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VO 709.049 Medical Informatics

14.10.2015 11:15-12:45

Lecture 01 Introduction

Computer Science meets Life Sciences: Challenges and Future Directions

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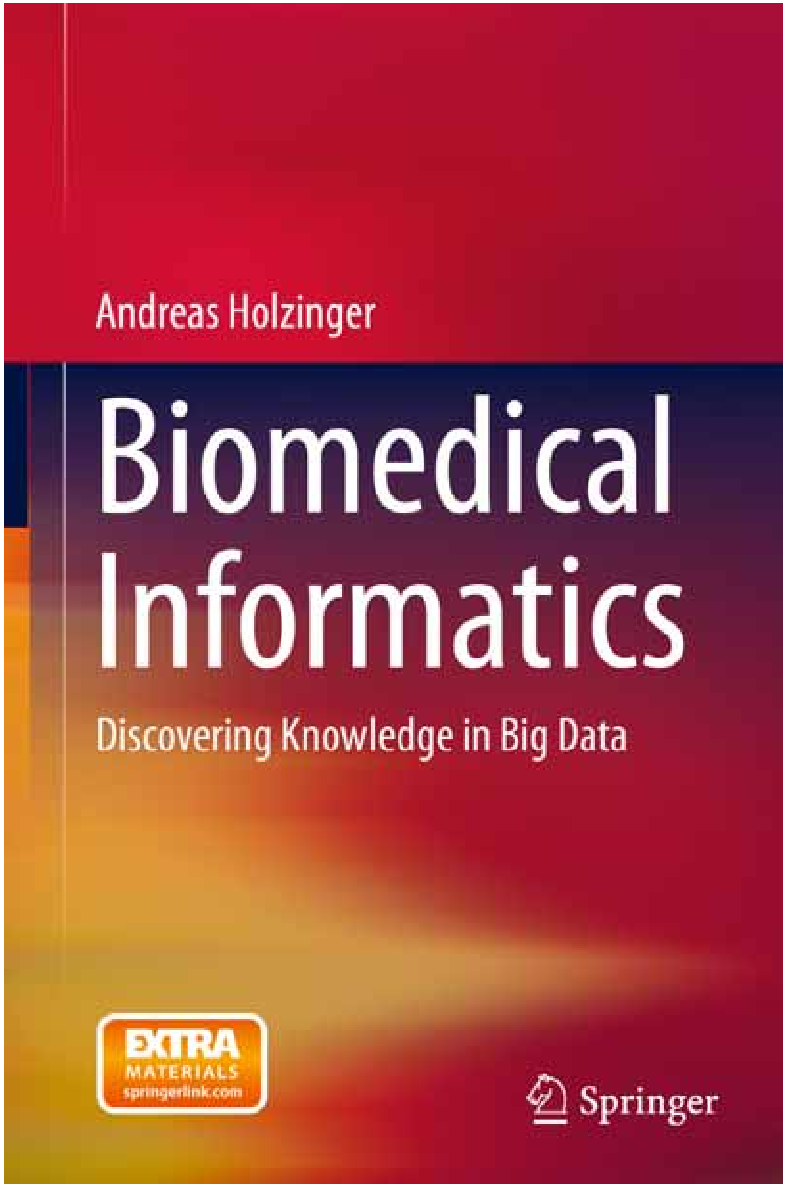
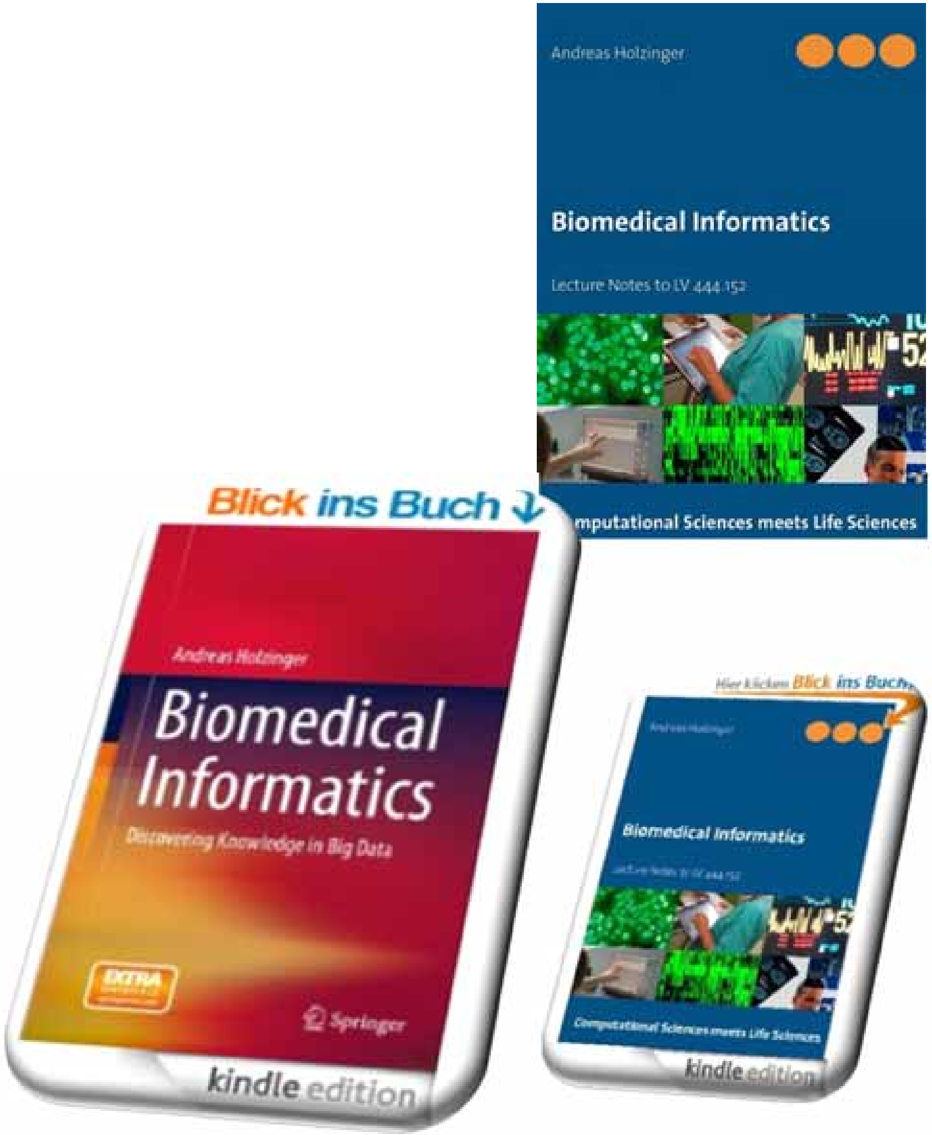
http://hci-kdd.org/biomedical-informatics-big-data

Reading on Paper or on any electronic device





Slide 0-1: Overview – Roadmap trough this Course

- **01. Intro: Computer Science meets Life Sciences, challenges, future directions**
- 02. Fundamentals of Data, Information and Knowledge
- 03. Structured Data: Coding, Classification (ICD, SNOMED, MeSH, UMLS)
- 04. Biomedical Databases: Acquisition, Storage, Information Retrieval and Use
- 05. Semi structured , weakly structured data and unstructured information
- 06. Multimedia Data Mining and Knowledge Discovery
- 07. Knowledge and Decision: Cognitive Science & Human-Computer Interaction
- 08. Biomedical Decision Making: Reasoning and Decision Support
- 09. Interactive Information Visualization and Visual Analytics
- 10. Biomedical Information Systems and Medical Knowledge Management
- 11. Biomedical Data: Privacy, Safety and Security
- 12. Methodology for Info Systems: System Design, Usability & Evaluation

Keywords of Lecture 01

- Big Data
- Life
- Proteins – DNA & RNA – Cell – Tissue – Organ – Cardiovascular Systems
- Medicine – Informatics – Computer
- Personalized Medicine
- Translational Informatics – Data Integration
- Open Medical Data
- Biomarker Discovery

- At the end of this first lecture you will …
- … be fascinated to see our world in data;
- … have a basic understanding of the building blocks of life;
- … be familiar with some differences between Life Sciences and Computer Sciences;
- … be aware of some possibilities and some limits of Biomedical Informatics;
- … have some ideas of some future directions of Biomedical Informatics;

Advance Organizer (1/2)

- **Bioinformatics** = discipline, as part of biomedical informatics, at the interface between *bio*logy and *infor*mation science and mathema*tics*; processing of biological data;
- **Biomarker** = a characteristic (e.g. body-temperature (fever) as a biomarker for an infection, or proteins measured in the urine) as an indicator for normal or pathogenic biological processes, or pharmacologic responses to a therapeutic intervention;
- **Biomedical data** = compared with general data, it is characterized by large volumes, complex structures, high dimensionality, evolving biological concepts, and insufficient data modeling practices;
- **Biomedical Informatics** = 2011-definition: similar to medical informatics but including the optimal use of biomedical data, e.g. from genomics, proteomics, metabolomics;
- **Classical Medicine** = is both the science and the art of healing and encompasses a variety of practices to maintain and restore health;
- **Genomics** = branch of molecular biology which is concerned with the structure, function, mapping & evolution of genomes;
- **Medical Informatics** = 1970-definition: "… scientific field that deals with the storage, retrieval, and optimal use of medical information, data, and knowledge for problem solving and decision making";
- **Metabolomics** = study of chemical processes involving metabolites (e.g. enzymes). A challenge is to integrate proteomic, transcriptomic, and metabolomic information to provide a more complete understanding of living organisms;
- **Molecular Medicine** = emphasizes cellular and molecular phenomena and interventions rather than the previous conceptual and observational focus on patients and their organs;

Advance Organizer (2/2)

- **Omics data** = data from e.g. genomics, proteomics, metabolomics, etc.
- **Pervasive Computing** = similar to ubiquitous computing (Ubicomp), a post-desktop model of Human-Computer Interaction (HCI) in which information processing is integrated into every-day, miniaturized and embedded objects and activities; having some degree of “intelligence”;
- **Pervasive Health** = all unobtrusive, analytical, diagnostic, supportive etc. information functions to improve health care, e.g. remote, automated patient monitoring, diagnosis, home care, self-care, independent living, etc.;
- **Proteome** = the entire complement of proteins that is expressed by a cell, tissue, or organism;
- **Proteomics** = field of molecular biology concerned with determining the proteome;
- **P-Health Model** = Preventive, Participatory, Pre-emptive, Personalized, Predictive, Pervasive (= available to anybody, anytime, anywhere);
- **Space** = a set with some added structure;
- **Technological Performance** = machine “capabilities”, e.g. short response time, high throughput, high availability, etc.
- **Time** = a dimension in which events can be ordered along a time line from the past through the present into the future;
- **Translational Medicine** = based on interventional epidemiology; progress of Evidence-Based Medicine (EBM), integrates research from basic science for patient care and prevention;
- **Von-Neumann-Computer** = a 1945 architecture, which still is the predominant machine architecture of today (opp.: Non-Vons, incl. analogue, optical, quantum computers, cell processors, DNA and neural nets (in silico));

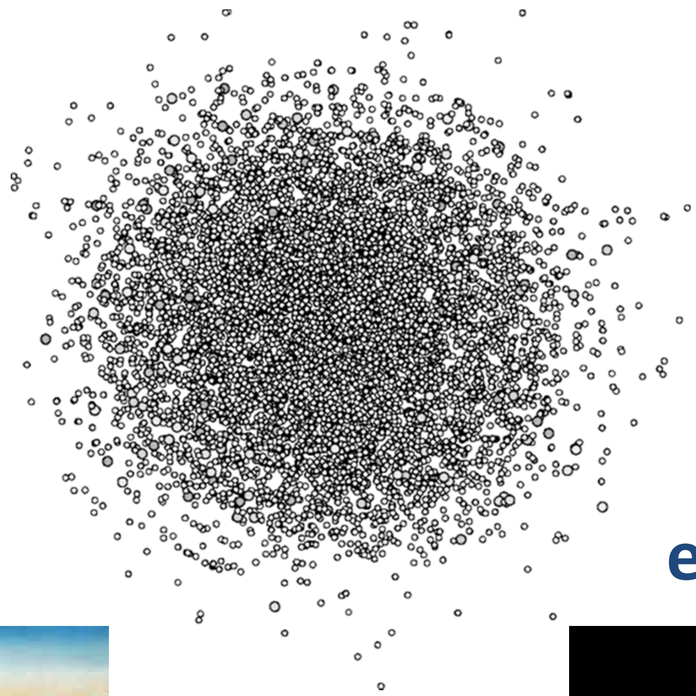
Acronyms/Abbreviations in Lecture 01

- AI = Artificial Intelligence
- AL = Artificial Life
- CPG = Clinical Practice Guideline
- CPOE = Computerized physician order entry
- CMV = Controlled Medical Vocabulary
- DEC = Digital Equipment Corporation (1957-1998)
- DNA = Deoxyribonucleic Acid
- EBM = Evidence Based Medicine
- EPR = Electronic Patient Record
- GBM = Genome Based Medicine
- GC = Gas Chromatography
- GPM = Genetic Polymorphism
- HCI = Human–Computer Interaction
- LC = Liquid Chromatography
- LNCS = Lecture Notes in Computer Science
- MS = Mass Spectrometry
- mRNA = Messenger RNA
- NGC = New General Catalogue of Nebulae and Star clusters in Astronomy
- NGS = Next Generation Sequencing
- NMR = Nuclear Magnetic Resonance
- PDB = Protein Data Base
- PDP = Programmable Data Processor (mainframe)
- PPI = Protein-Protein Interaction
- RFID = Radio-frequency identification device
- RNA = Ribonucleic Acid
- SNP = Single Nucleotide Polymorphism
- TNF = Tumor Necrosis Factor
- TQM = Total Quality Management

- **Zillions** of different biological species (humans, animals, bacteria, virus, plants, …);
- Enormous **complexity** of the medical domain [1];
- **Complex,** heterogeneous, high-dimensional, big data in the life sciences [2];
- Limited **time,** e.g. a medical doctor in a public hospital has only 5 min. to make a decision [3];
- Limited **computational power** in comparison to the complexity of life (and the natural limitations of the Von-Neumann architecture, …);

1. Patel VL, Kahol K, & Buchman T (2011) Biomedical Complexity and Error. *J. Biomed. Inform.* 44(3):387-389.
2. Holzinger A, Dehmer M, & Jurisica I (2014) Knowledge Discovery and interactive Data Mining in Bioinformatics - State-of-the-Art, future challenges and research directions. BMC Bioinformatics 15(S6):I1.
3. Gigerenzer G (2008) Gut Feelings: Short Cuts to Better Decision Making (Penguin, London).


What is
the
challenge ?
ESO, Atacama, Chile (2011)



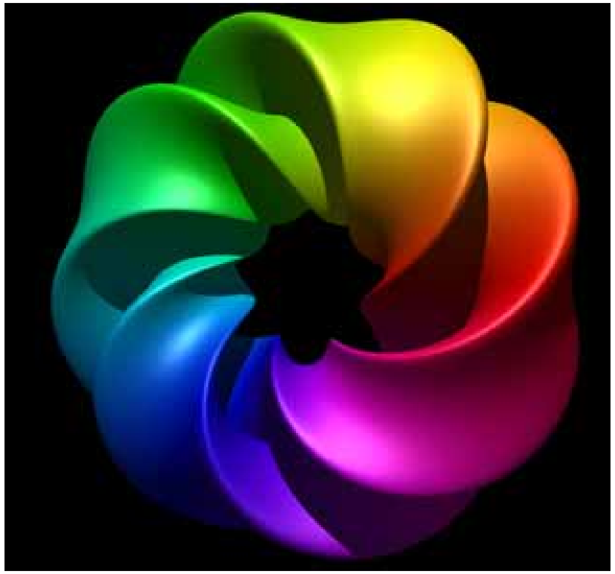
Time

Space

e.g. Entropy

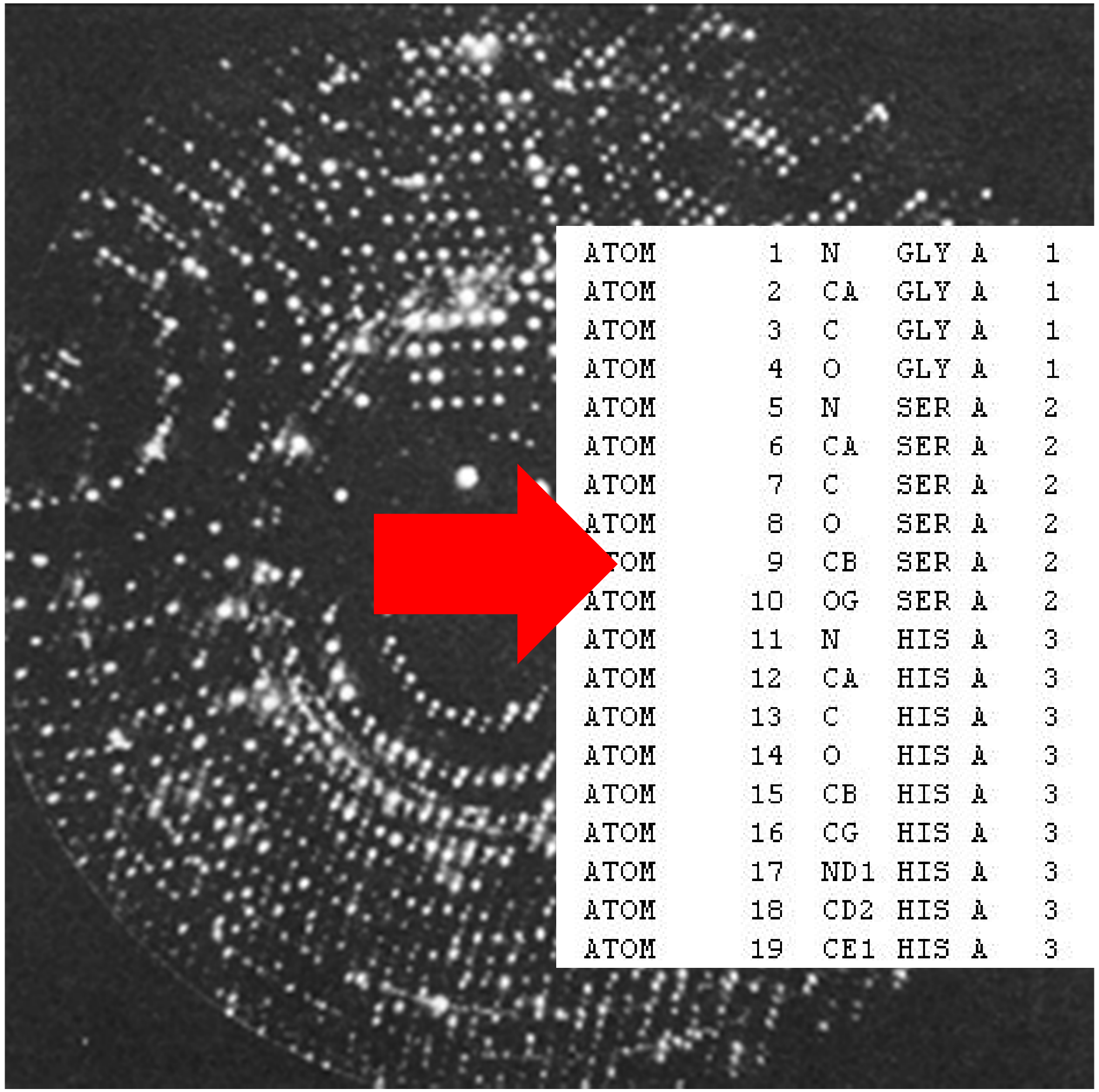
e.g. Topology

Dali, S. (1931) The persistence of memory



Bagula & Bourke (2012) Klein-Bottle

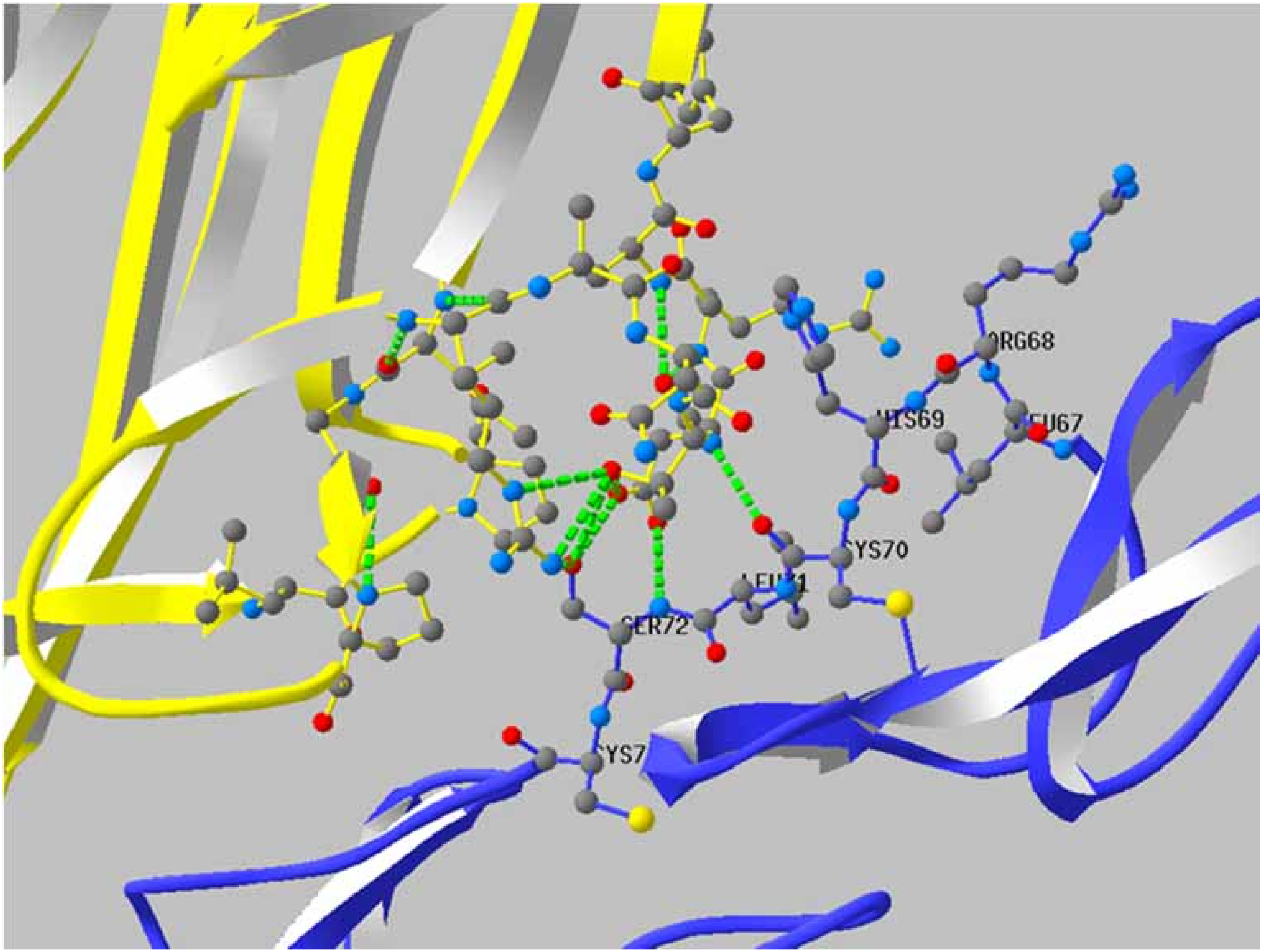
Slide 1-2: Our World in Data (2/2) – Microscopic Structures



