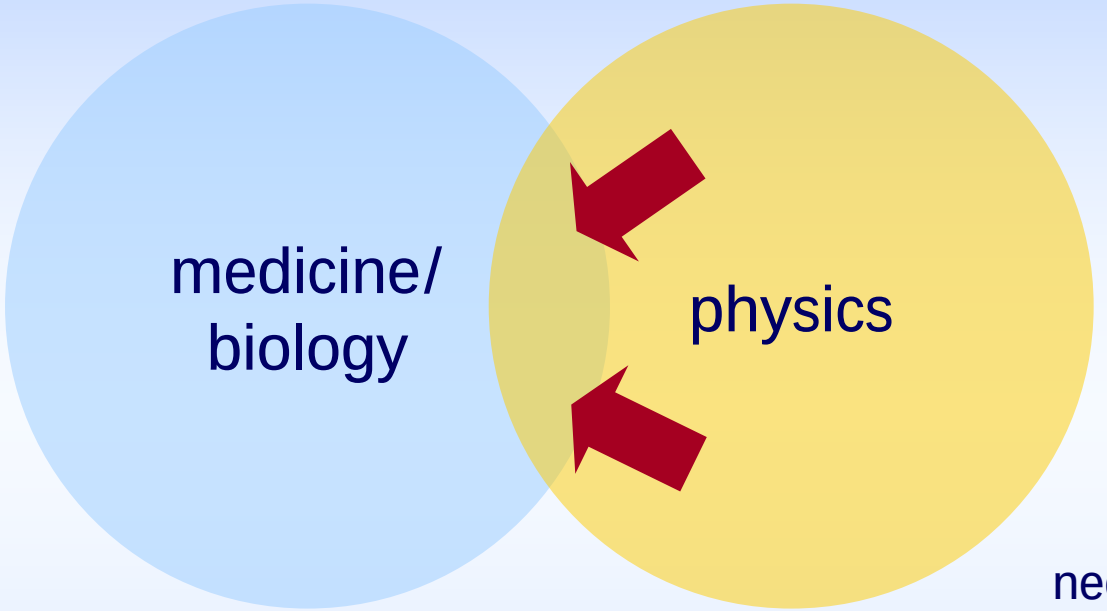
15.10.	Introduction, Aims, Diving Line, the „Standard Man", Scaling Relationsships, The Circulatory System
22.10.	The Circulatory System, blood flow, compliant vessel, cardiac output, model of a simple circulatory system
29.10.	Blood, Myoglobin and Hemoglobin (Biochemical Reactions), Red Blood Cell Production, Leukocytes
5.11.	Respiration, Capillary-Alveoli Gas Exchange (CO_2, O_2, CO), ventilation and its regulation
12.11.	Muscle, Anatomy, The Hill Model, A Simple Crossbridge Model: The Huxley Model
19.11.	Bone I (static), Hierarchical Structure, Theory of Composites, Staggered Model of Bone Nanostructure
26.11.	Bone II (dynamic – architectural level of spongy bone), Bone Remodeling, Wolff-Roux law, Computersimulation, Markov Model
3.12.	Bone III (dynamic – bone material), bone mineral density distribution (BMDD), time evolution of the BMDD, mechanical implications, bone healing

Outlook

10.12.	Hormone Physiology, Ovulation in Mammals, Ultradian Oscillations (Insulin – Glucose)
17.12.	Renal Physiology, The Glomerulus, Urinary Concentration: The Loop of Henle
14.1.	The Retina and Vision, Weber-Fechner law, Nonlinear Feedback Model, Photoreceptor Physiology, The Pupil Light Reflex
21.1.	The Inner Ear, Models of the Cochlea, Electrical Resonance in Hair Cells
28.1.	The Immune System I, The Innate and the Adaptive Immune System, The Inflammatory Response
4.2.	The Immune System II, Time Course of an Infection