ATOM	1	N	GLY	A	1	44.842	51.034	101.284	0.01	27.20
ATOM	2	CA	GLY	A	1	45.640	50.230	100.389	0.01	26.99
ATOM	3	C	GLY	A	1	46.692	49.648	101.308	0.01	26.80
ATOM	4	O	GLY	A	1	46.895	50.222	102.381	0.01	26.91
ATOM	5	N	SER	A	2	47.283	48.516	100.951	1.00	26.26
ATOM	6	CA	SER	A	2	48.277	47.866	101.761	1.00	26.17
ATOM	7	C	SER	A	2	49.212	47.031	100.845	1.00	24.21
ATOM	8	O	SER	A	2	49.060	47.195	99.630	1.00	19.77
ATOM	9	CB	SER	A	2	47.438	47.091	102.800	1.00	26.31
ATOM	10	OG	SER	A	2	46.276	46.356	102.404	1.00	27.99
ATOM	11	N	HIS	A	3	50.147	46.186	101.370	1.00	23.93
ATOM	12	CA	HIS	A	3	51.129	45.389	100.609	1.00	21.44
ATOM	13	C	HIS	A	3	50.953	43.905	100.849	1.00	20.32
ATOM	14	O	HIS	A	3	50.530	43.595	101.950	1.00	22.00
ATOM	15	CB	HIS	A	3	52.555	45.674	100.990	1.00	19.69
ATOM	16	CG	HIS	A	3	52.940	47.090	100.611	1.00	21.44
ATOM	17	ND1	HIS	A	3	53.371	47.470	99.422	1.00	20.87
ATOM	18	CD2	HIS	A	3	52.956	48.175	101.433	1.00	21.69
ATOM	19	CE1	HIS	A	3	53.676	48.730	99.476	1.00	20.57

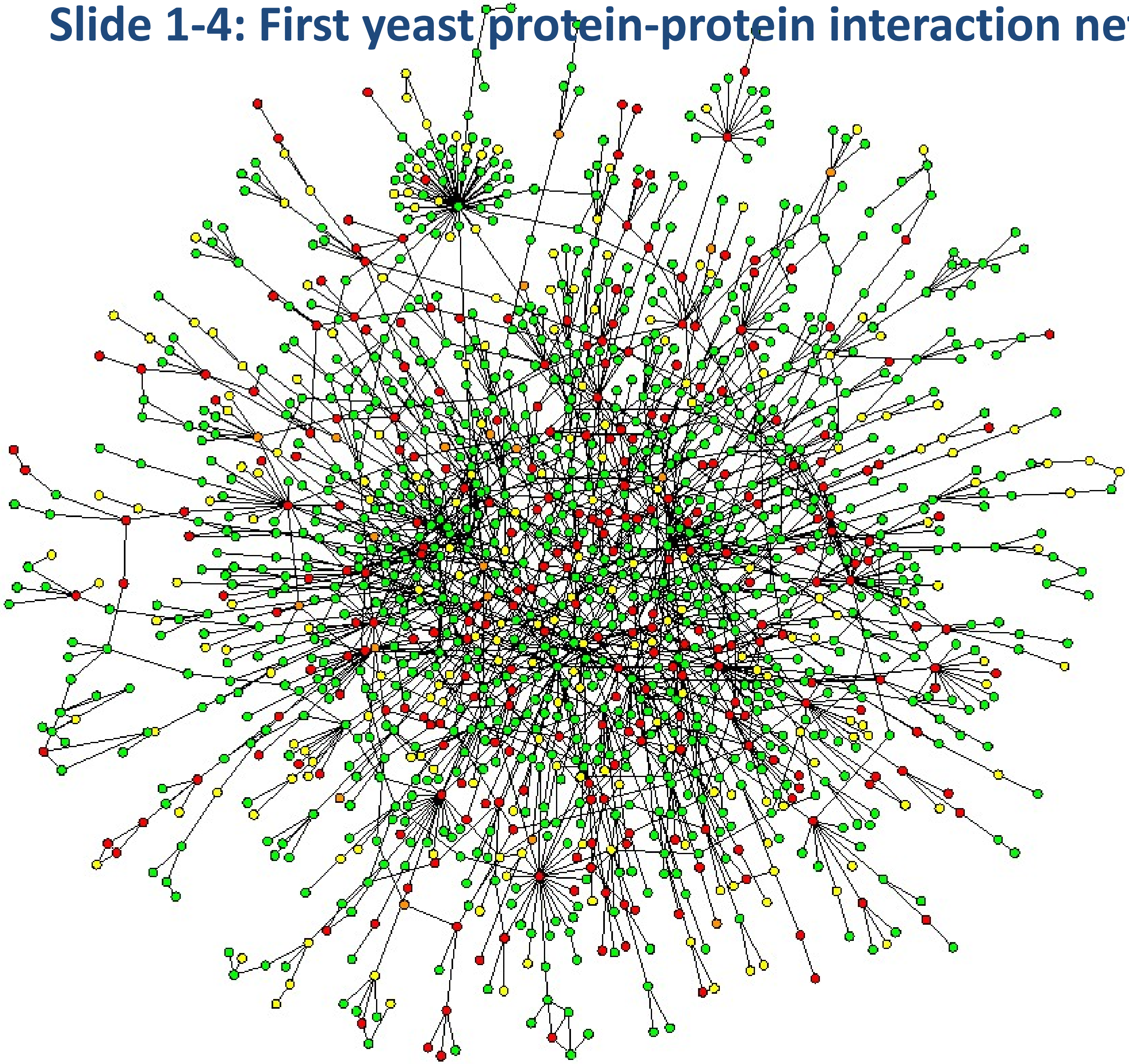
Wiltgen, M. & Holzinger, A. (2005) Visualization in Bioinformatics: Protein Structures with Physicochemical and Biological Annotations. In: *Central European Multimedia and Virtual Reality Conference. Prague, Czech Technical University (CTU), 69-74*

Slide 1-3: Knowledge Discovery from Data



Wiltgen, M., Holzinger, A. & Tilz, G. P. (2007) Interactive Analysis and Visualization of Macromolecular Interfaces Between Proteins. In: *Lecture Notes in Computer Science (LNCS 4799). Berlin, Heidelberg, New York, Springer, 199-212.*

Slide 1-4: First yeast protein-protein interaction network

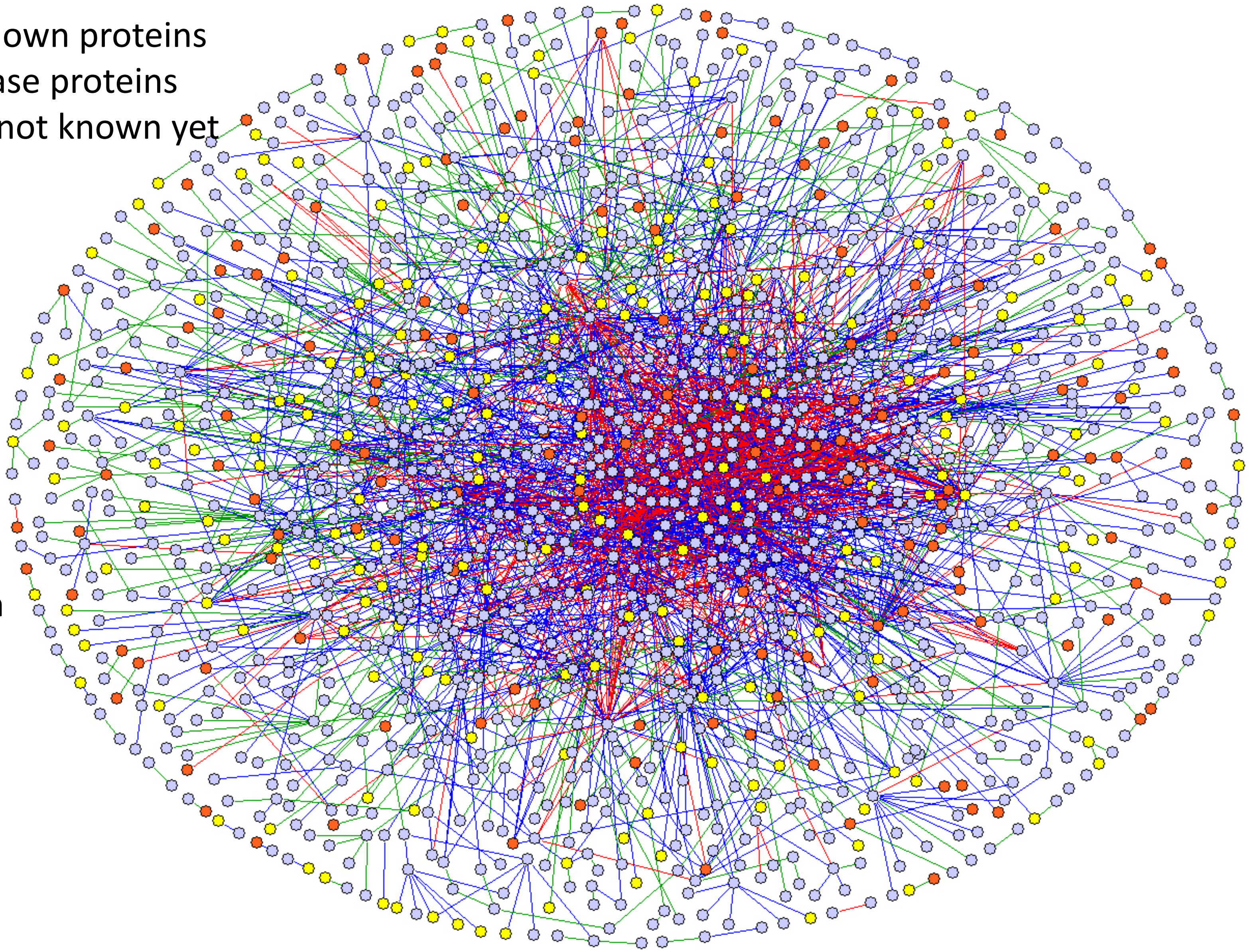


Nodes = proteins
Links = physical interactions (bindings)
Red Nodes = lethal
Green Nodes = non-lethal
Orange = slow growth
Yellow = not known

Jeong, H., Mason, S. P., Barabasi, A. L. & Oltvai, Z. N. (2001) Lethality and centrality in protein networks. *Nature, 411, 6833, 41-42.*

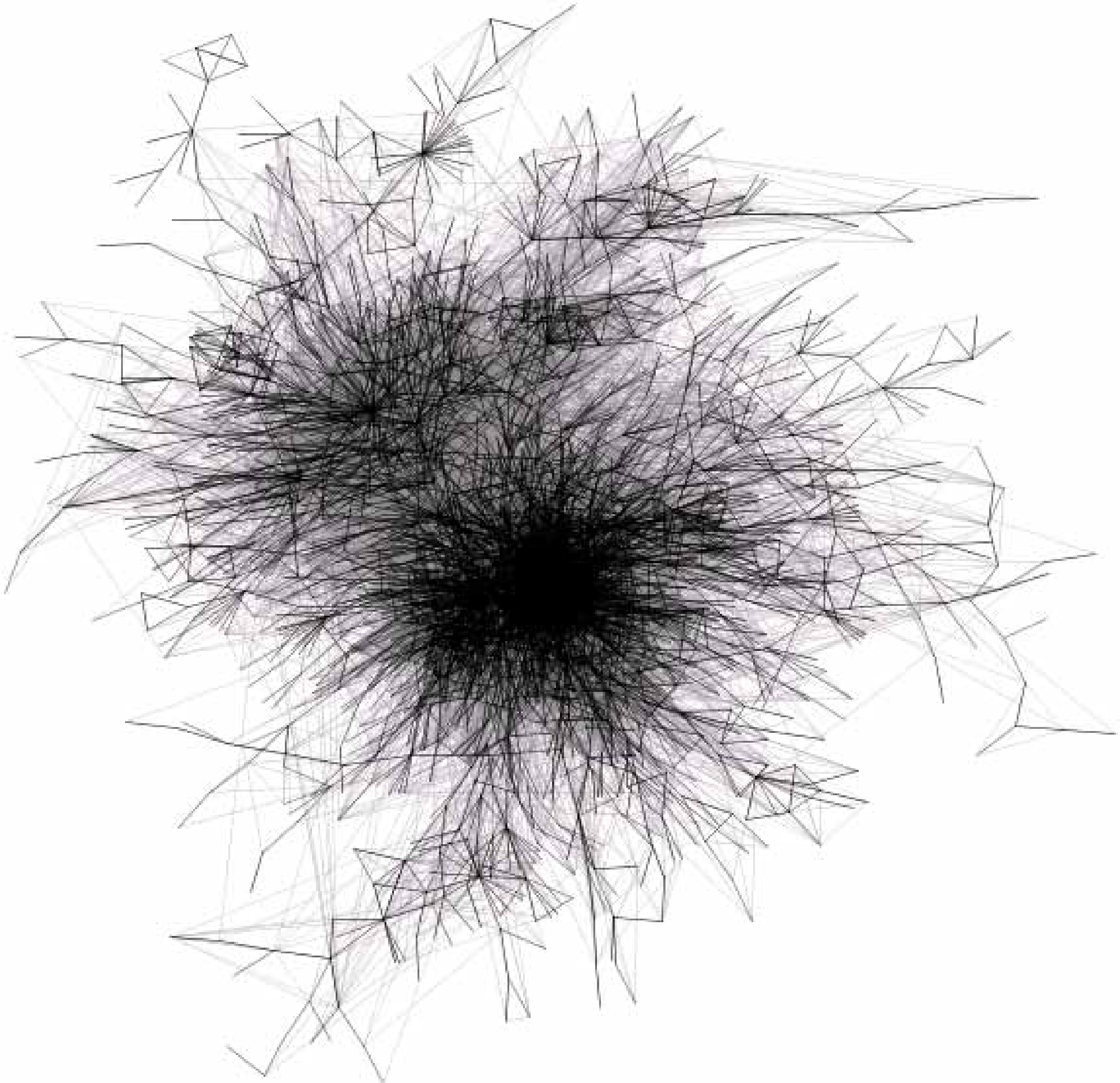
Slide 1-5: First human protein-protein interaction network

Light blue = known proteins
Orange = disease proteins
Yellow ones = not known yet

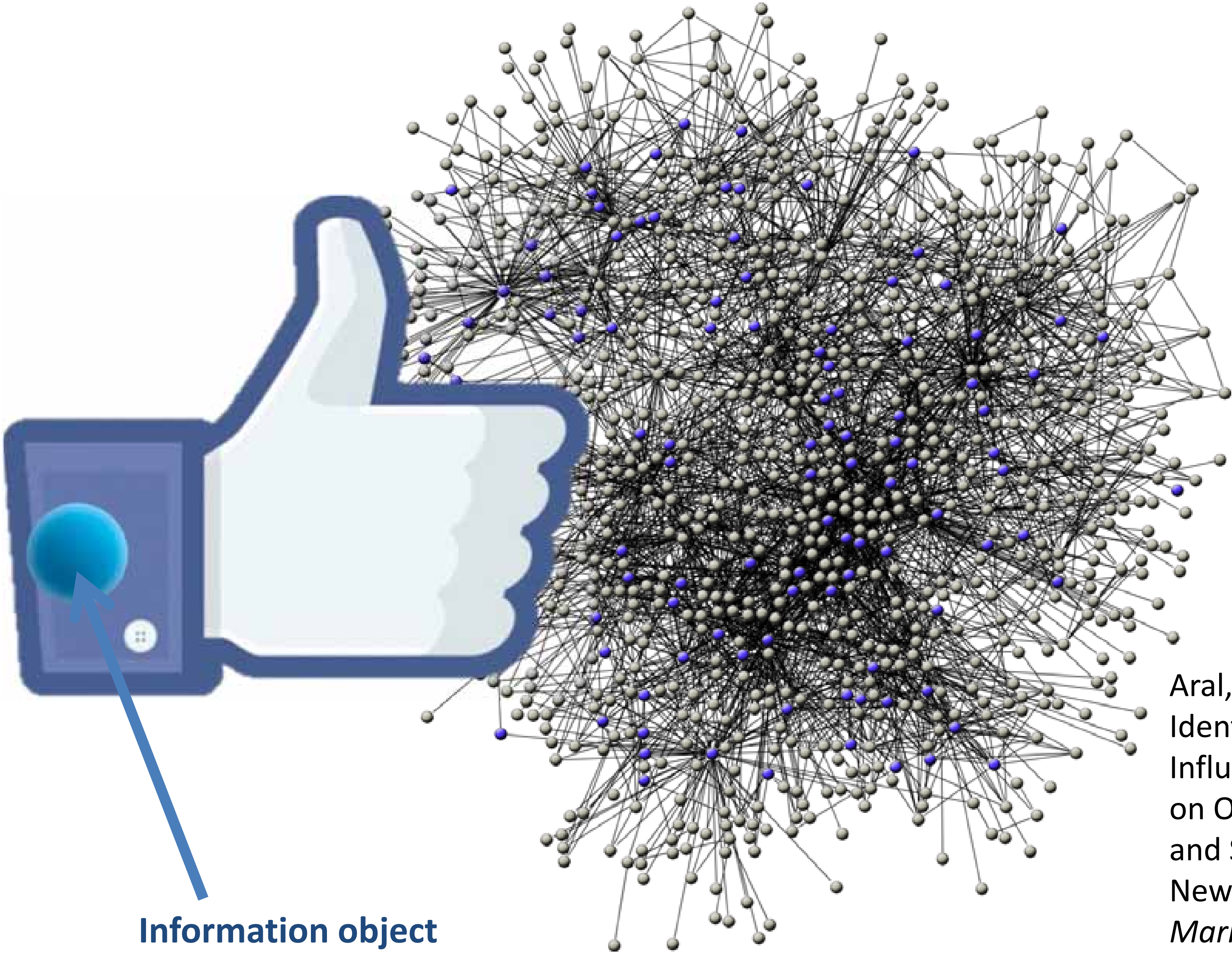


Stelzl, U. et al. (2005) A Human Protein-Protein Interaction Network: A Resource for Annotating the Proteome. *Cell, 122, 6, 957-968.*