quantitative description of physiological processes

interdisciplinary topic

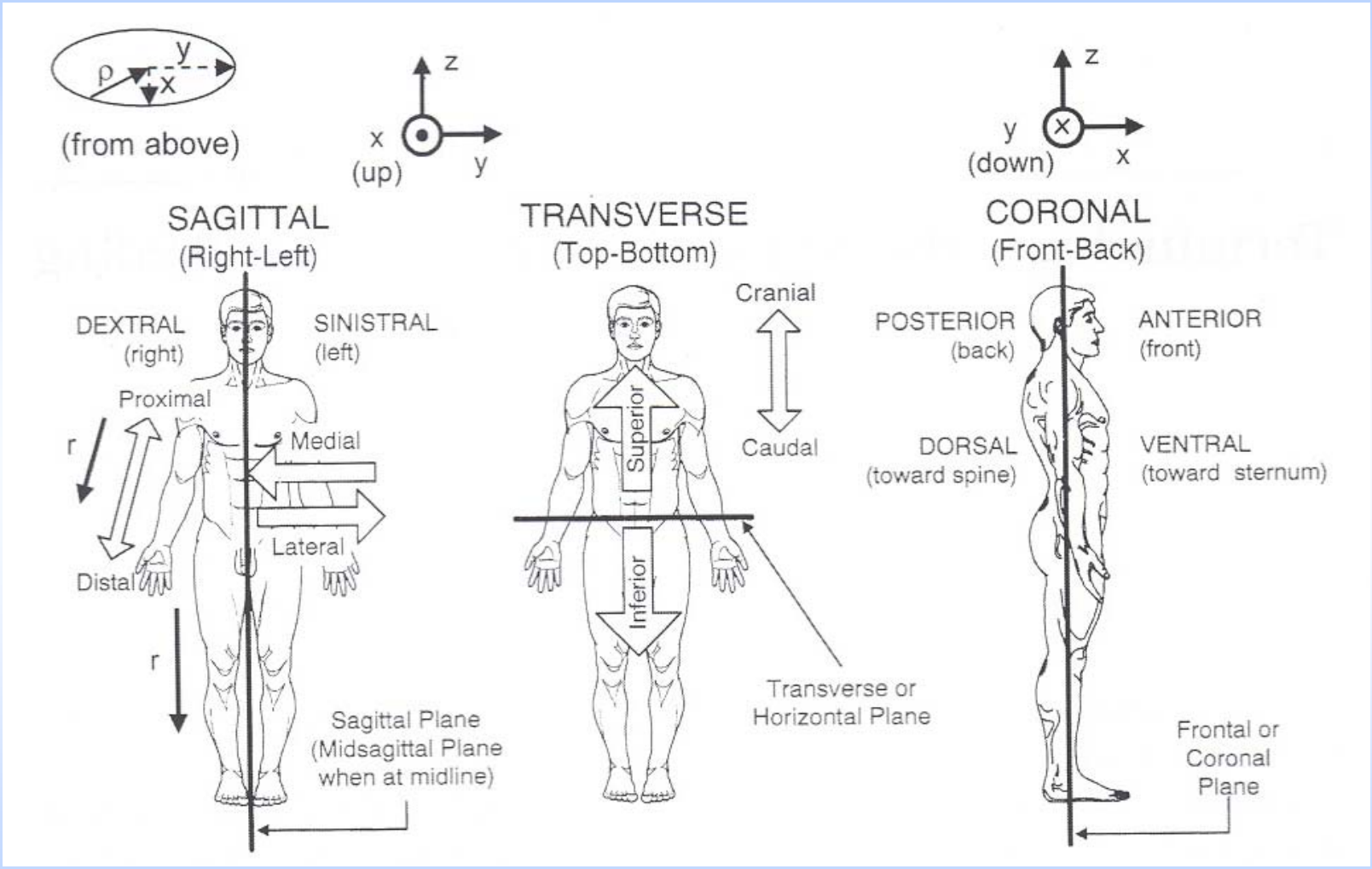


physicists are more
“flexibel” and
“have to” move

large amount of
“uninterpreted” data -
need of input from physicists

problem of interdisciplinary research
is not so much to understand their ideas,
but to understand their jargon

example: coordinate system

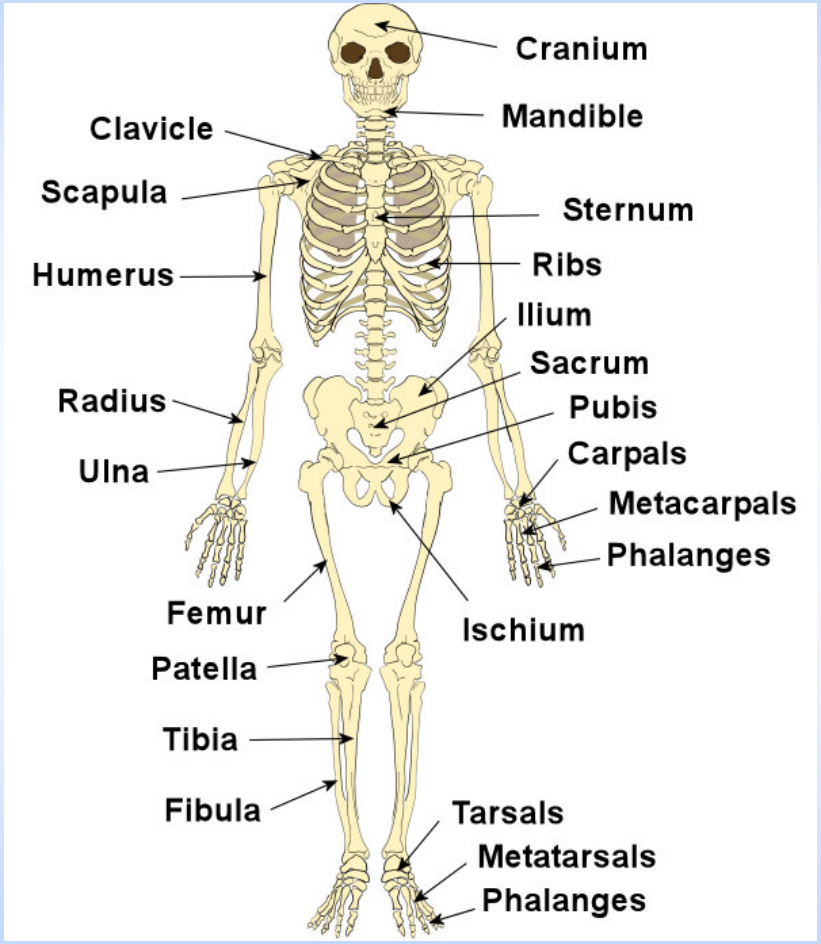


medial (¬ lateral): nearer the midline of the body, smaller |y|

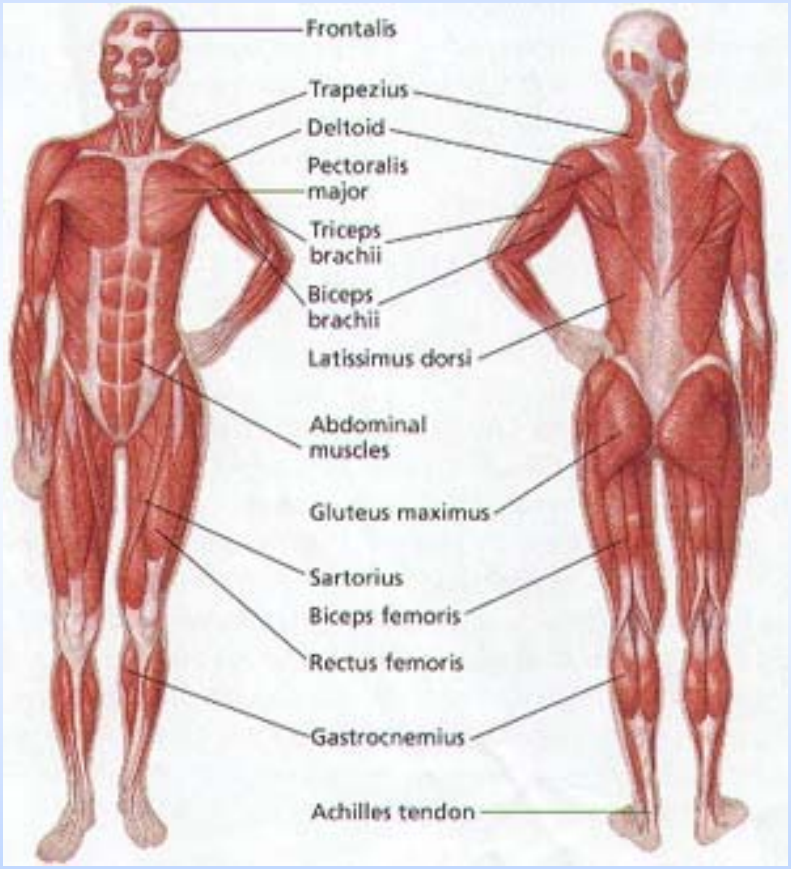
proximal (¬ distal): near the point of attachment