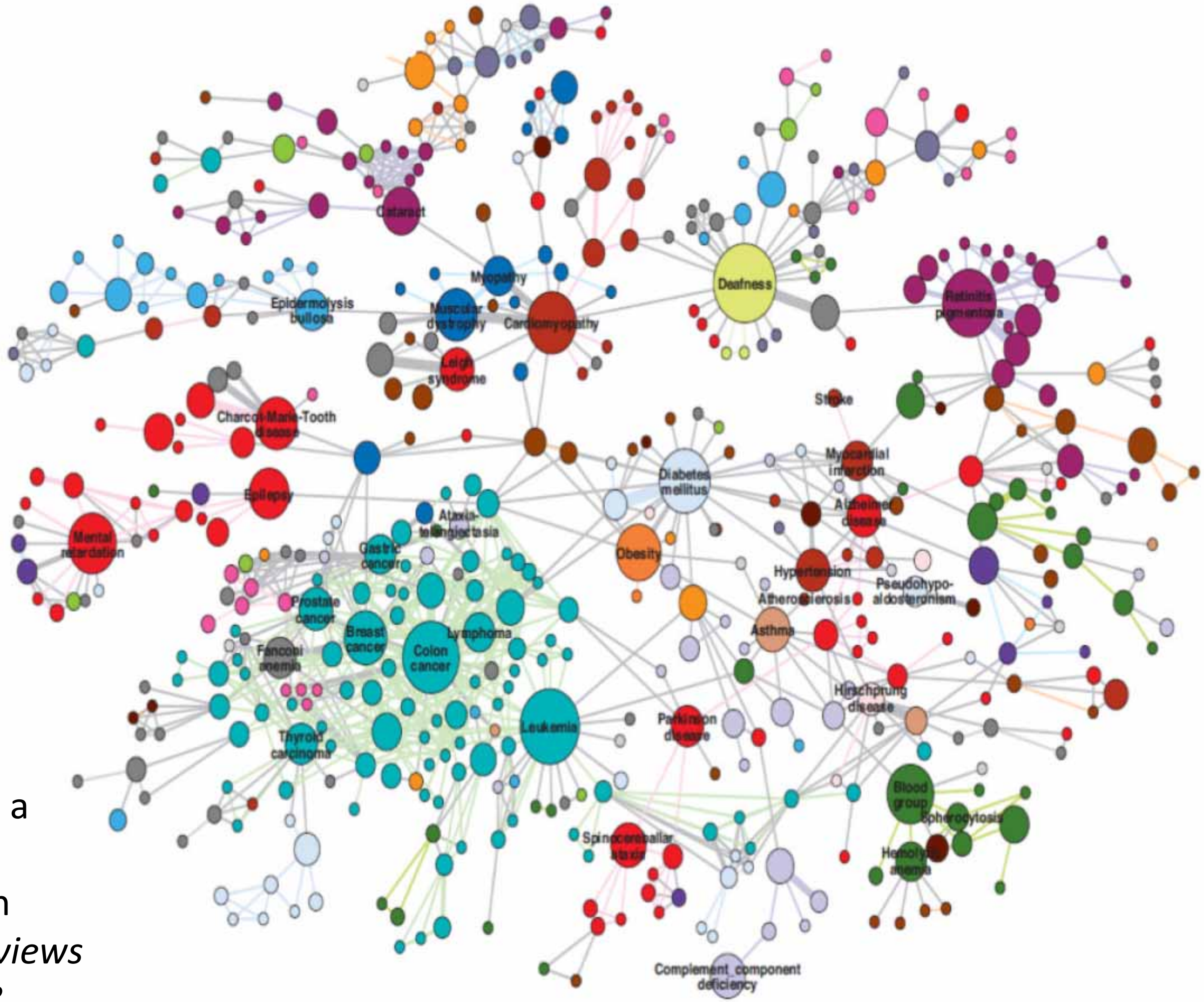
Slide 1-6: Non-Natural Network Example: Blogosphere



Hurst, M. (2007), Data Mining: Text Mining, Visualization and Social Media. Online available: http://datamining.typepad.com/data_mining/2007/01/the_blogosphere.html, last access: 2011-09-24



Aral, S. (2011) Identifying Social Influence: A Comment on Opinion Leadership and Social Contagion in New Product Diffusion. *Marketing Science, 30, 2, 217-223.*



Barabási, A. L., Gulbahce, N. & Loscalzo, J. 2011. Network medicine: a network-based approach to human disease. *Nature Reviews Genetics, 12*, ***56-68.***

$$\left(-\frac{\hbar^2}{2m}\Delta + U(\vec{r},t)\right)\psi(\vec{r},t) = i\hbar\frac{\partial}{\partial t}\psi(\vec{r},t)$$

to reproduce …

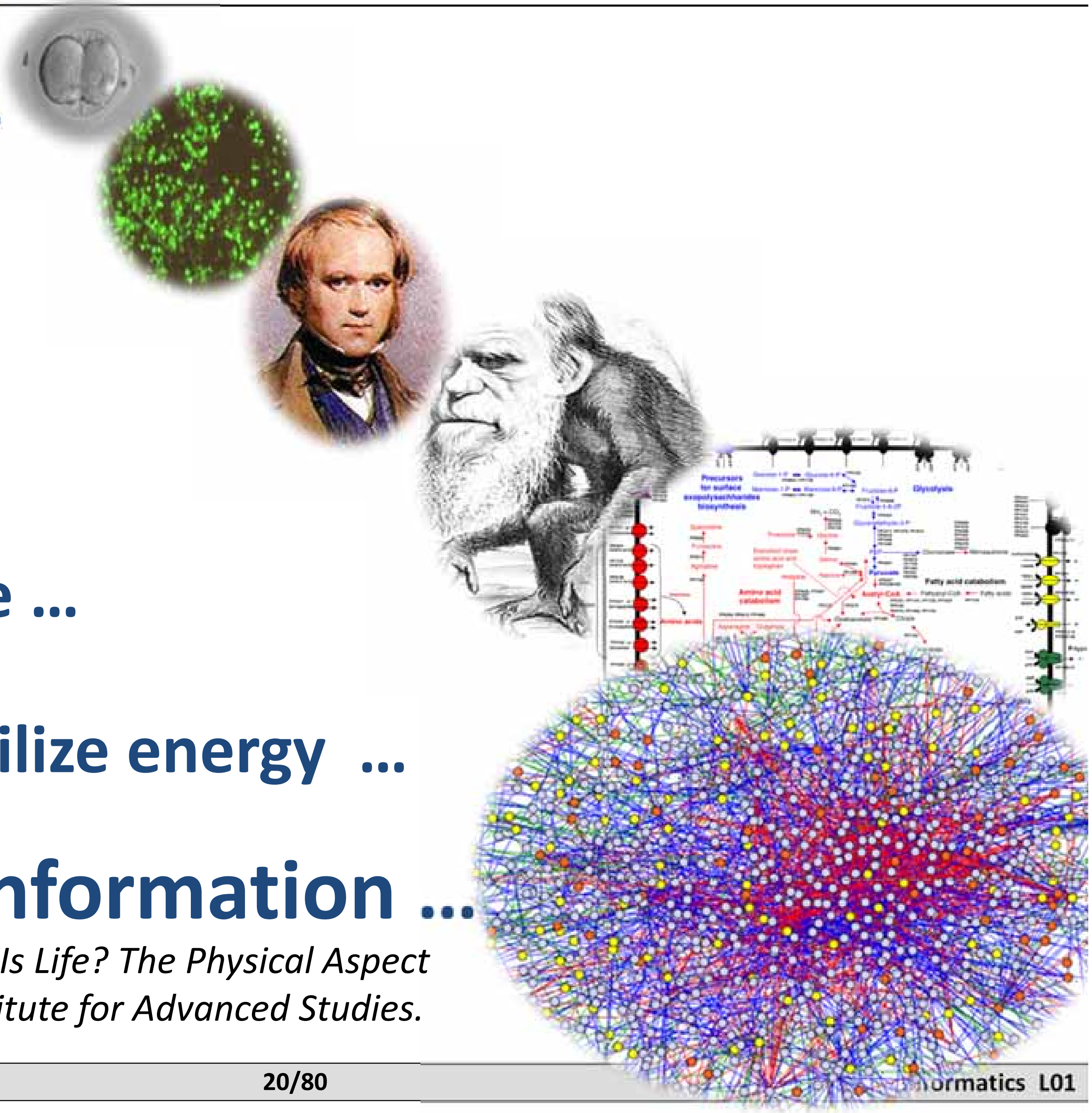
to grow …

to evolve …

to self-replicate …

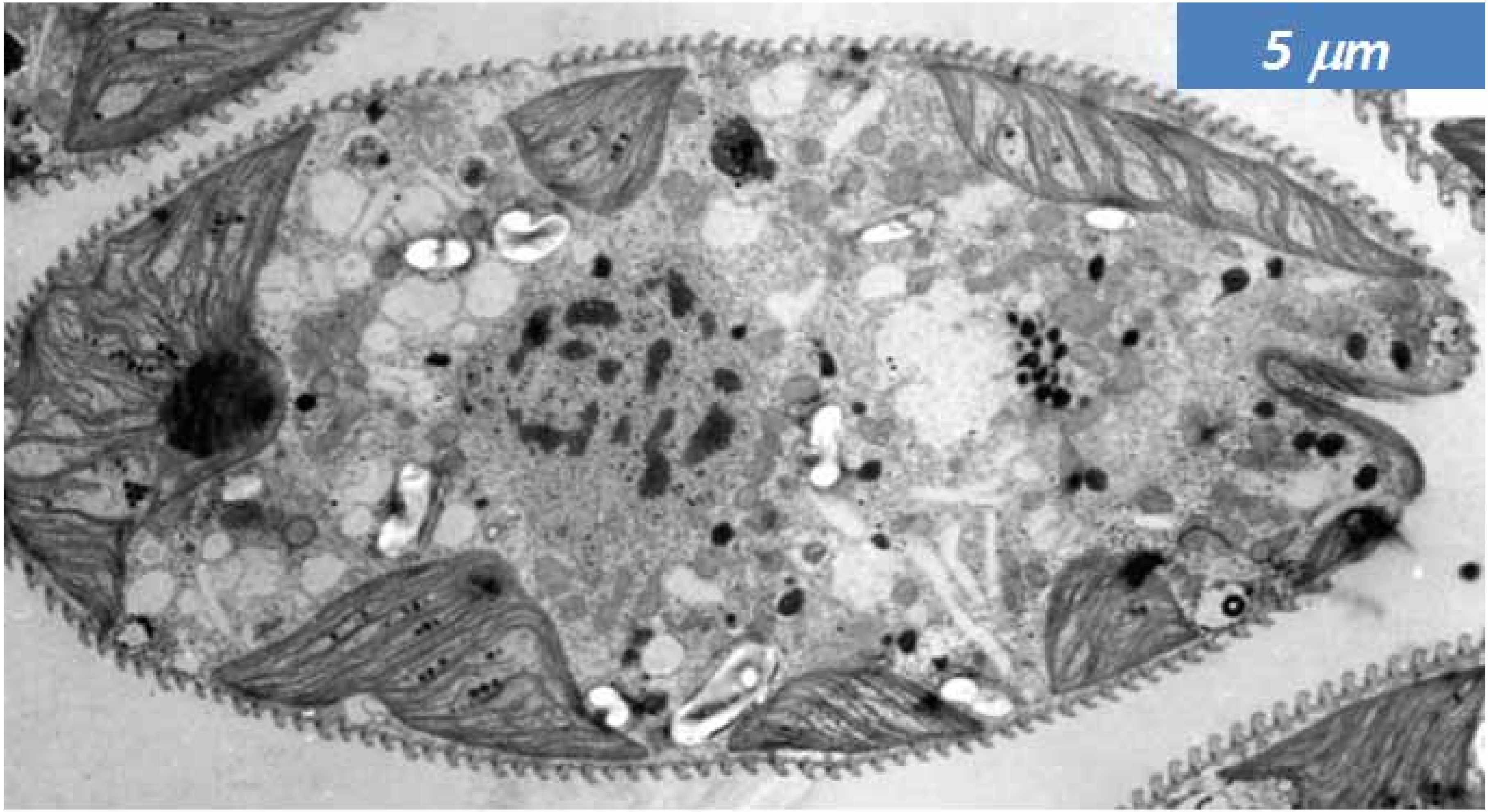
to generate/utilize energy …

to process information …



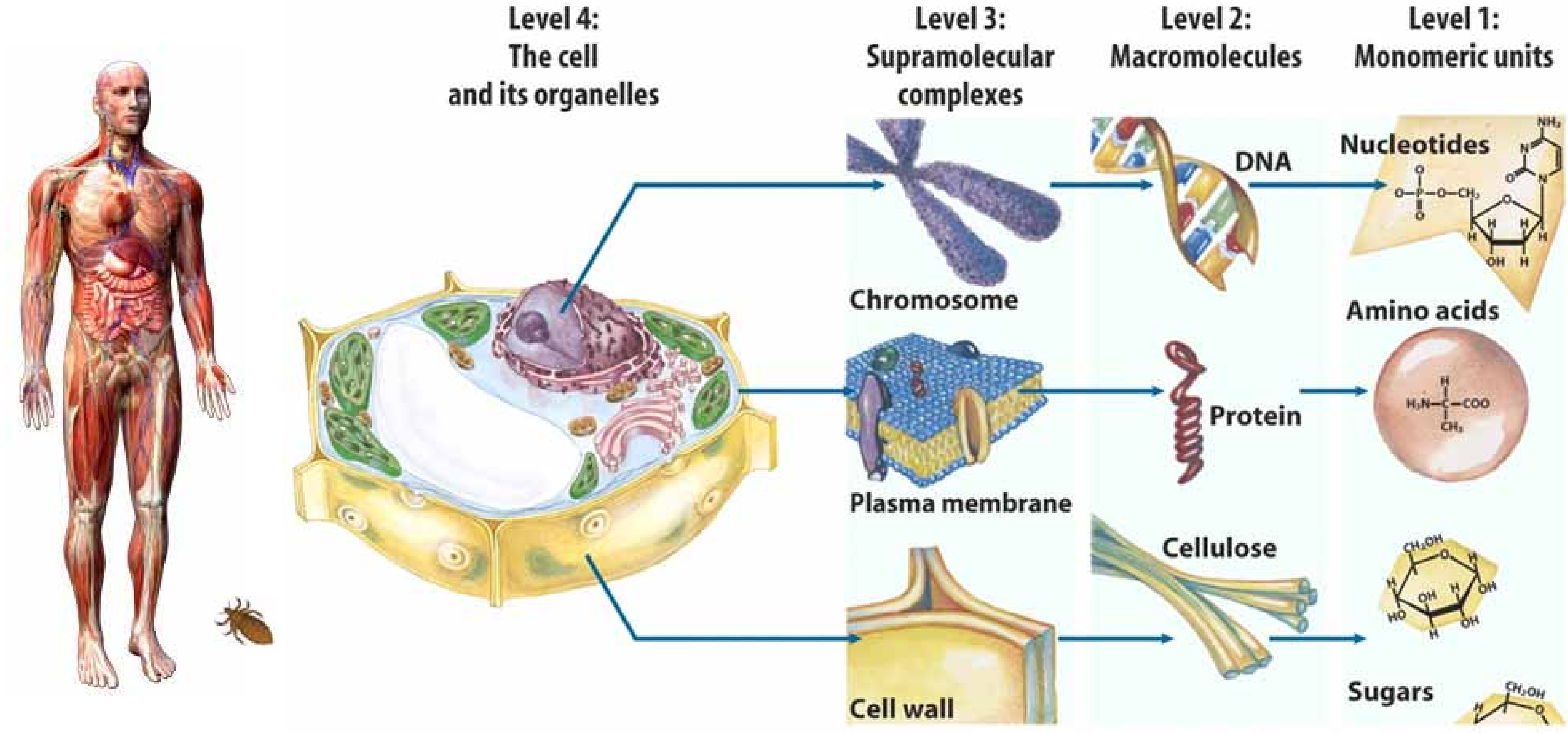
Schrödinger, E. (1944) *What Is Life? The Physical Aspect of the Living Cell. Dublin Institute for Advanced Studies.*

Slide 1-10: Life is complex information



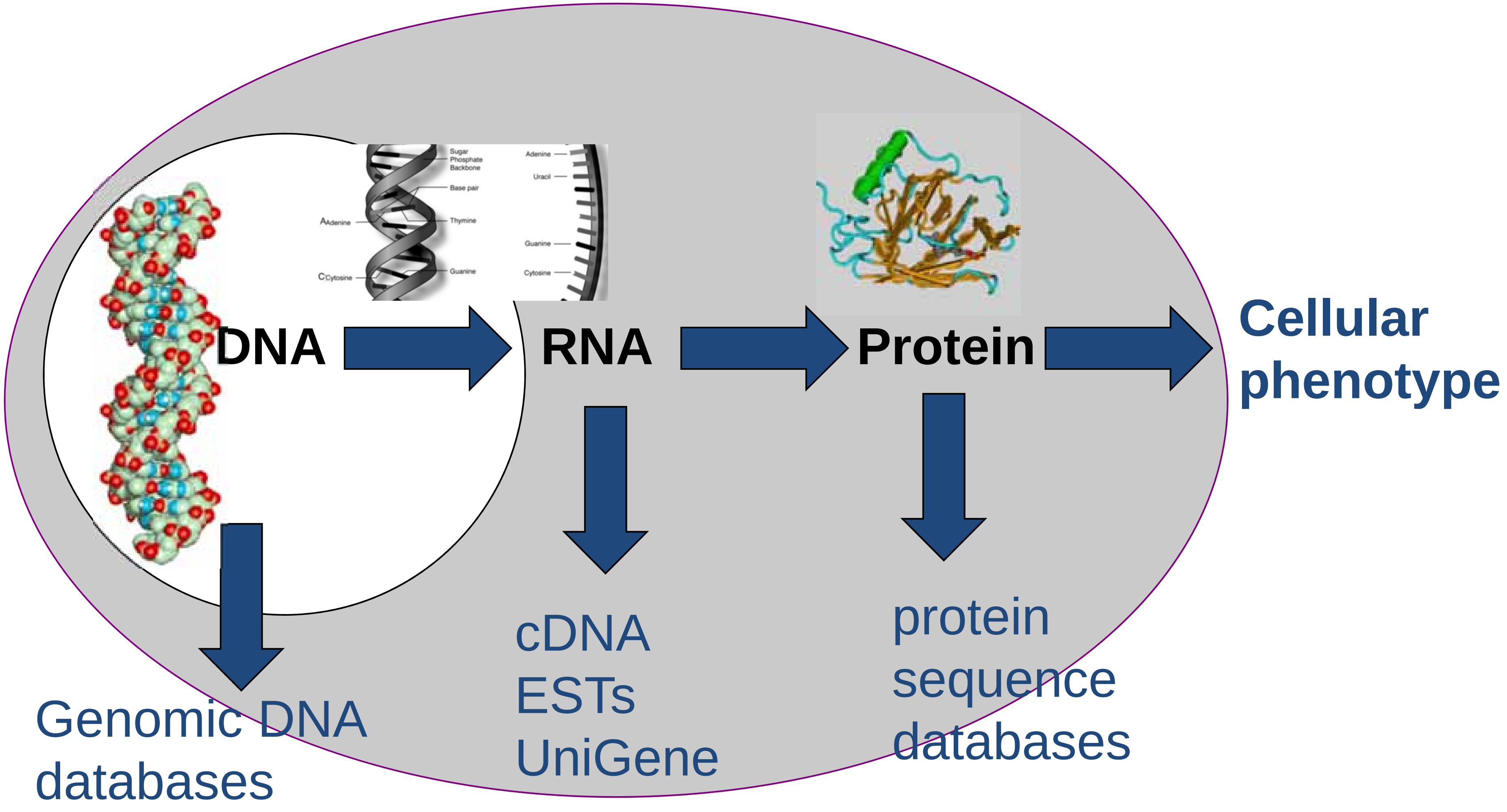
Lane, N. & Martin, W. (2010) The energetics of genome complexity. *Nature, 467, 7318, 929-934.*