example: standard anatomy

the skeletal system:



the muscular system:



arm: humerus, ulna + radius
leg: femur, tibia + fibula

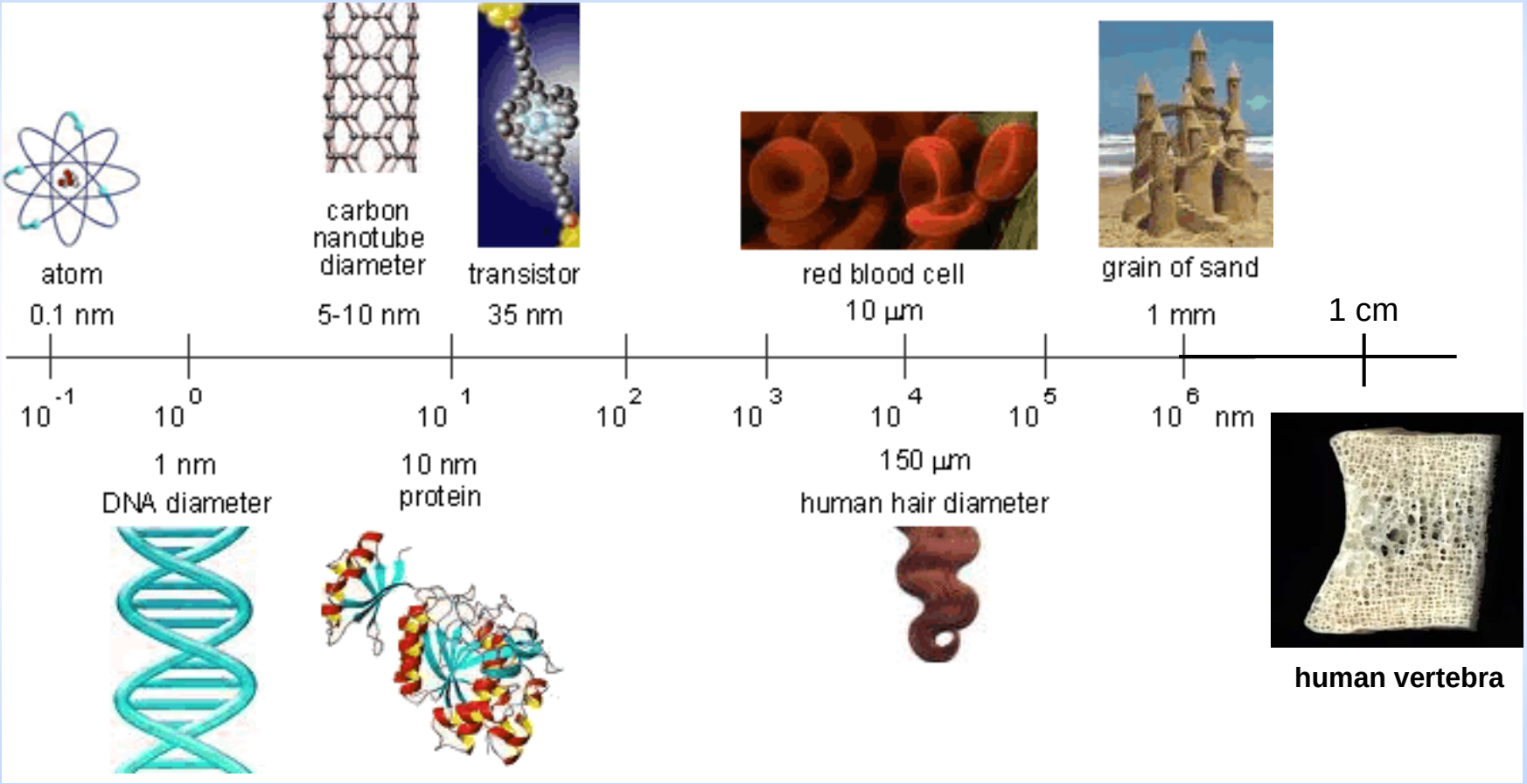
biceps (triceps): any muscle with two (three) points of origin