Slide 1-11 Building Blocks of Life - Overview

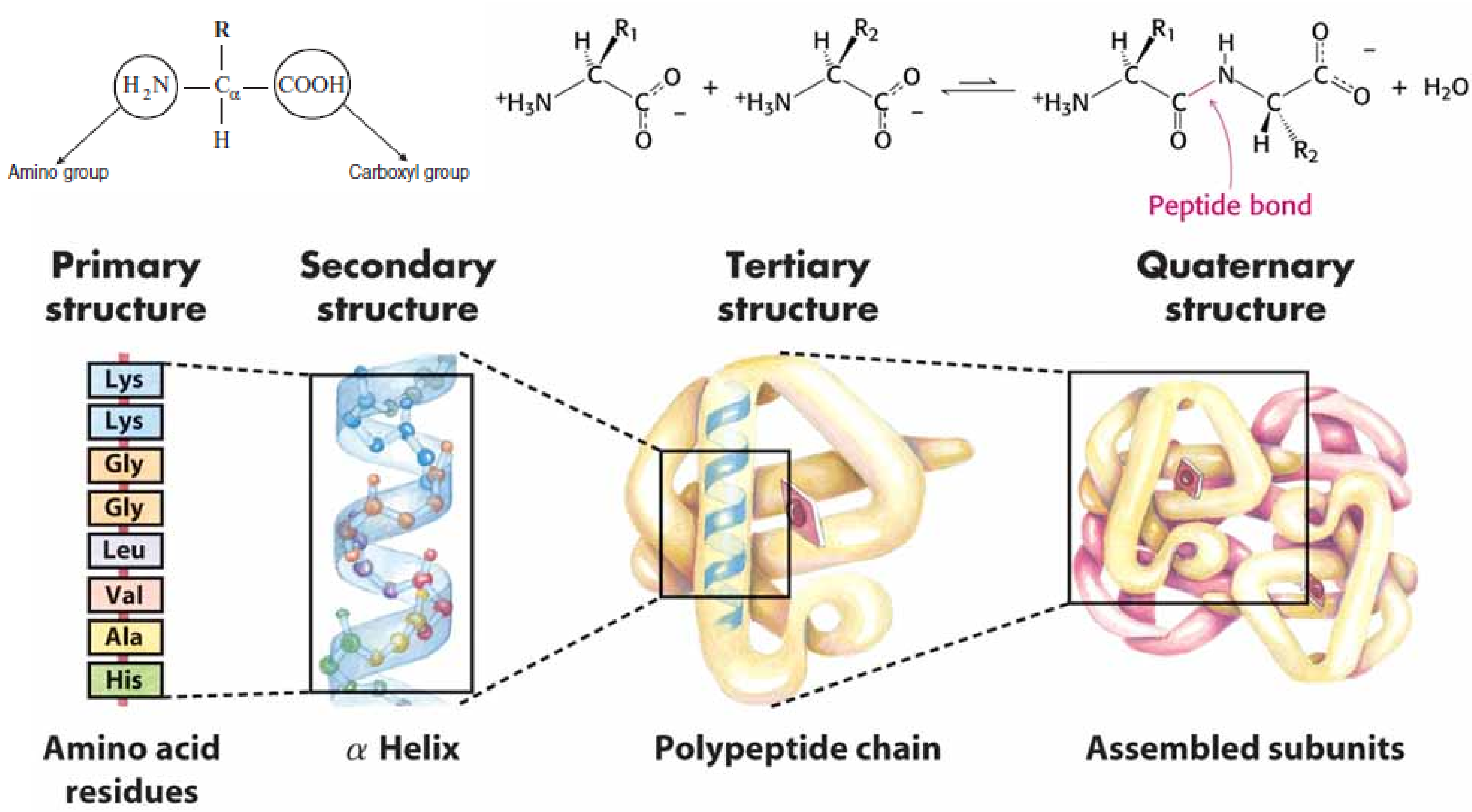


Human eye		Light microscope	Electron microscope	Special
1m	1mm	1 µm	1nm	100 pm

Slide 1-12: The Dogma of Molecular Biology

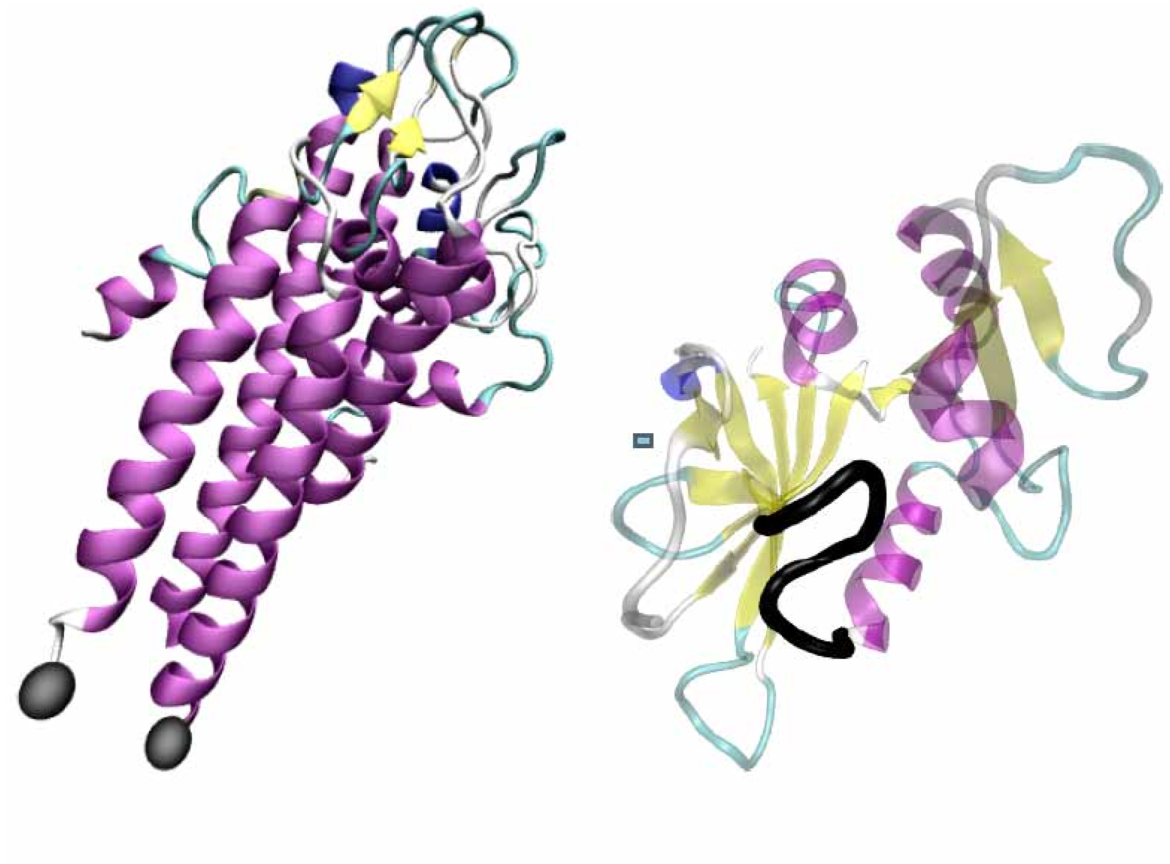


Crick, F. 1970. Central Dogma of Molecular Biology. *Nature, 227, (5258), 561-563.*

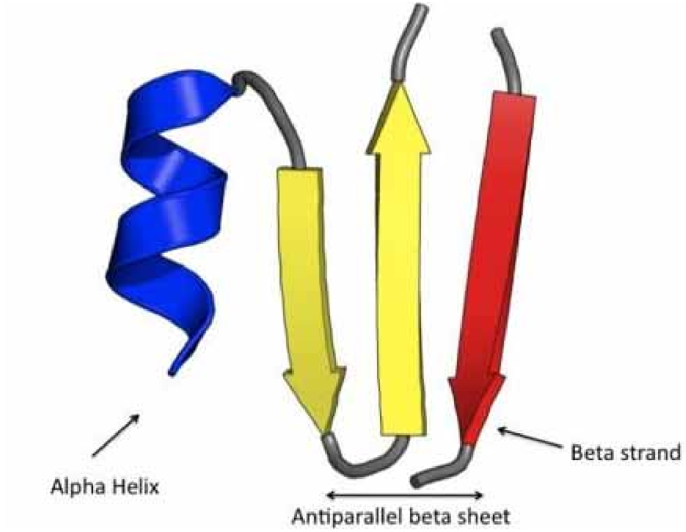


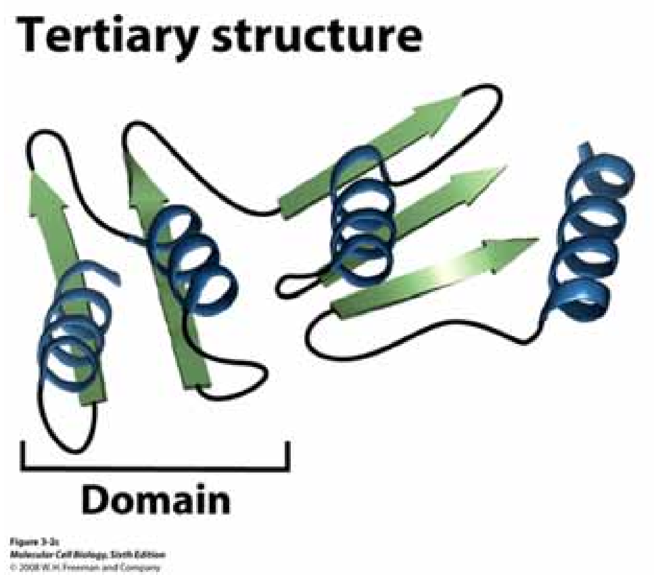
Gromiha, M. 2010. *Protein Bioinformatics, Amsterdam, Elsevier.*

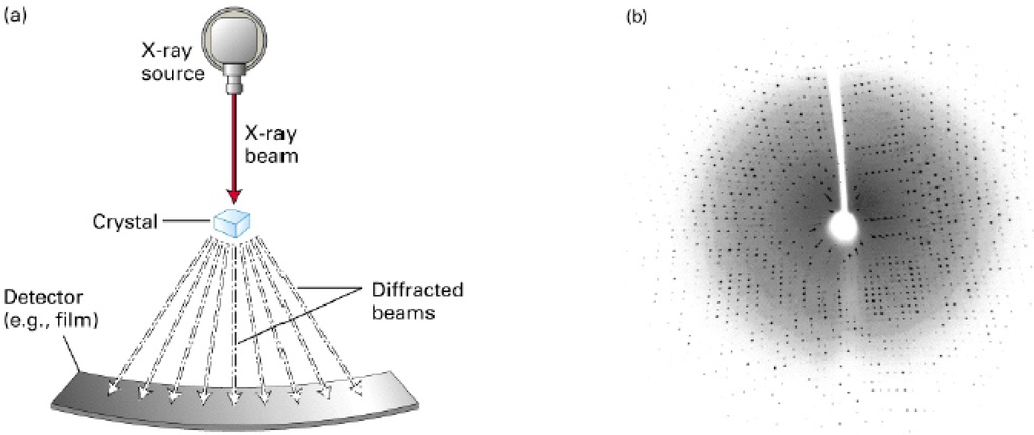
Slide 1-14 Tertiary Structure of a Protein

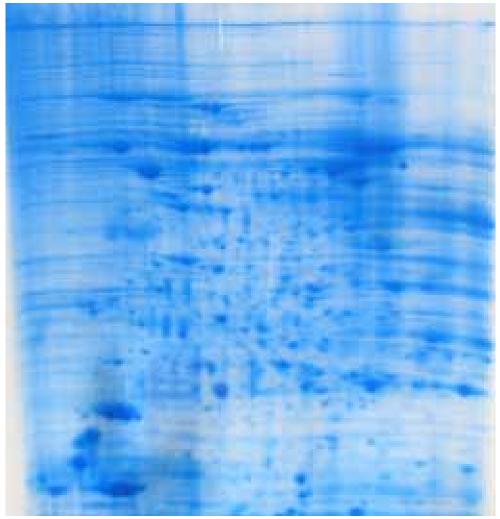


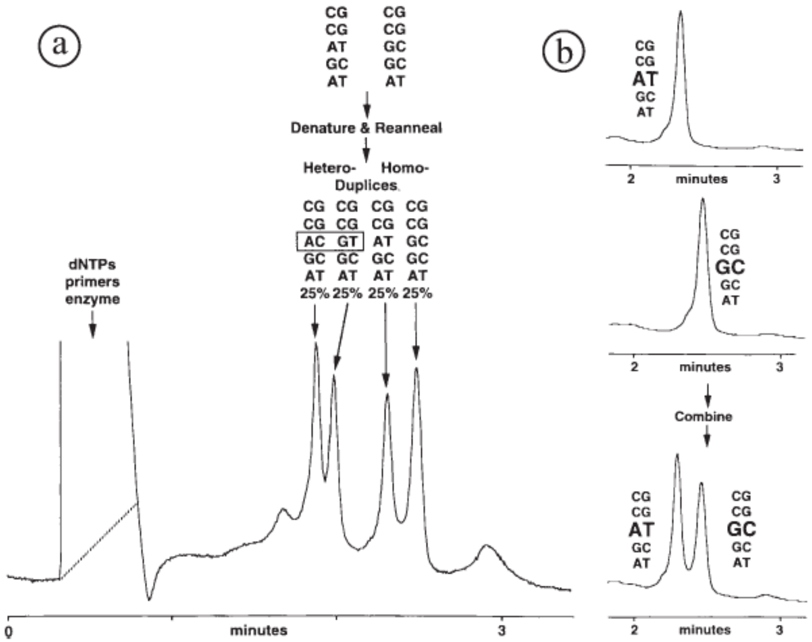
Shehu, A. & Kavraki, L. E. 2012. Modeling structures and motions of loops in protein molecules. *Entropy, 14, (2), 252-290.*











Rabilloud, et al. 2010. Two-dimensional gel electrophoresis in proteomics: past, present and future. *Journal of proteomics, 73, (11), 2064-2077.*

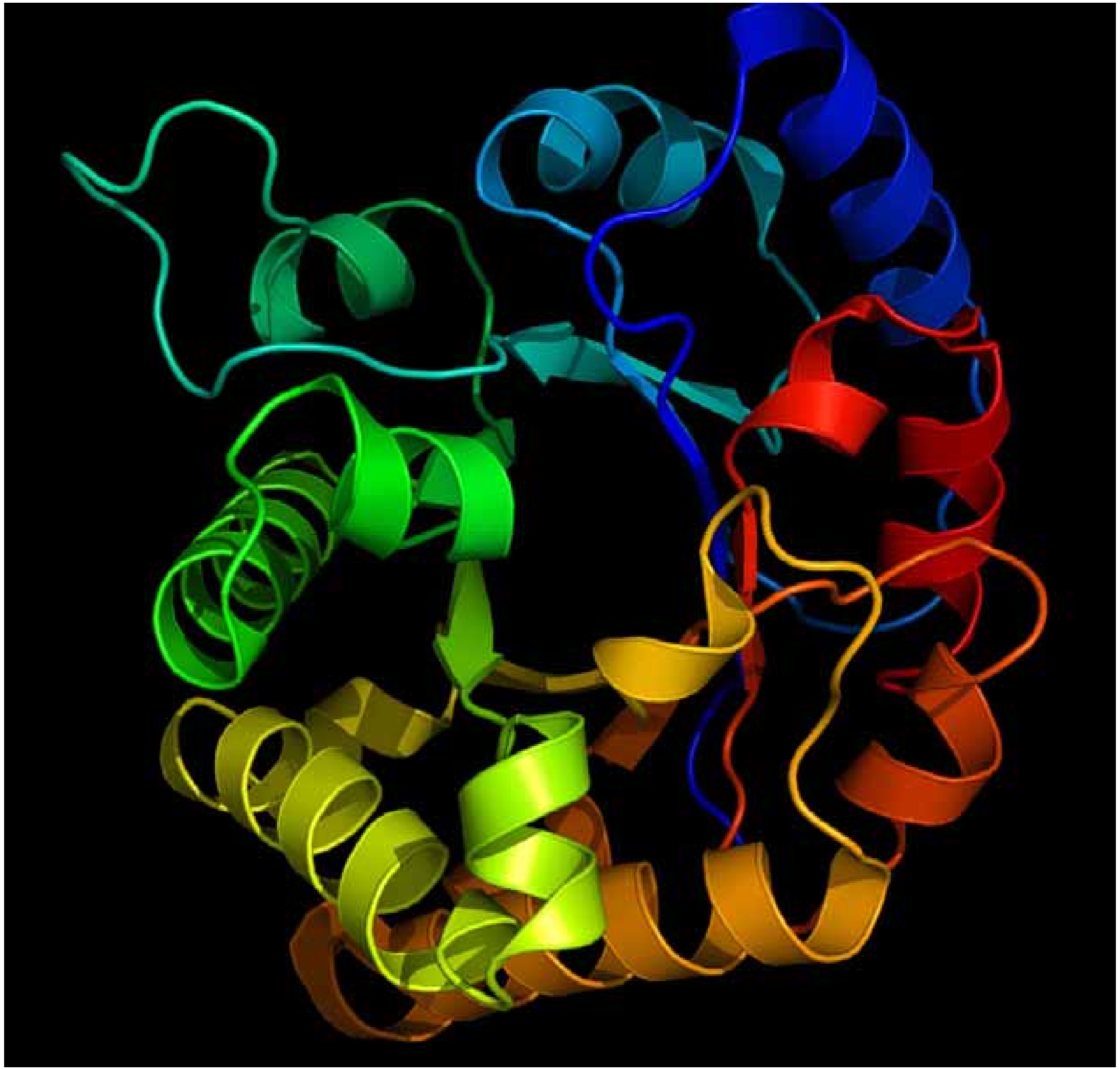
Xiao, W. Z. & Oefner, P. J. 2001. Denaturing high-performance liquid chromatography: A review. *Human Mutation, 17, (6), 439-474.*

Slide 1-16: Comparison of some current Methods

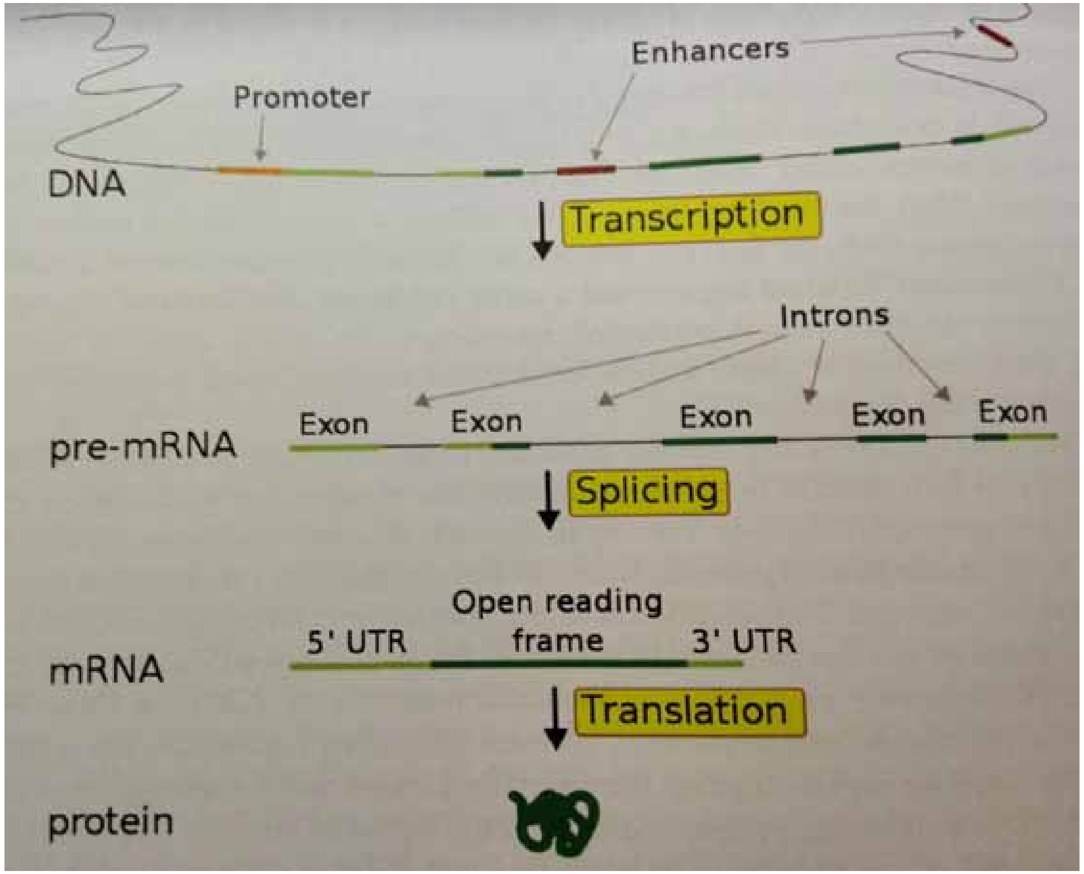
Technology	Sensitivity	Subcellular resolution	Cellular resolution	Minimally invasive?	Live cells?	Real time?
Genetically encoded nanosensors	Nanomolar to millimolar	Nanometer to millimeter	Yes	Yes	Yes	Yes
MRI	Mid-micromolar to millimolar (213)	No	Yes	Yes	Yes	Yes
PET	1–40 Bq mm^{-2} (18)	No	No	No	Yes	Yes
X-ray synchrotron	<1 mg kg^{-1} tissue (transit metals) (204)	No	Yes	No	No	No
SIMS	<1 fmol (67)	Yes	Yes	No	No	No
MALDI or TOF imaging	<1 ppm	Yes	50–300 µm (MALDI) 1–2 µm (TOF)	No	No	No
NIMS imaging	Yoctomolar (85)	No	50–300 µm	No	No	No
Mass spectrometry	Yoctomolar	No?	Yes	No	No	No
Raman	50 µM (70)	Yes	Yes	Yes	Yes	Yes

Okumoto, S., Jones, A. & Frommer, W. B. 2012. Quantitative imaging with fluorescent biosensors. *Annual review of plant biology, 63, 663-706.*

Klibanov, A. M. 2001. Improving enzymes by using them in organic solvents. *Nature, 409, (6817), 241-246.*

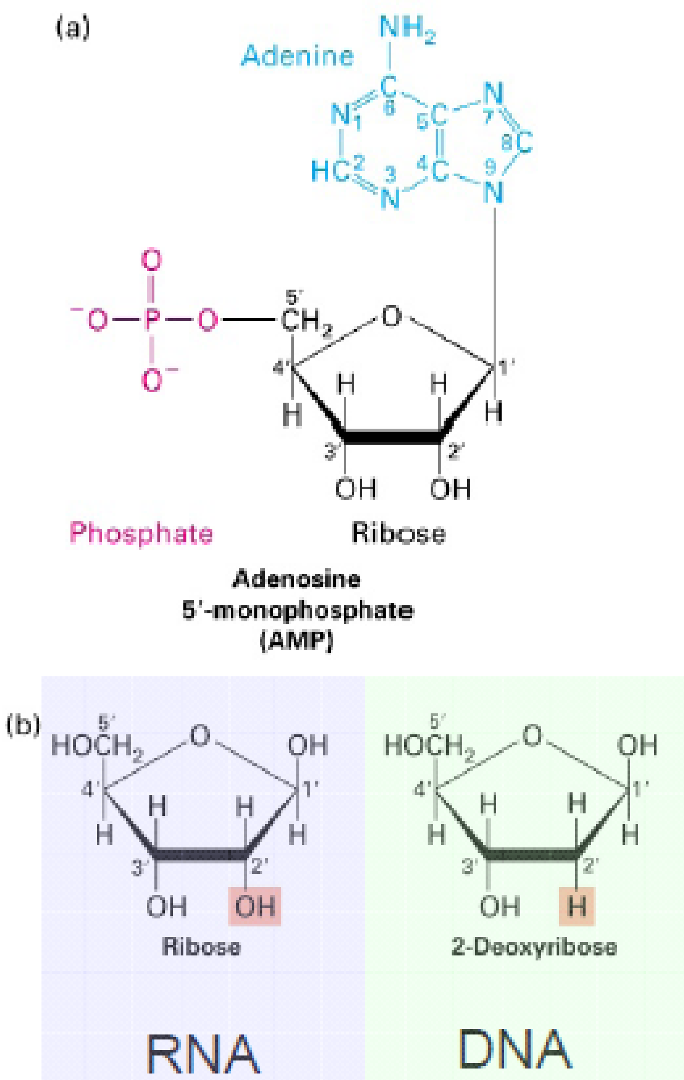


The DNA, the RNA and the proteins are the three major macromolecules essential for all known forms of life.