typical lecture

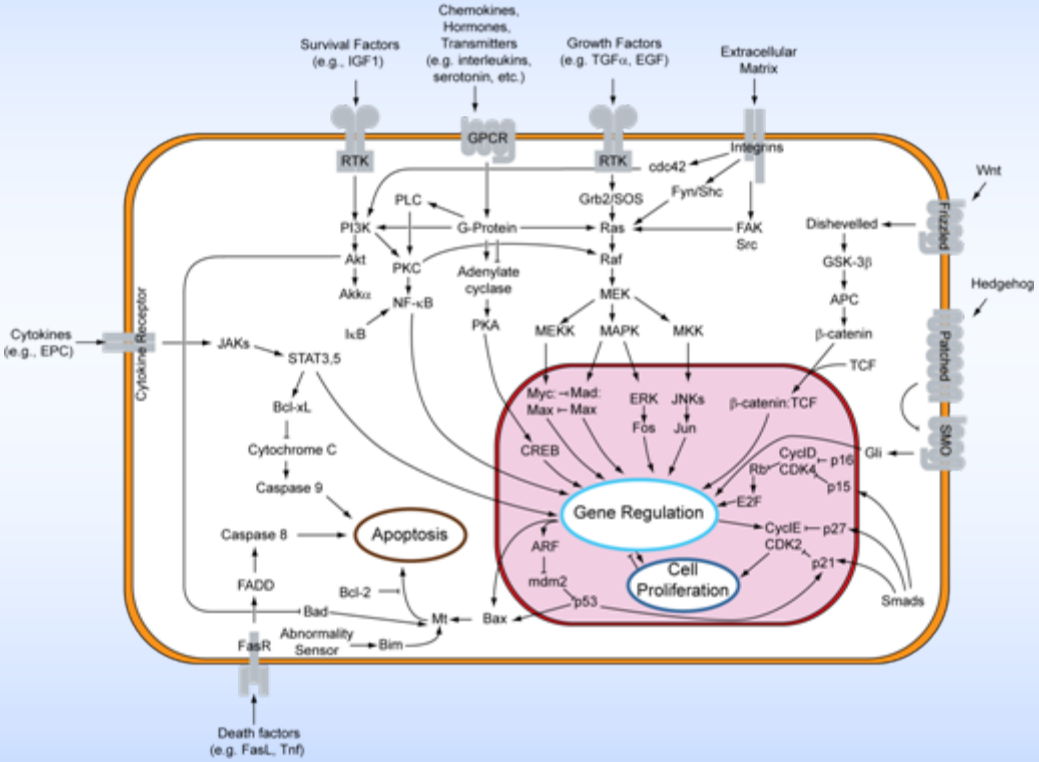
1. anatomy and physiology (new terminology)
2. physical background – problem to solve
3. introduction of the model – model assumptions
4. solution of the model
5. discussion of the results –
   what did we learn about human physiology

biophysics

length scales in biology



systems biology and bioinformatics



signal transduction pathways

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GTGAAACTTGCCAGCTTACTTCGGCATGTCCTGGTCATTTTGGAAAATTTCATCTTACT
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TTCTTTCTGTGGTGCTTTACAAAATCTTGAACTTCTGGAATTGATCAAGCAGATAGACG
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ACCAAACAAAGCAAATTCAAGTGTATTGCACCTAATTGCCAAAAACAAGTCTCTCCTTT
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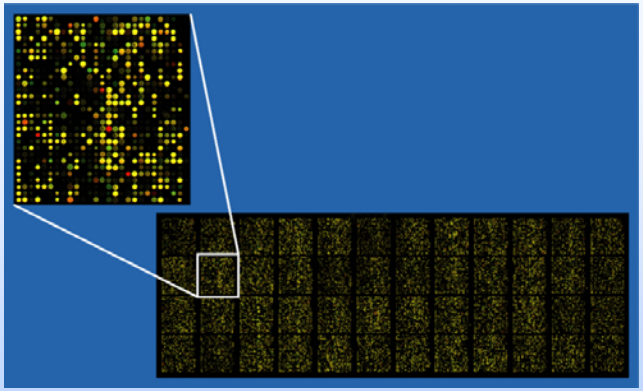
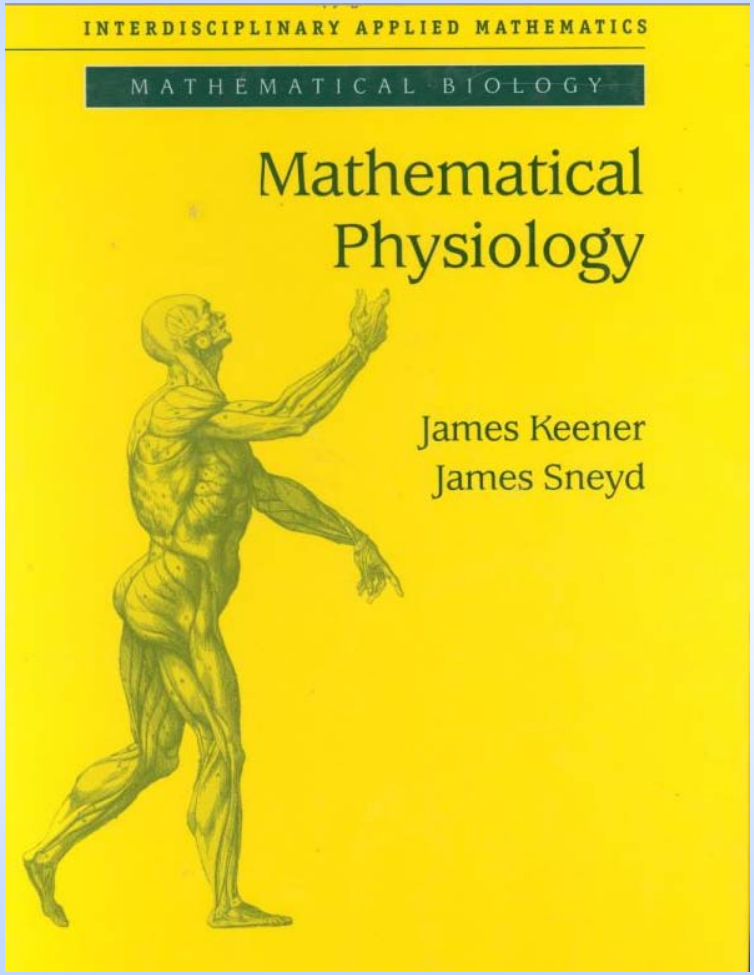
DNA sequence



DNA microarrays

sources for the lecture



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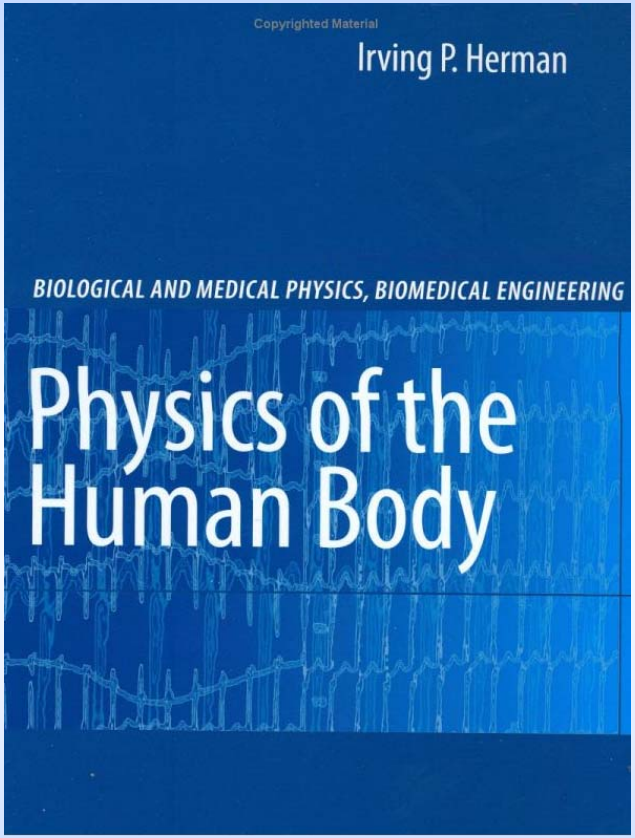


+ own research

The Standard Human

PART 1

AIM: to define “the typical human”

age	30 yr
height	1.72 m (5 ft 8 in)
mass	70 kg
weight	690 N (154 lb)
surface area	1.85 m^2
body core temperature	37.0°C
body skin temperature	34.0°C
heat capacity	0.83 kcal/kg-°C (3.5 kJ/kg-°C)
basal metabolic rate	70 kcal/h (1,680 kcal/day, 38 kcal/m^2-h, 44 W/m^2)
body fat	15%
subcutaneous fat layer	5 mm
body fluids volume	51 L
body fluids composition	53% intracellular; 40% interstitial, lymph; 7% plasma
heart rate	65 beats/min