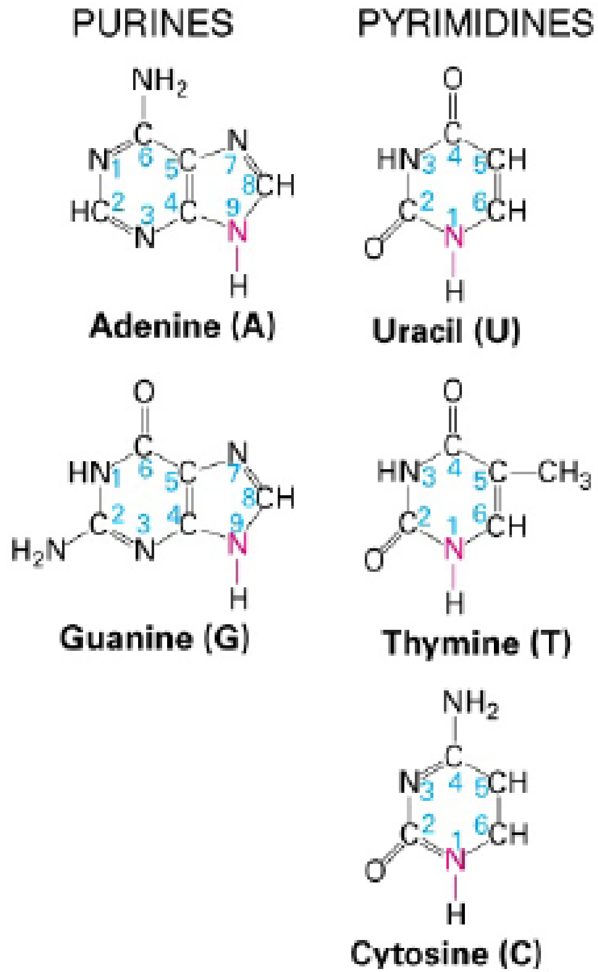


Manca, V. (2013). Infobiotics. Springer.

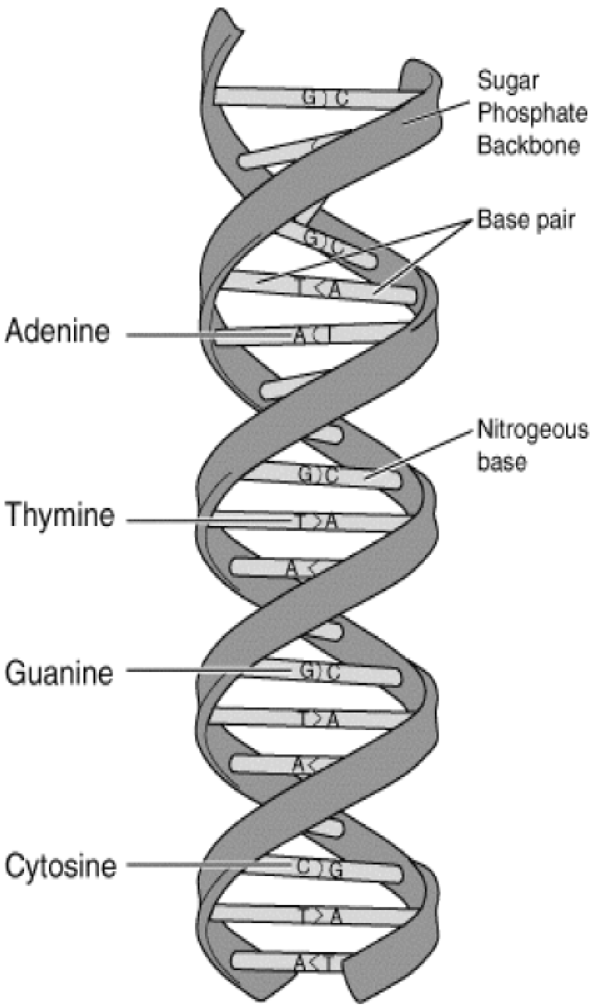
Slide 1-19 DNA & RNA – and the five principal bases

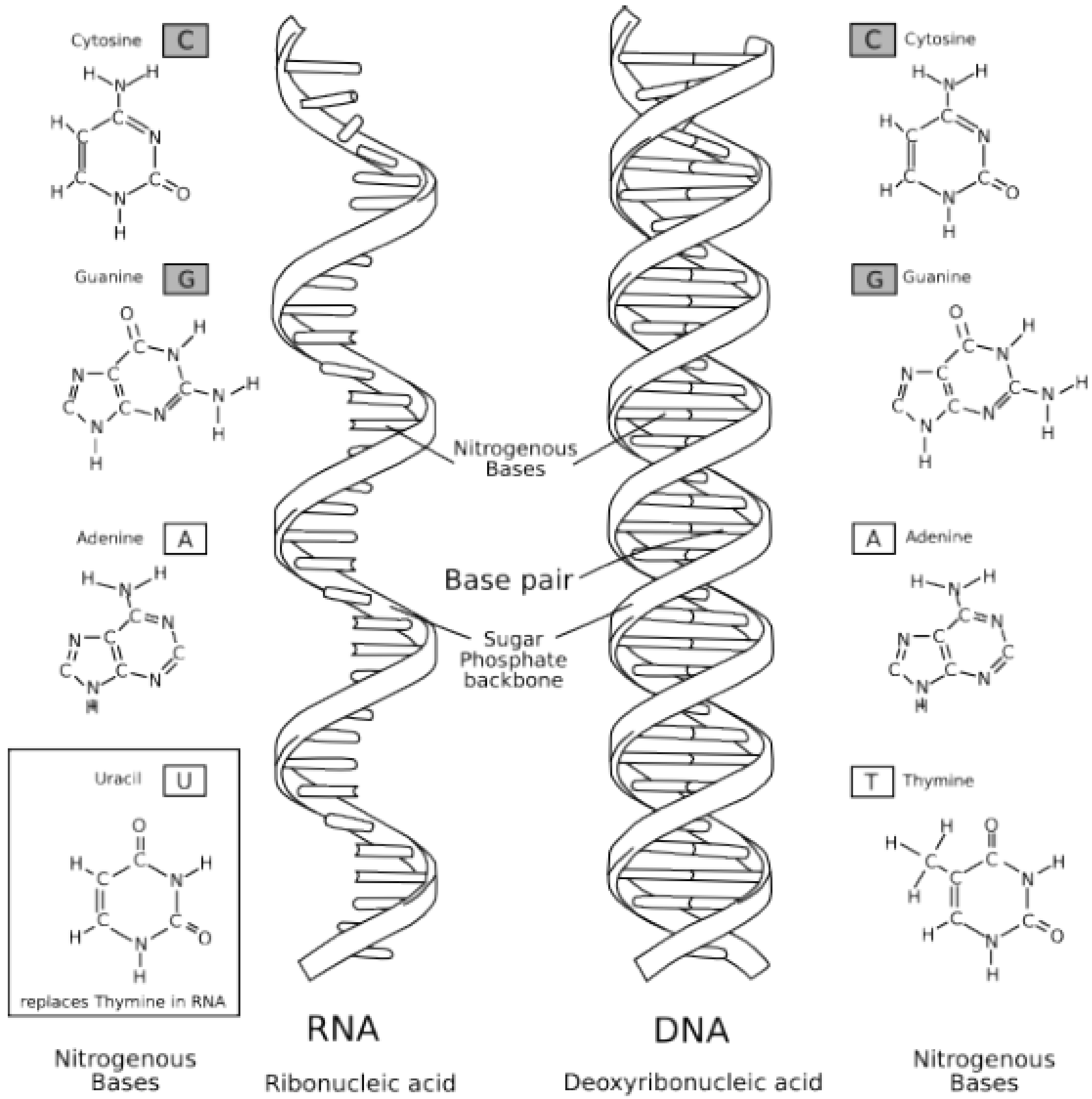


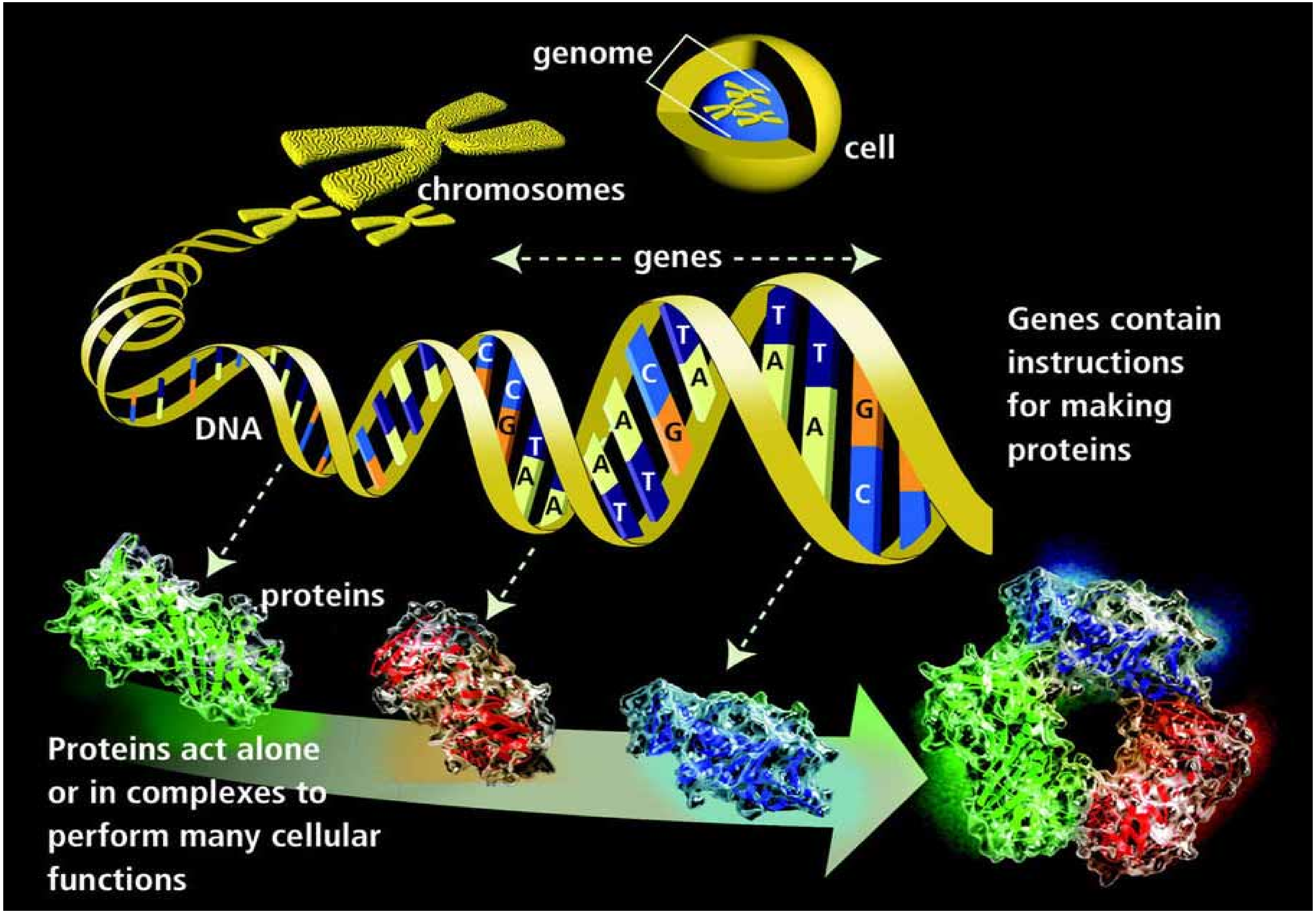
The five principal bases

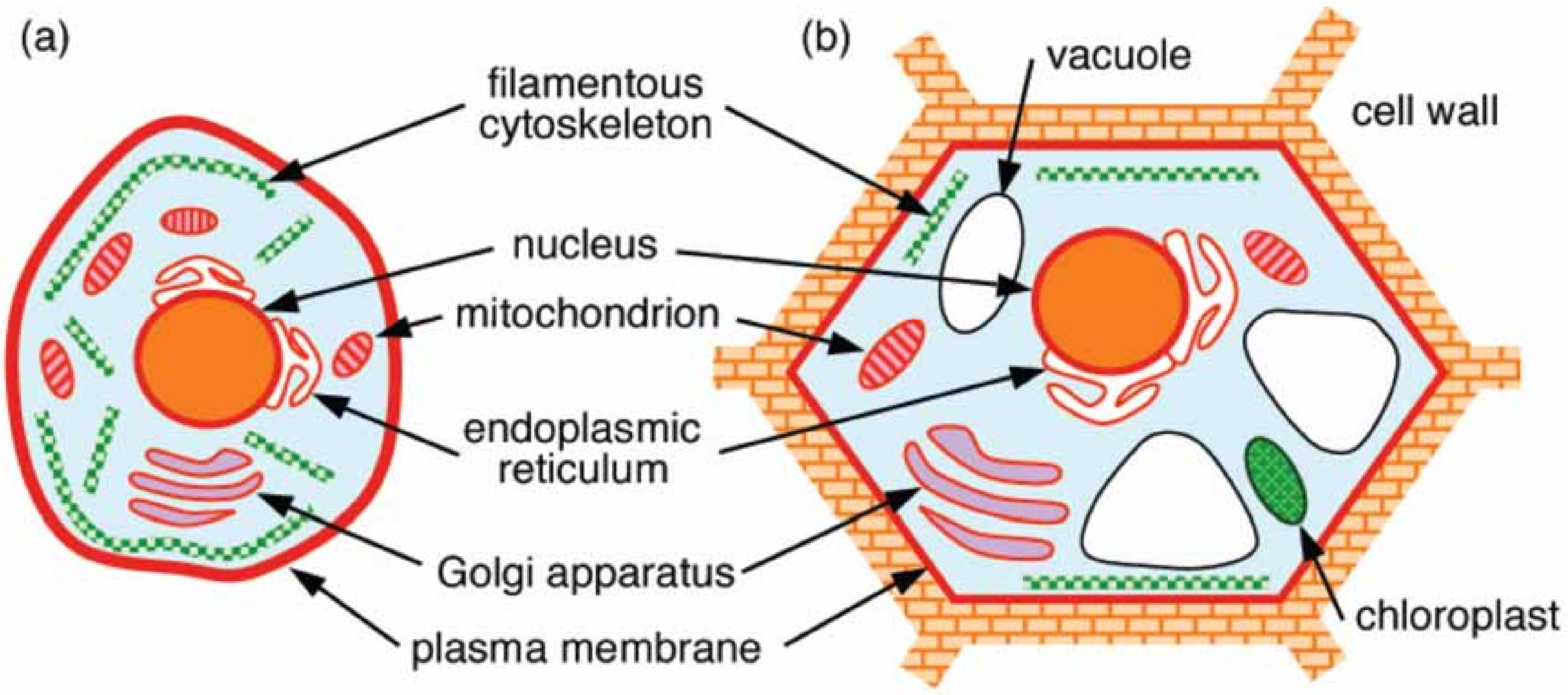


A, G, T, C are present in DNA (DeoxyriboNucleic Acid)
A, G, U, C are present in RNA (RiboNucleic Acid)

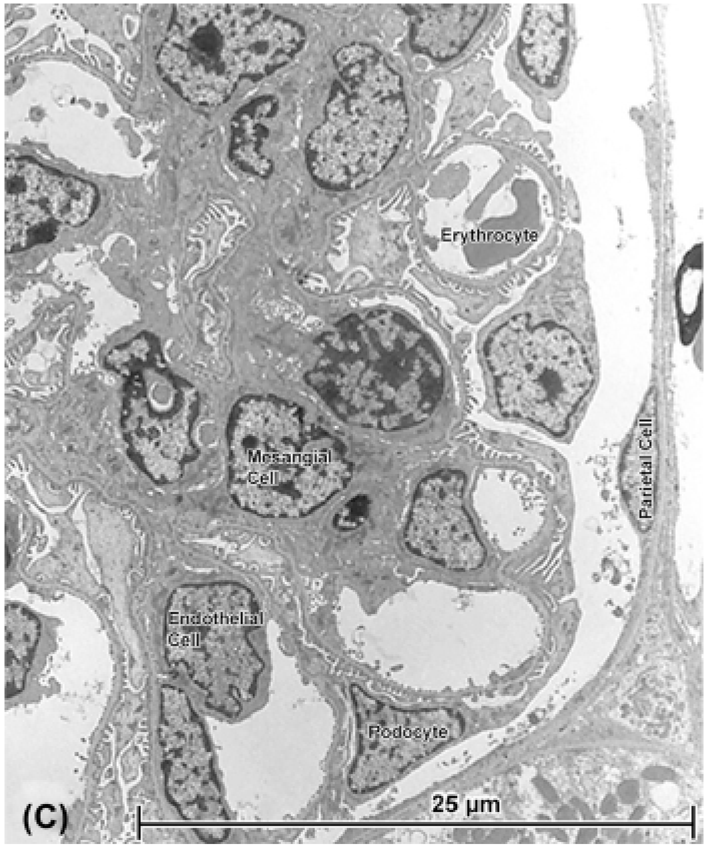

Sugar Phosphate Backbone
Base pair
Adenine
Nitrogeous base
Thymine
Guanine
Cytosine

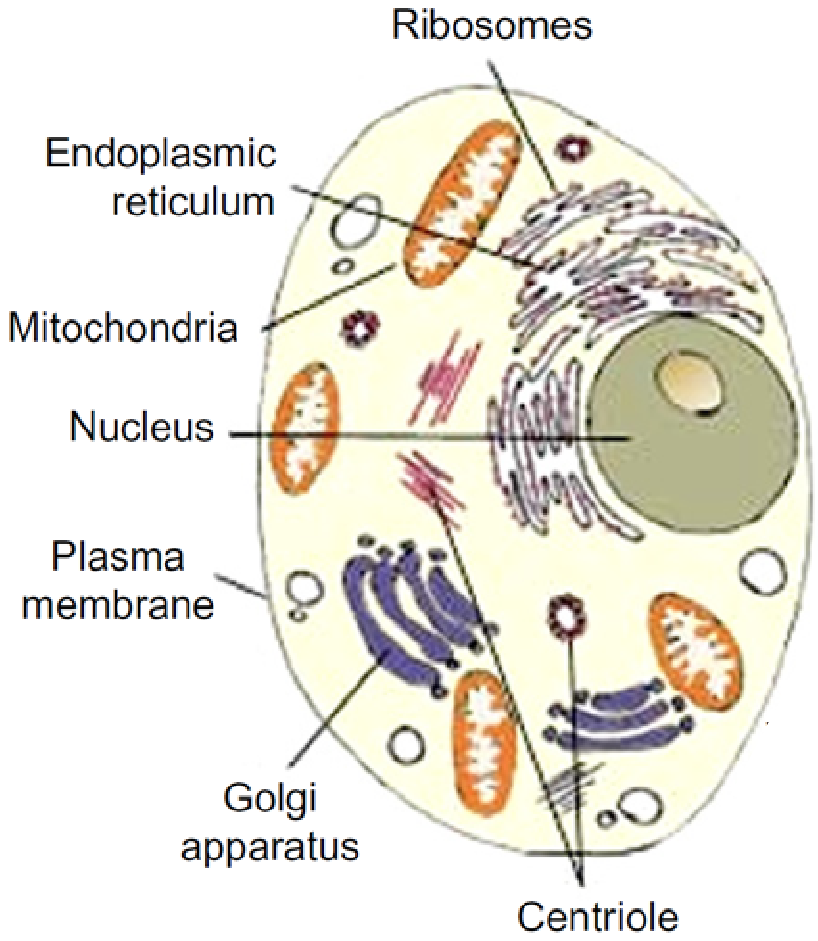

Cytosine C
Guanine G
Adenine A
Uracil U
replaces Thymine in RNA
Nitrogenous Bases
Nitrogenous Bases
Base pair
Sugar Phosphate backbone
RNA
Ribonucleic acid
DNA
Deoxyribonucleic acid
C Cytosine
G Guanine
A Adenine
T Thymine
Nitrogenous Bases


genome
cell
chromosomes
genes
Genes contain instructions for making proteins
DNA
T
A
T
T
A
C
A
G
G
C
C
G
T
A
A
A
A
T
T
proteins
Proteins act alone or in complexes to perform many cellular functions



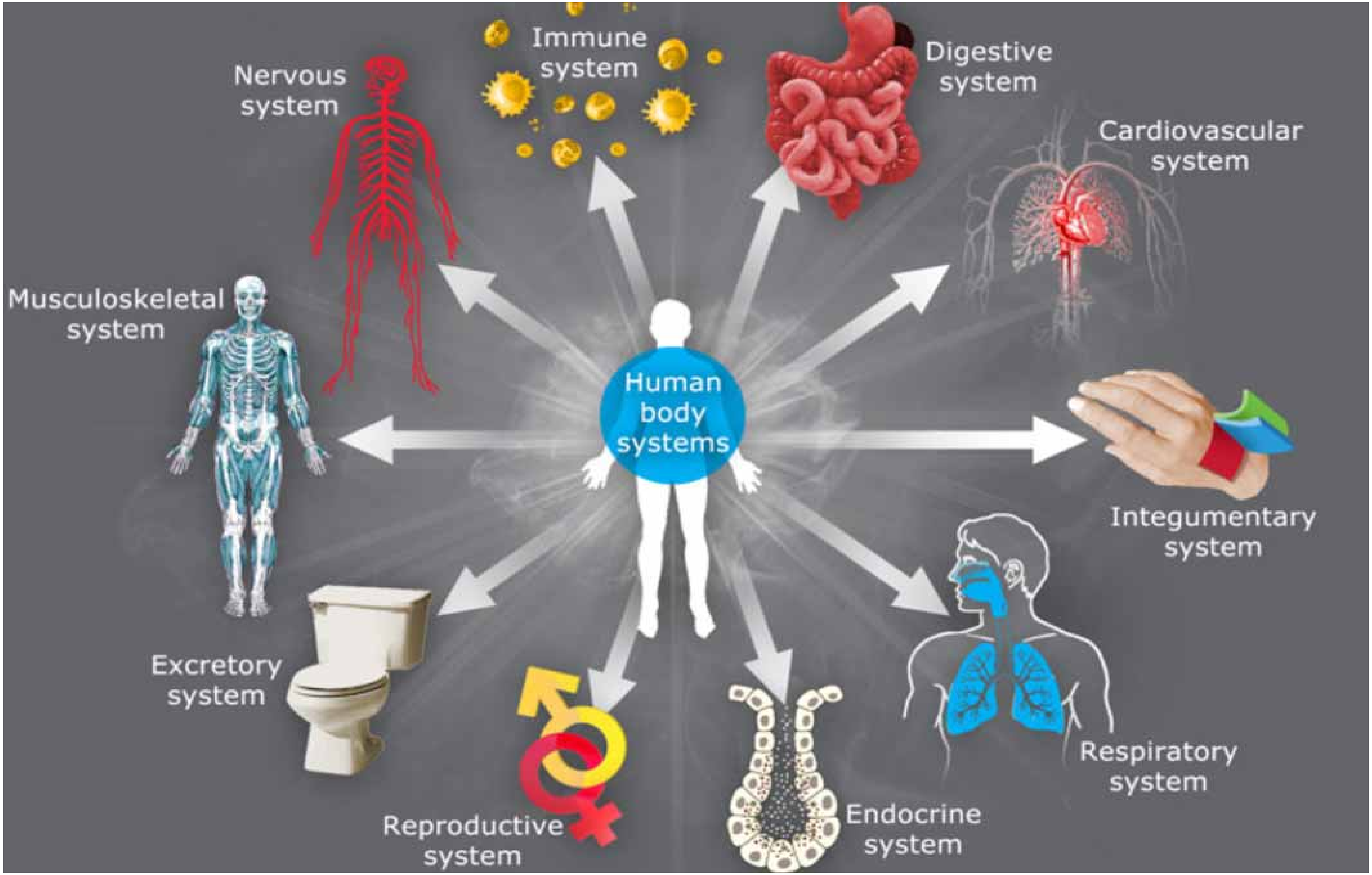
Boal, D. 2012. *Mechanics of the Cell, Cambridge University Press.*



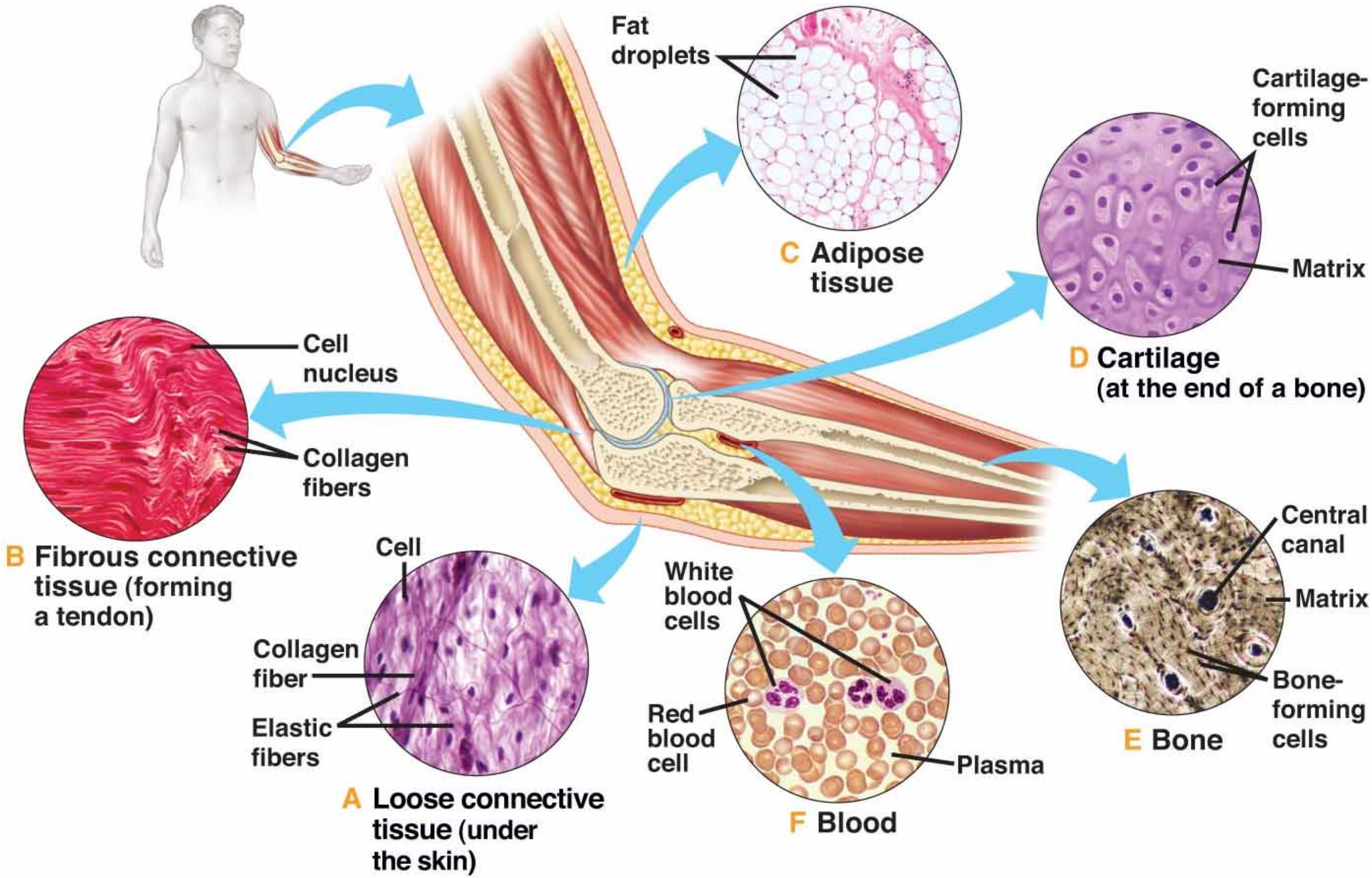


Sperelakis, N. 2012. *Cell Physiology Sourcebook: Essentials of Membrane Biophysics. Fourth Edition, Amsterdam, Elseviere.*

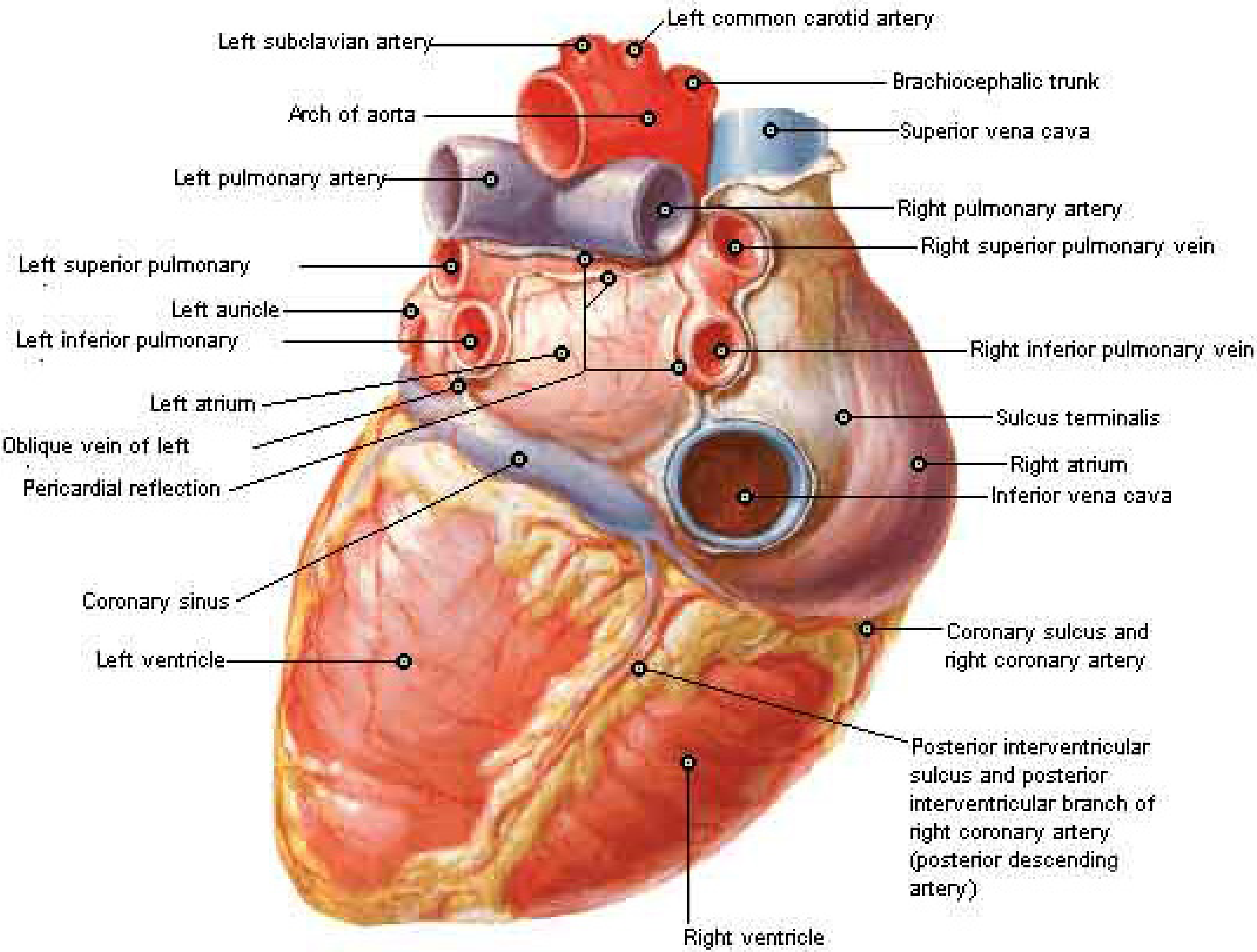
Slide 1-24: Human Organ Systems

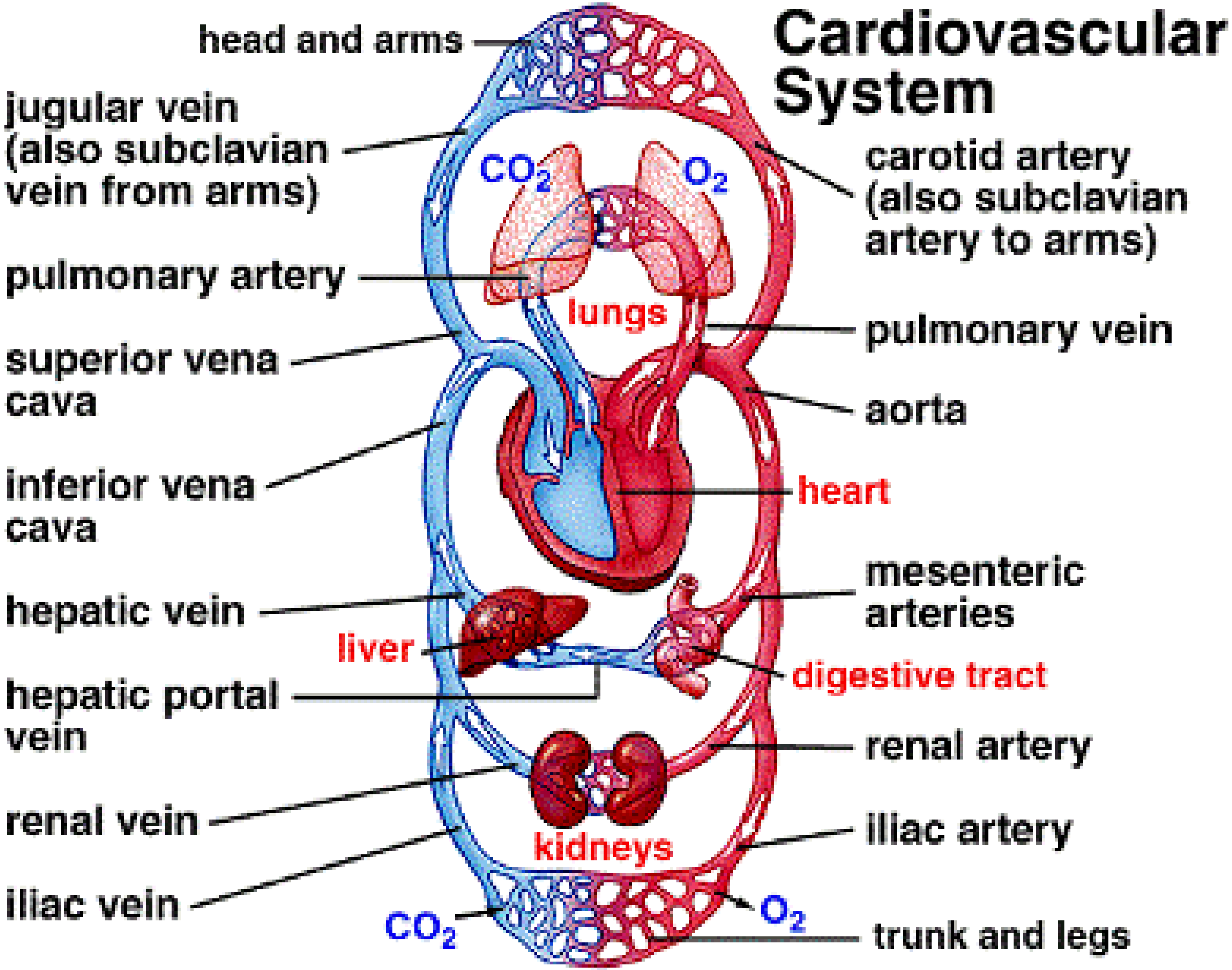


Slide 1-25: Tissue

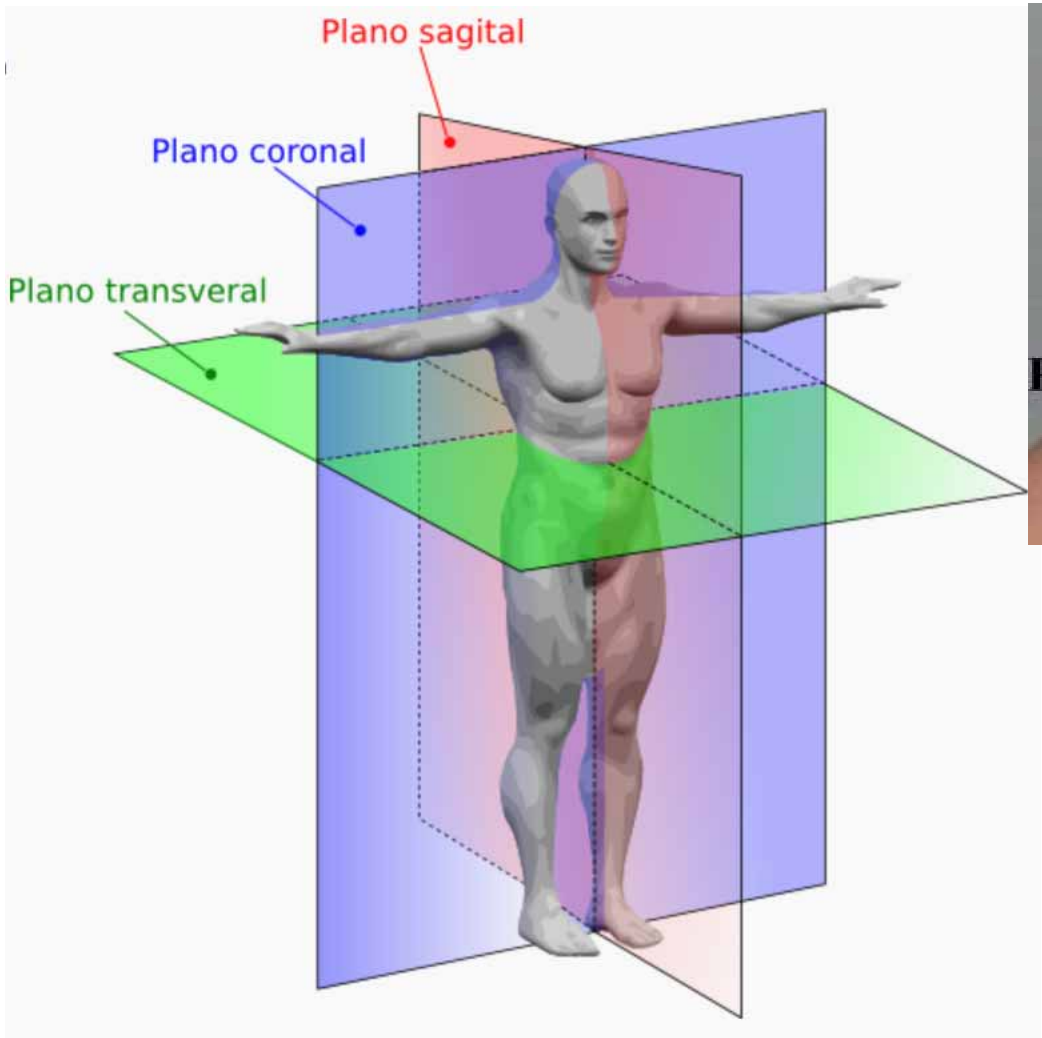


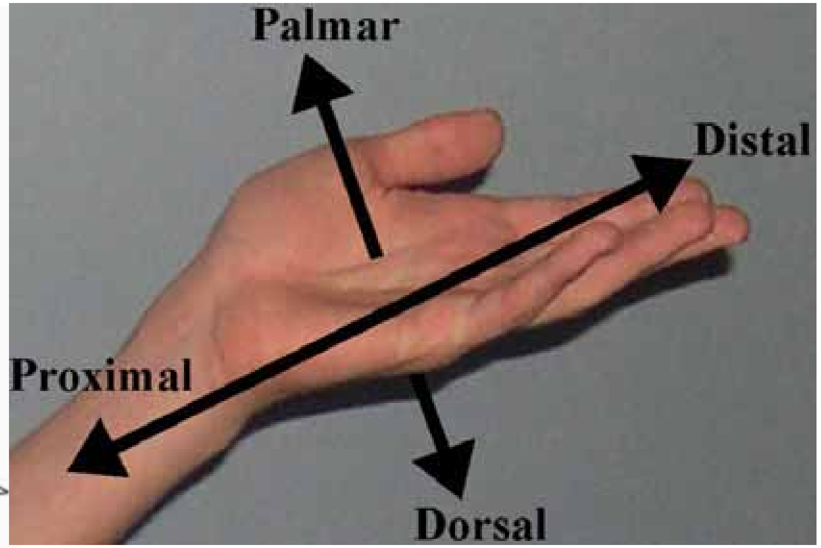
Slide 1-26: Organ Example: Heart

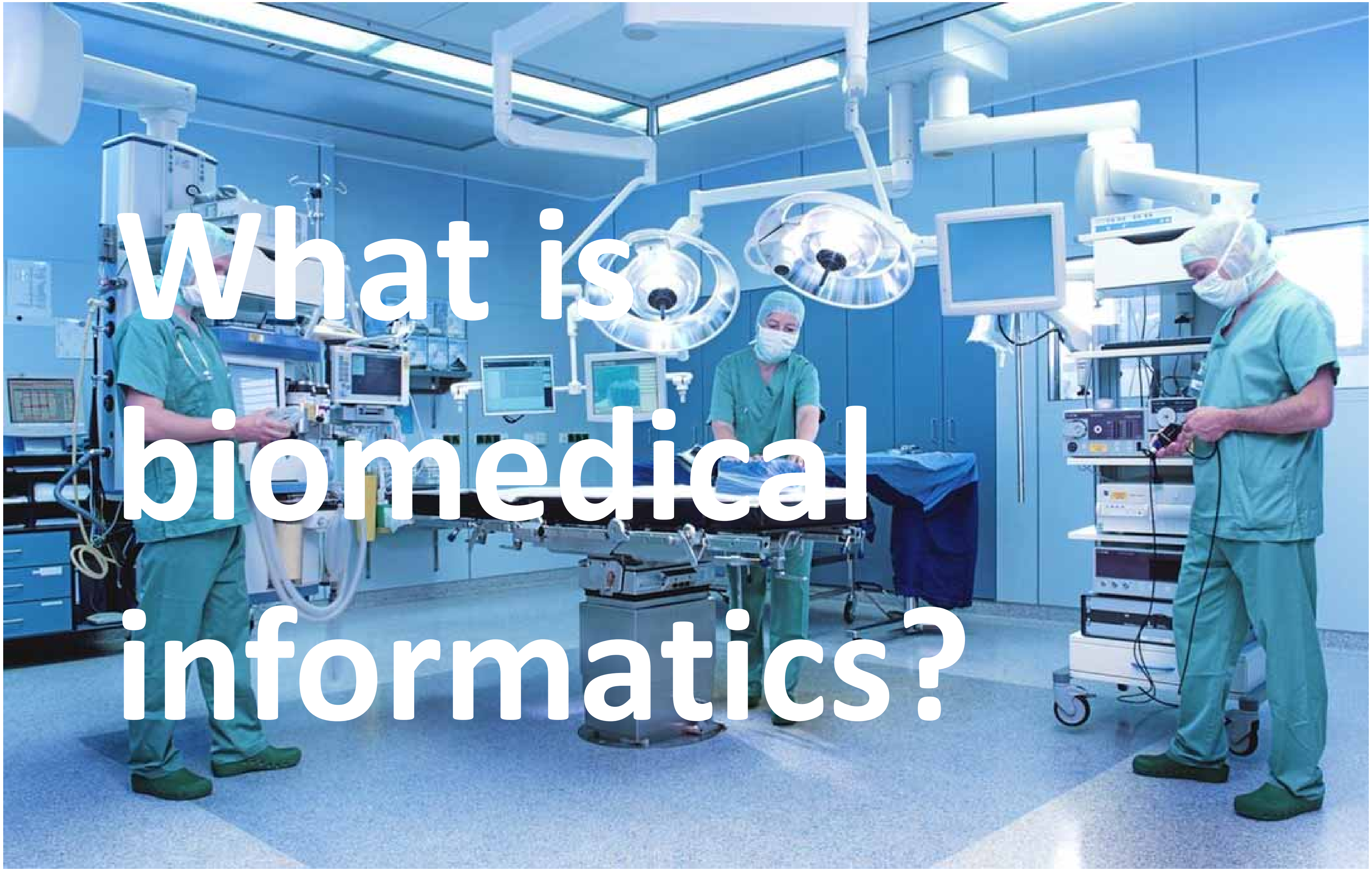



Cardiovascular System
head and arms
jugular vein (also subclavian vein from arms)
pulmonary artery
superior vena cava
inferior vena cava
hepatic vein
liver
hepatic portal vein
renal vein
iliac vein
CO_2
O_2
lungs
carotid artery (also subclavian artery to arms)
pulmonary vein
aorta
heart
mesenteric arteries
digestive tract
renal artery
iliac artery
kidneys
CO_2
O_2
trunk and legs