The Standard Human

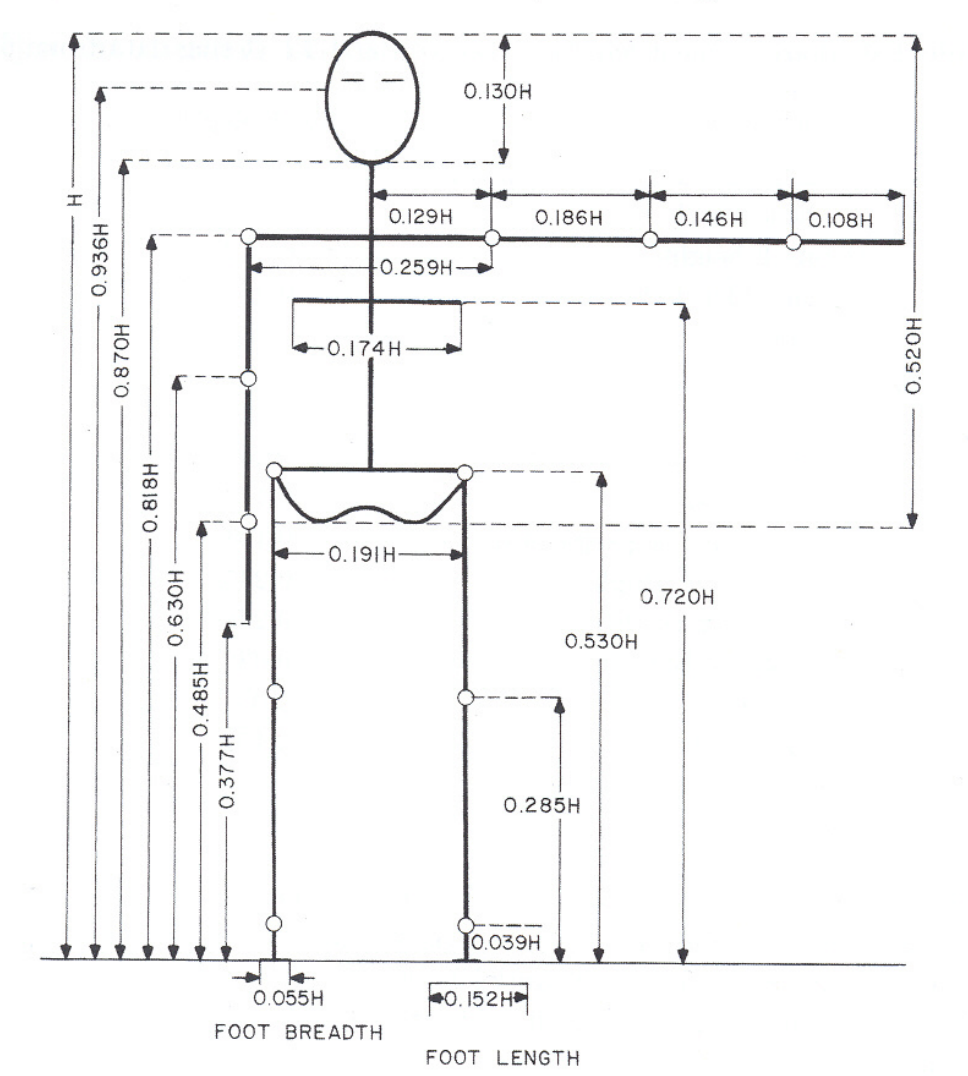
PART 2

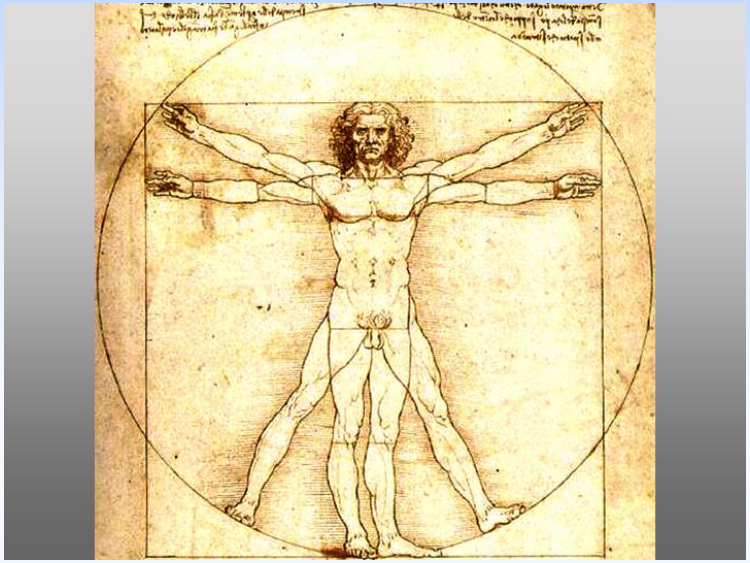
AIM: to define “the typical human”

blood volume	5.2 L
blood hematocrit	0.43
cardiac output (at rest)	5.0 L/min
cardiac output (in general)	3.0 + 8 × O_2 consumption (in L/min) L/min
systolic blood pressure	120 mmHg (16.0 kPa)
diastolic blood pressure	80 mmHg (10.7 kPa)
breathing rate	15/min
O_2 consumption	0.26 L/min
CO_2 production	0.21 L/min
total lung capacity	6.0 L
vital capacity	4.8 L
tidal volume	0.5 L
lung dead space	0.15 L
lung mass transfer area	90 m^2
mechanical work efficiency	0–25%

Anthropometry

AIM: to define “the typical human”





Leonardo da Vinci

H ... body height

mass and volume

of the organs
in the human body:

fluid, tissue, organ, or system	total mass (g)	total volume (cm^3)
adult male body	70,000	60,000
muscle	30,000	23,000
fat	10,500	12,000
skin	2,000	1,800
subcutaneous tissue	4,100	3,700
skeleton	10,000	6,875
gastrointestinal track	2,000	1,800
contents (chyme/feces)	~2,000	~2,000
blood vessels	1,800	1,700
contents (blood)	5,600	5,400
liver	1,650	1,470
brain	1,400	1,350
lungs (2)	825	775
contents (air)	~7.7	~6,000
heart	330	300
chamber volume	–	450
kidneys (2)	300	270
urinary bladder	150	140
contents (urine)	~500	~500
digestive fluids	~150	~150
pancreas	110	100
salivary glands (6)	50	48