Slide 1-28 Anatomical Axes

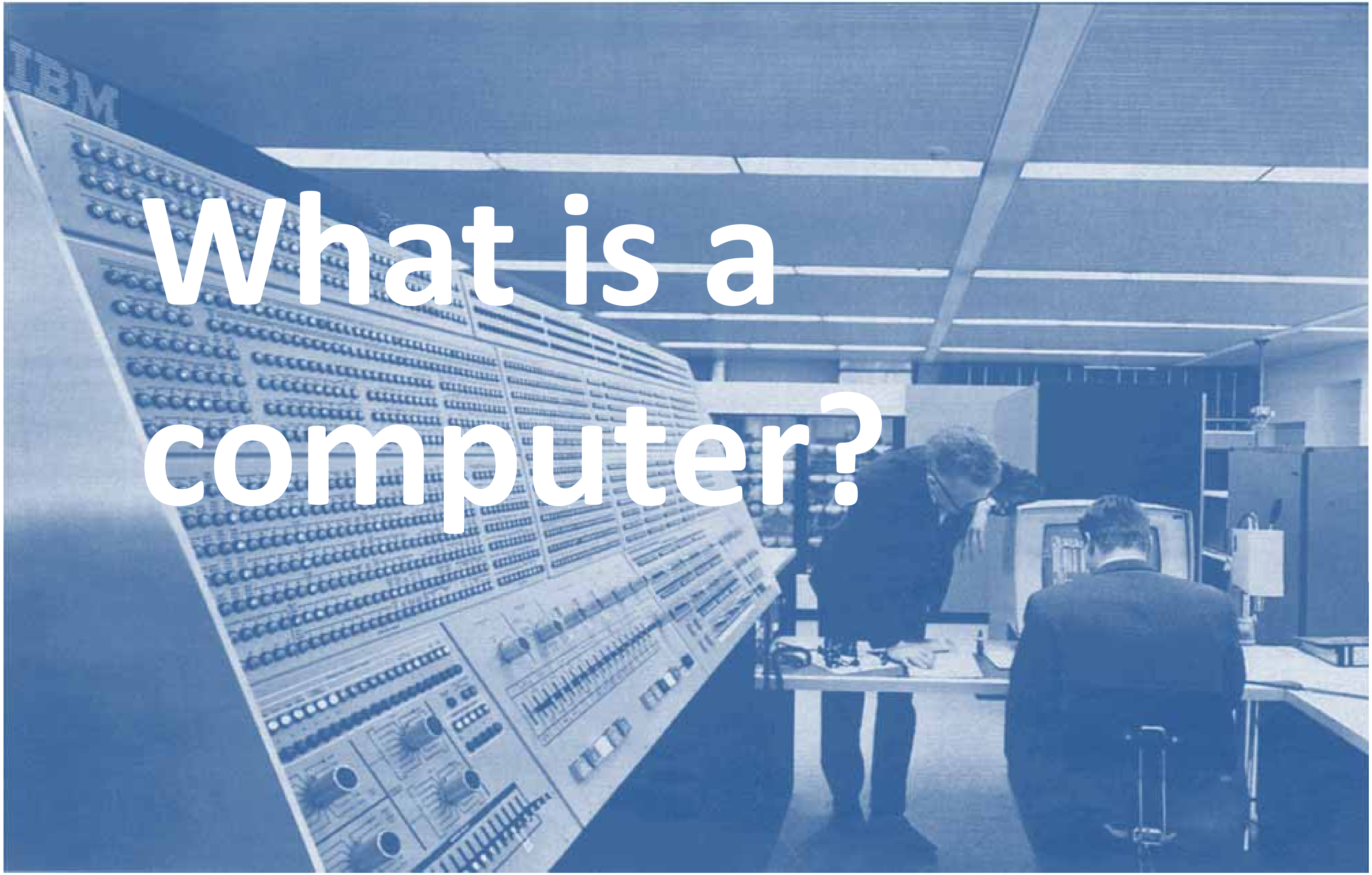




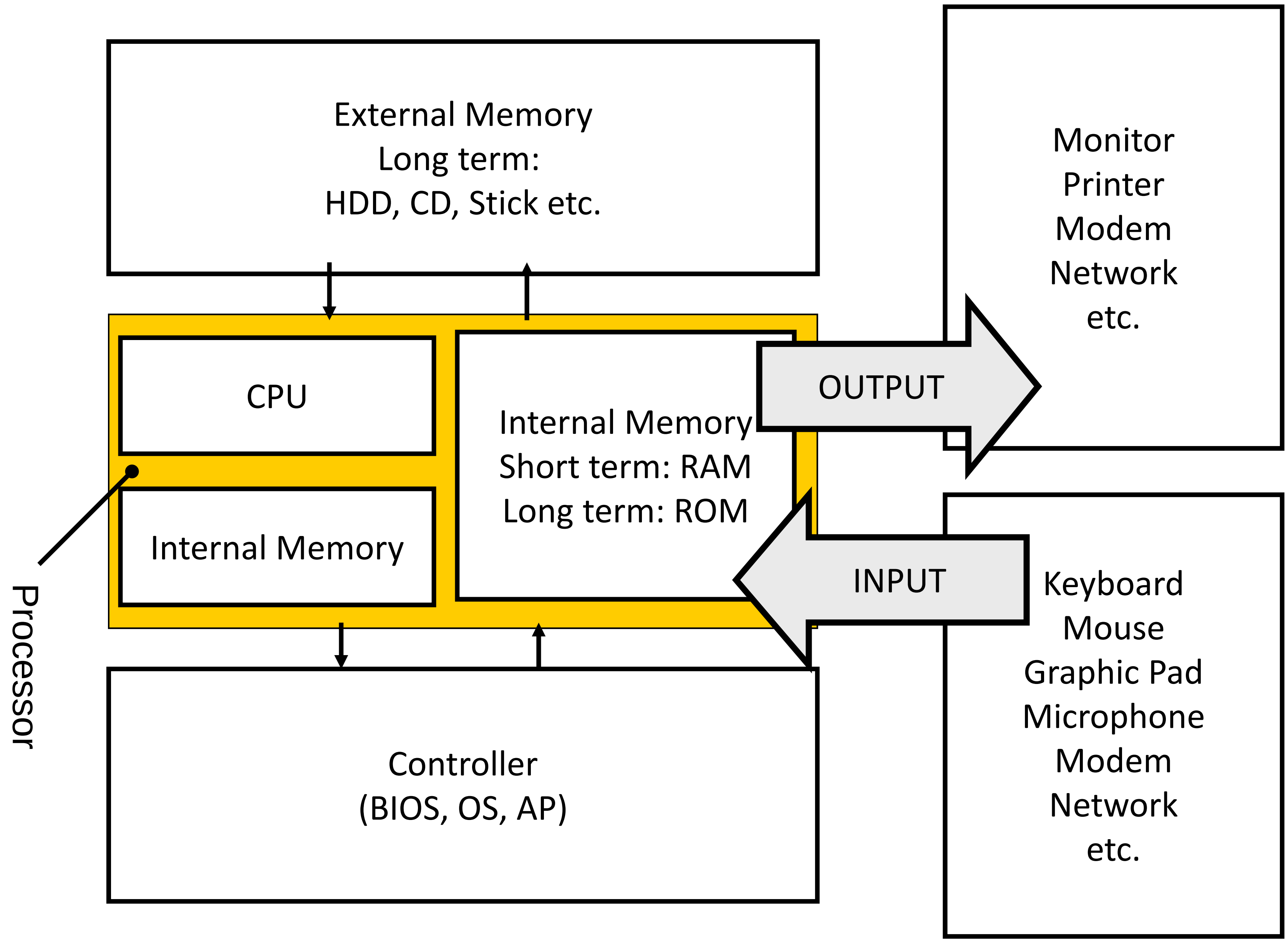

What is biomedical informatics?

Yapijakis, C. (2009) Hippocrates of Kos, the Father of Clinical Medicine, and Asclepiades of Bithynia, the Father of Molecular Medicine. *In Vivo, 23, 4, 507-514.*

What is a computer?



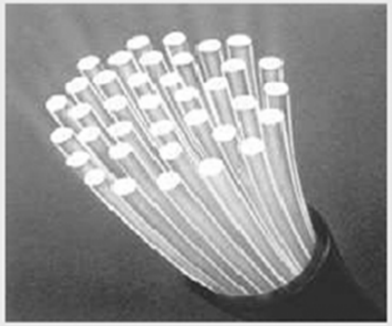
Slide 1-29: Computer: Von-Neumann Architecture



Gordon E. Moore (1965, 1989, 1997)

Digital Power :=

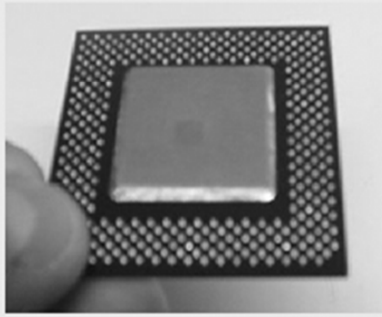
communication × **computing** × **storage** × **content**



„fiber law“

⇓

doubles every 9 months



„Moore's law“

⇓

doubles every 18 months

„disk law“

⇓

doubles every 12 months

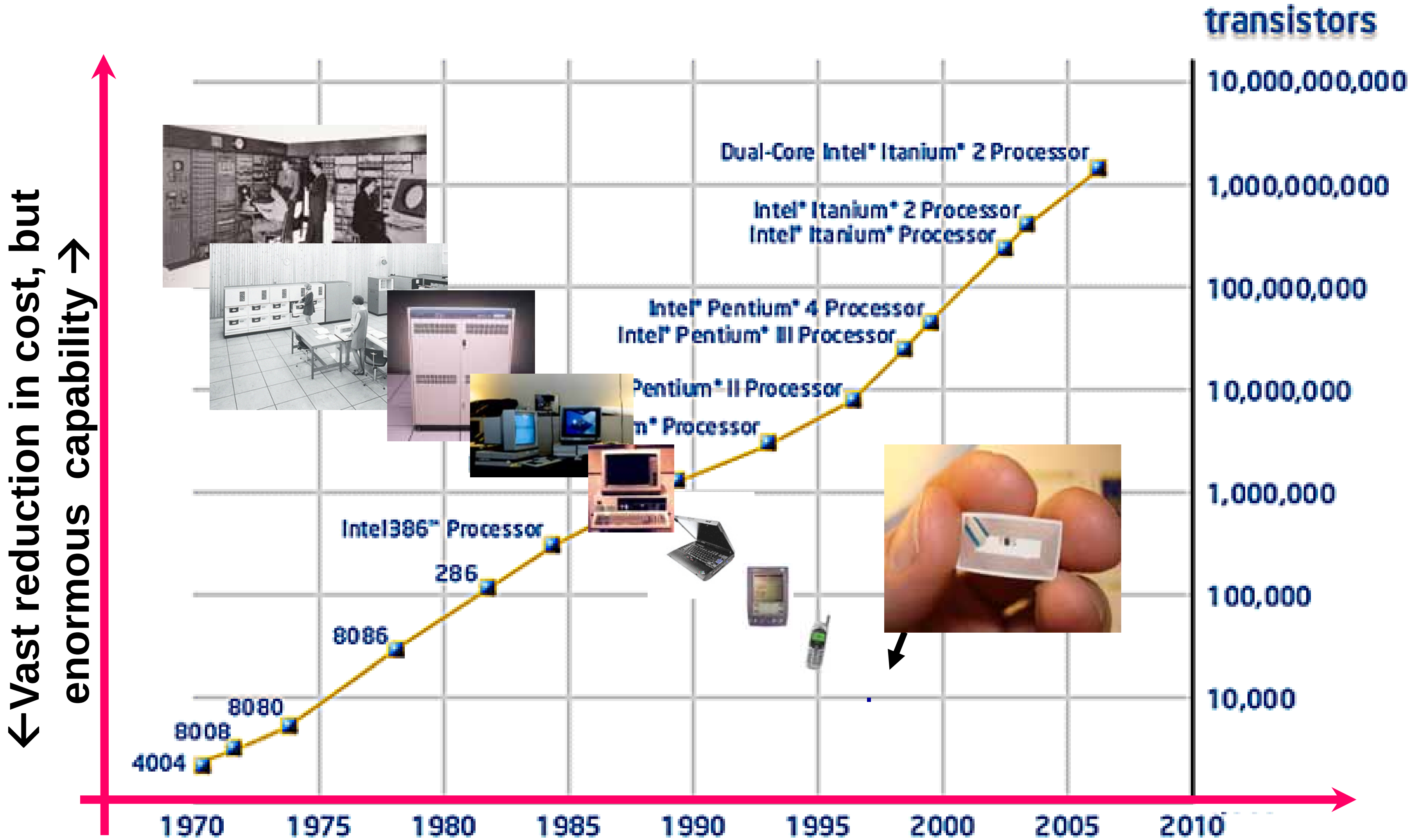
„community law“

⇓

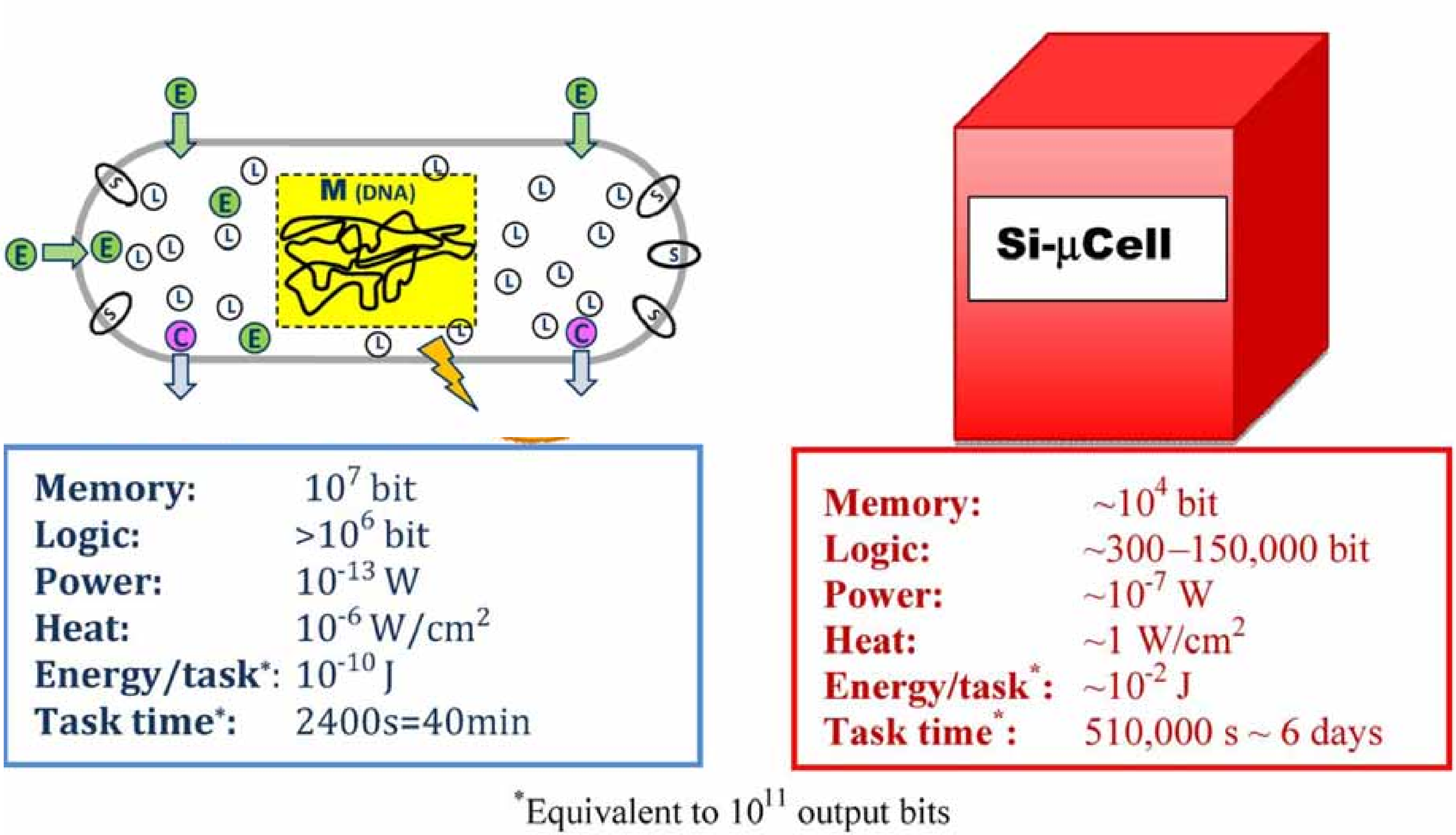
2^n wherin n is the # of people

Holzinger, A. 2002. *Basiswissen IT/Informatik Band 1: Informationstechnik. Das Basiswissen für die Informationsgesellschaft des 21. Jahrhunderts, Wuerzburg, Vogel Buchverlag.*

Slide 1-31: Computer cost/size versus Performance

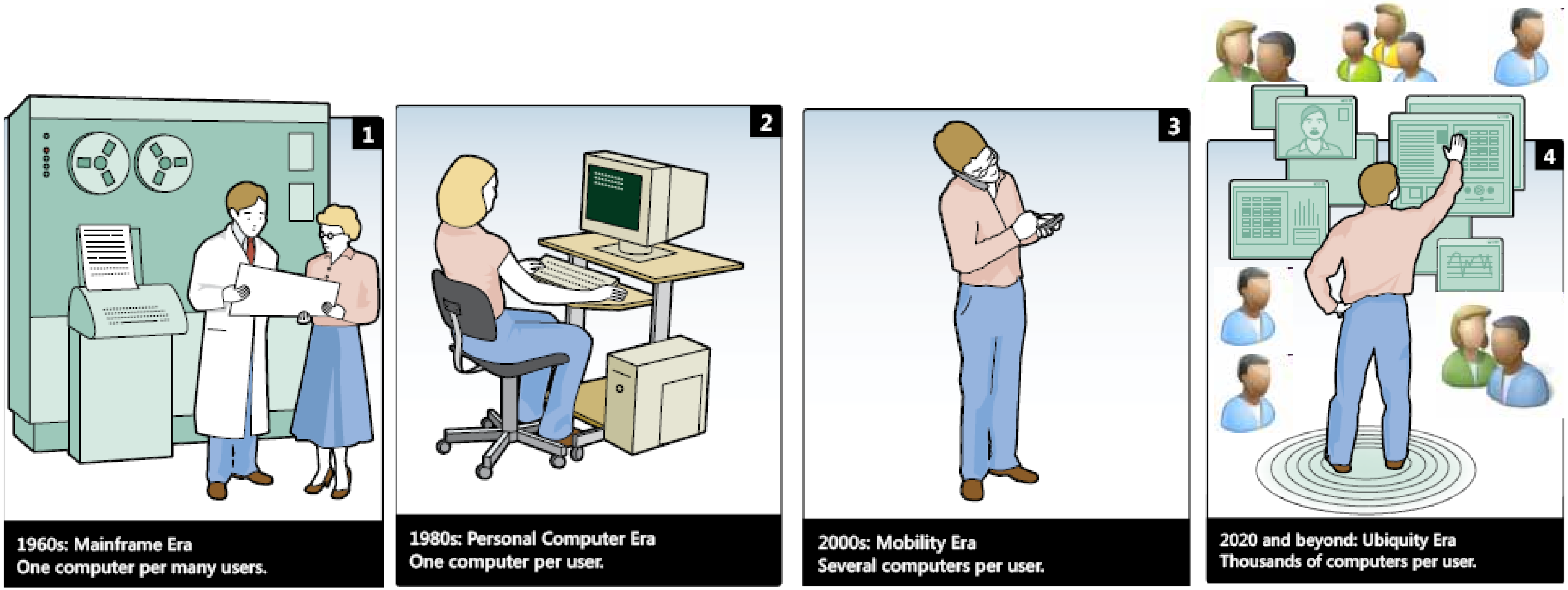


Cf. with Moore (1965), Holzinger (2002), Scholtz & Consolvo (2004), Intel (2007)