synovial fluid	~50	~50
teeth (32)	42	14
eyes (2)	30	27
hair (average haircut)	21	16
gall bladder	7	7
contents (bile)	~50	~50
fingernails and toenails (20)	1.1	0.9

typical cell

molecular content of a typical 20-μm human cell:

molecule	mass	molecular weight (amu, daltons)	number of molecules	number of molecular entities
water	65	18	1.74×10^{14}	1
other inorganic	1.5	55	1.31×10^{12}	20
lipid (fat)	12	700	8.4×10^{11}	50
other organic	0.4	250	7.7×10^{10}	~200
protein	20	50,000	1.9×10^{10}	~5,000
RNA	1.0	1×10^{6}	5×10^{7}	–
DNA	0.1	1×10^{11}	46	–

scaling relationships

allometric parameters for mammals:

property f

$$f = a\, m_b^{\alpha}$$

m_b ... body mass

allometric if $\alpha \neq 1$

isometric if $\alpha = 1$

parameter	a	α
basal metabolic rate (BMR), in W	4.1	0.75
body surface area, in m^2	0.11	0.65
brain mass in man, in kg	0.085	0.66
brain mass in nonprimates, in kg	0.01	0.7
breathing rate, in Hz	0.892	−0.26
energy cost of running, in J/m-kg	7	−0.33
energy cost of swimming, in J/m-kg	0.6	−0.33
effective lung volume, in m^2	5.67×10^{-5}	1.03
heart beat rate, in Hz	4.02	−0.25
heart mass, in kg	5.8×10^{-3}	0.97
lifetime, in y	11.89	0.20
muscle mass, in kg	0.45	1.0
skeletal mass (terrestrial), in kg	0.068	1.08
speed of flying, in m/s	15	0.167
speed of walking, in m/s	0.5	0.167

alternative index: $\frac{m_b}{H^p}$ p = 2 Quetelet's index, BMI