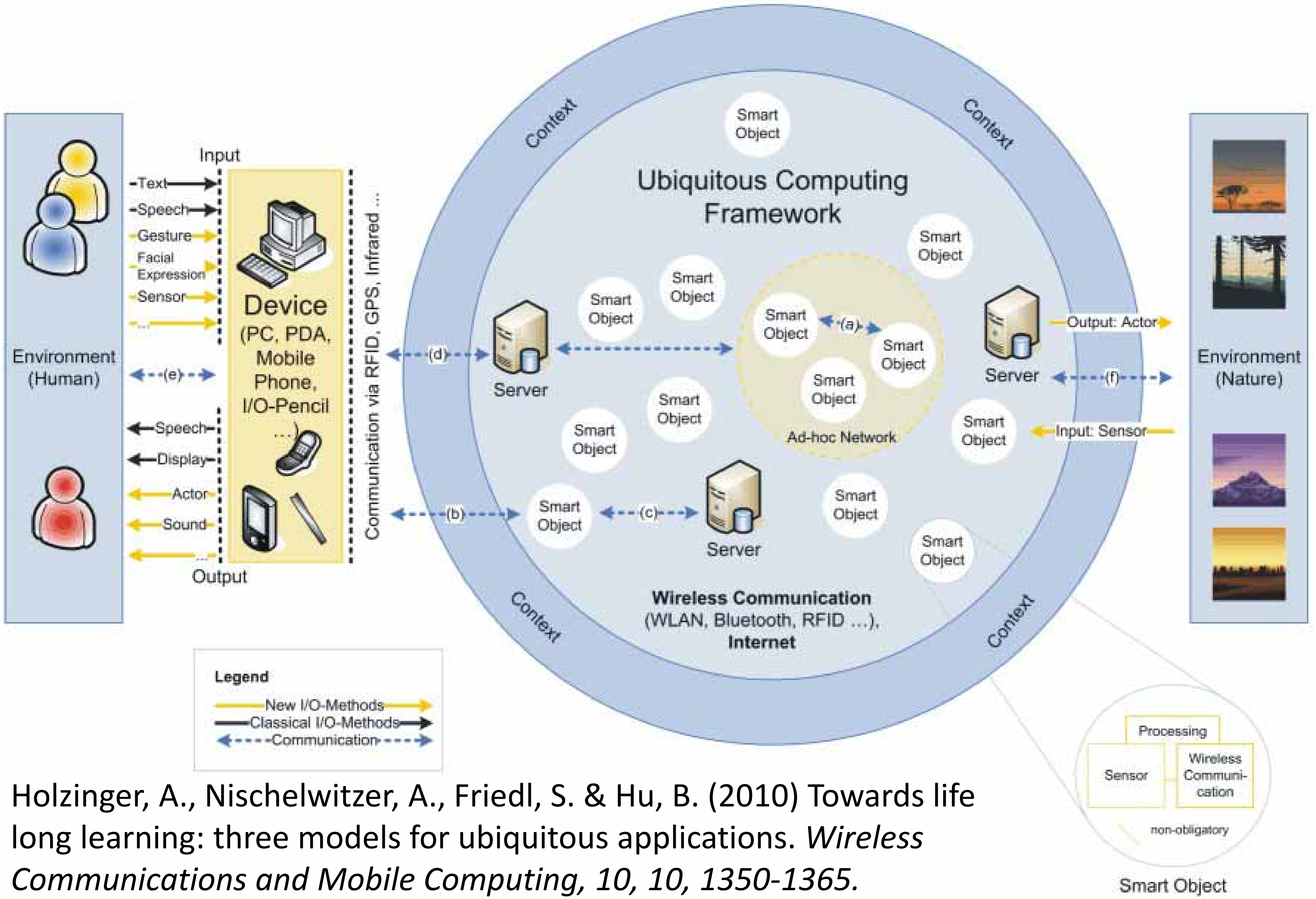
Cavin, R., Lugli, P. & Zhirnov, V. 2012. Science and Engineering Beyond Moore's Law. *Proc. of the IEEE, 100, 1720-49* (L=Logic-Protein; S=Sensor-Protein; C=Signaling-Molecule, E=Glucose-Energy)

- … using technology to augment human capabilities for structuring, retrieving and managing information



Harper, R., Rodden, T., Rogers, Y. & Sellen, A. (2008) *Being Human: Human-Computer Interaction in the Year 2020. Cambridge, Microsoft Research.*

Slide 1-34: Ubiquitous Computing – Smart Objects

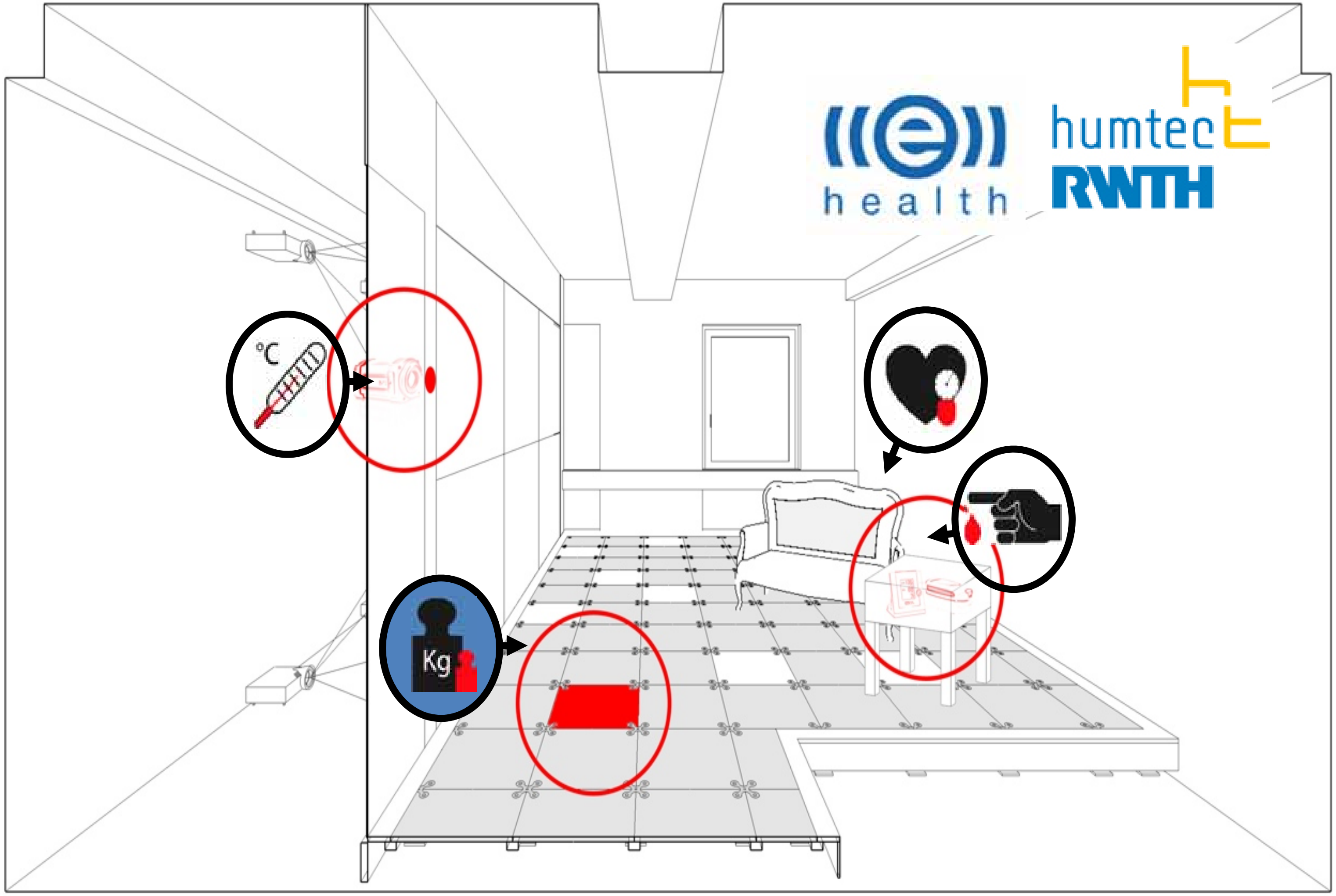


Holzinger, A., Nischelwitzer, A., Friedl, S. & Hu, B. (2010) Towards life long learning: three models for ubiquitous applications. *Wireless Communications and Mobile Computing, 10, 10, 1350-1365.*

Slide 1-35 Example: Pervasive Health Computing

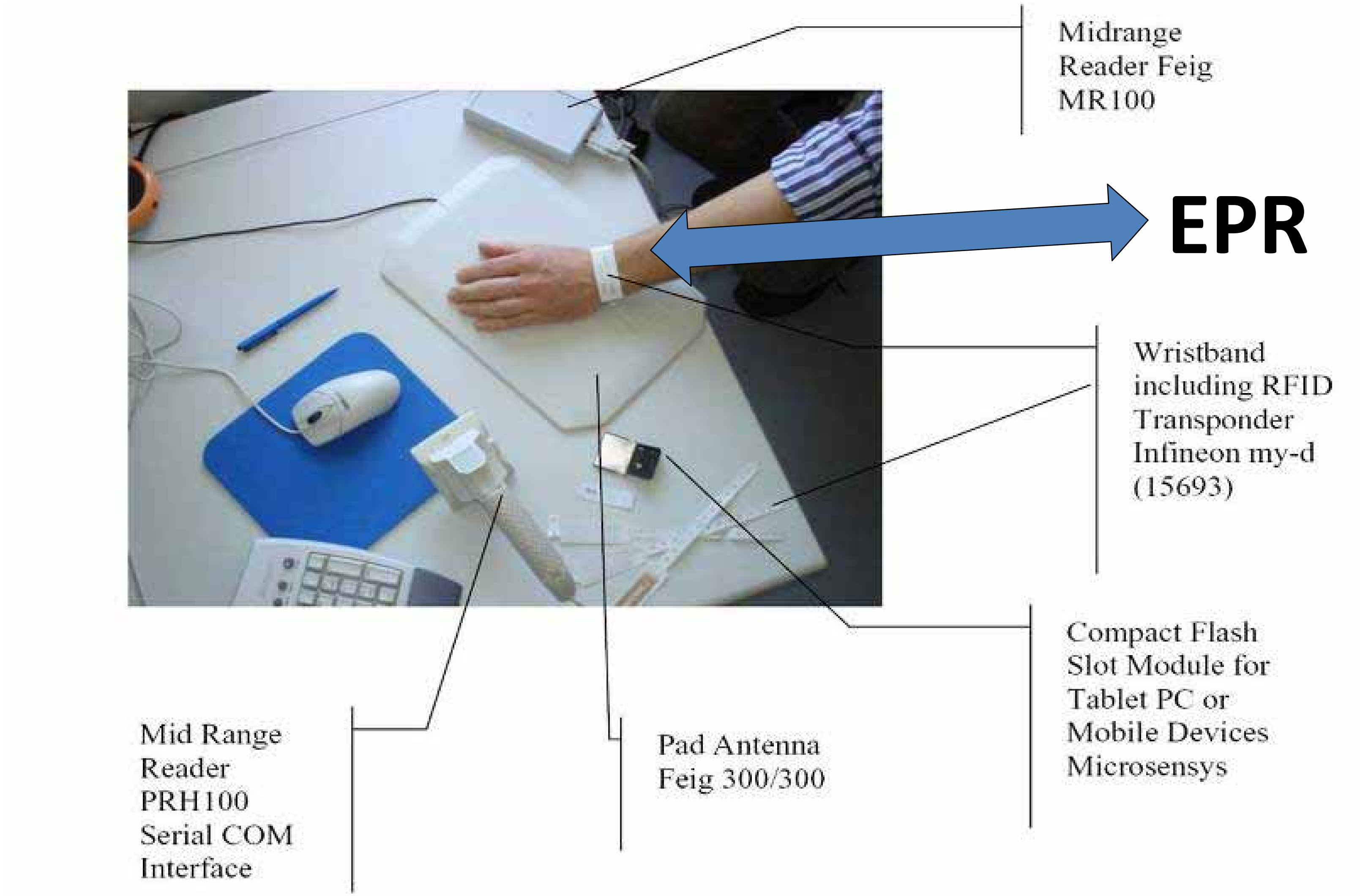
Holzinger, A., Schaupp, K. & Eder-Halbedl, W. (2008) An Investigation on Acceptance of Ubiquitous Devices for the Elderly in an Geriatric Hospital Environment: using the Example of Person Tracking In: *Lecture Notes in Computer Science (LNCS 5105). Heidelberg, Springer, 22-29.*

Slide 1-36: Ambient Assisted Living - pHealth



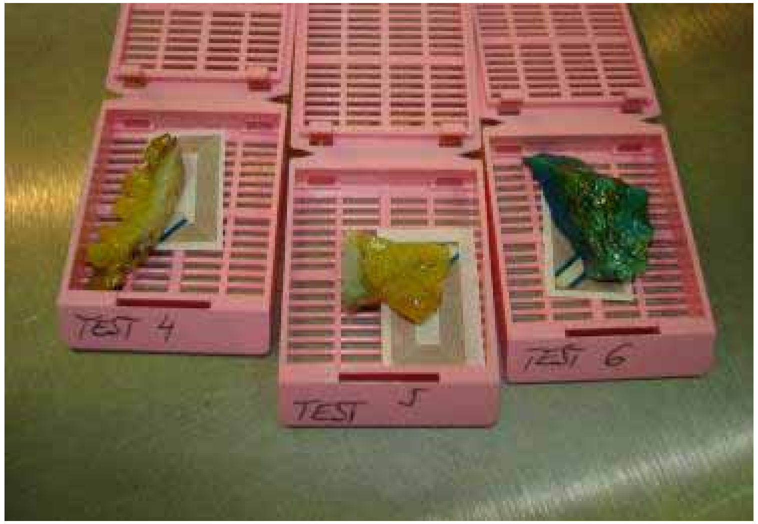
Alagoez, F., Valdez, A. C., Wilkowska, W., Ziefle, M., Dorner, S. & Holzinger, A. (2010) From cloud computing to mobile Internet, from user focus to culture and hedonism: The crucible of mobile health care and Wellness applications. *5th International Conference on Pervasive Computing and Applications (ICPCA). IEEE, 38-45.*

Slide 1-37: Pervasive Computing in the Hospital



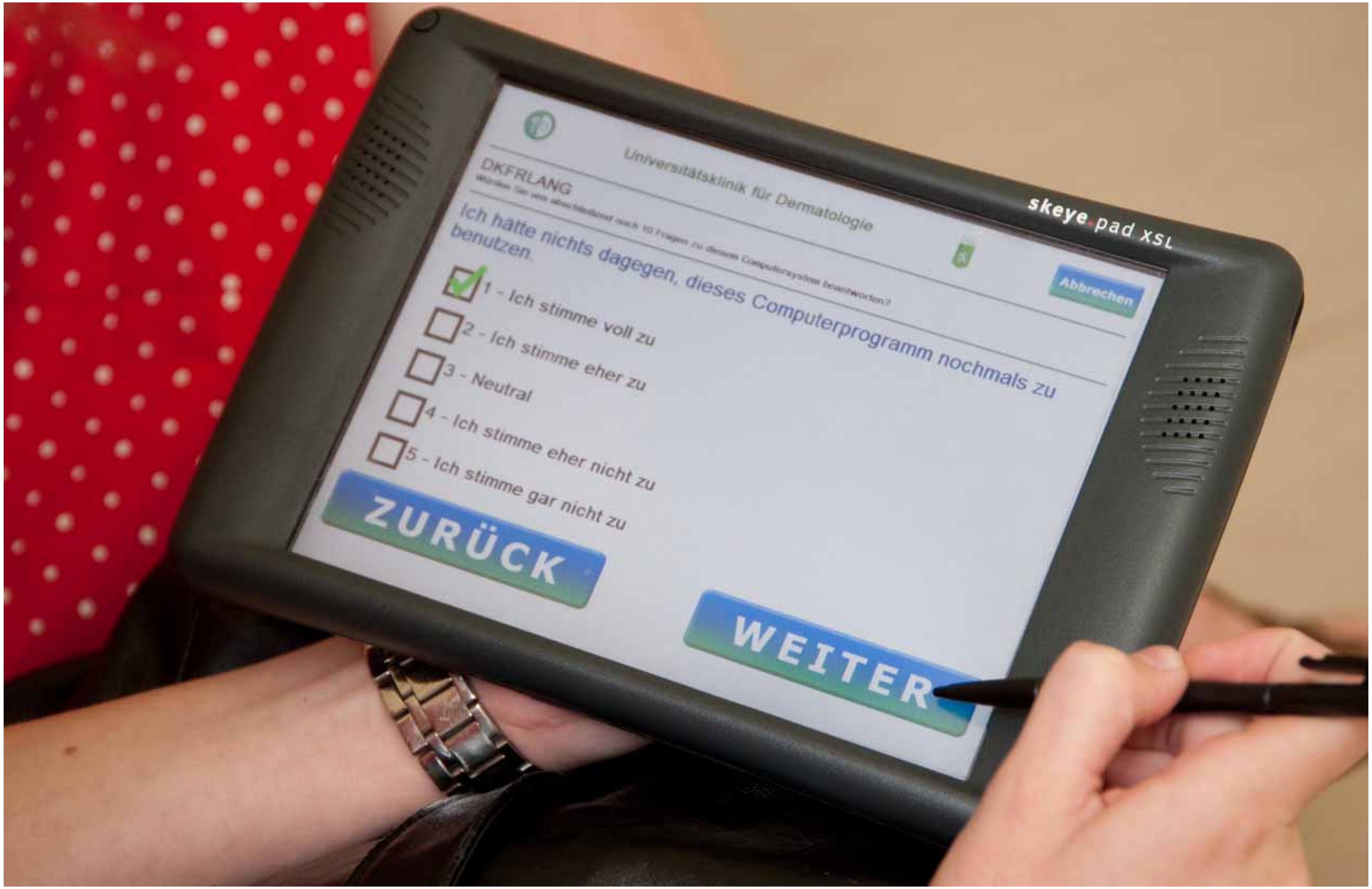
Holzinger, A., Schwaberger, K. & Weitlaner, M. (2005) Ubiquitous Computing for Hospital Applications: RFID-Applications to enable research in Real-Life environments *29th Annual IEEE International Computer Software & Applications Conference (IEEE COMPSAC), 19-20.*

Slide 1-38: Smart Objects in the pathology



Holzinger et al. (2005)

Slide 1-39 The medical world is mobile (Mocomed)



Holzinger, A., Kosec, P., Schwantzer, G., Debevc, M., Hofmann-Wellenhof, R. & Frühauf, J. 2011. Design and Development of a Mobile Computer Application to Reengineer Workflows in the Hospital and the Methodology to evaluate its Effectiveness. *Journal of Biomedical Informatics, 44****, 968-977.***

Slide 1-40: 1970 - Turning Knowledge into Data

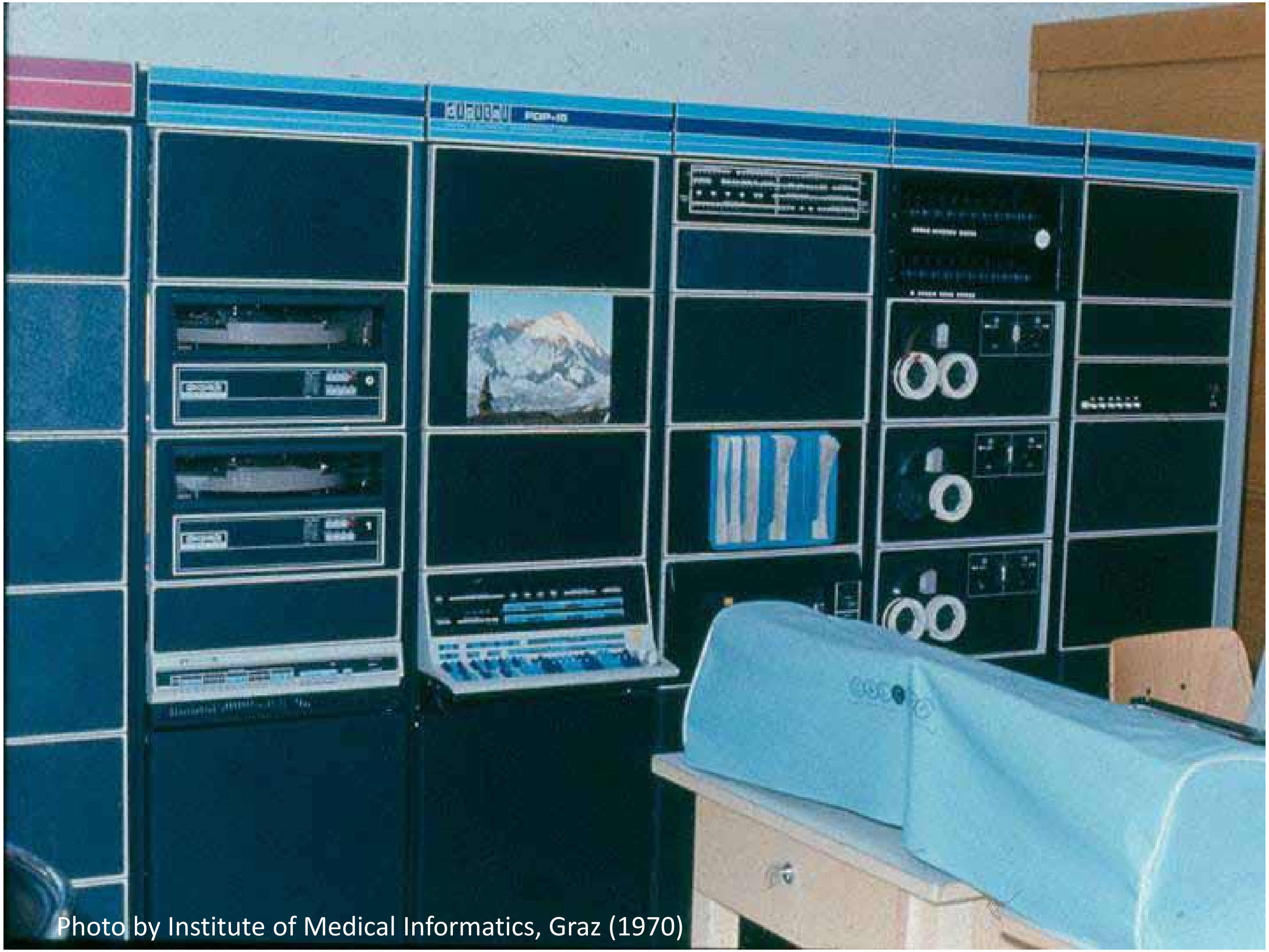


Photo by Institute of Medical Informatics, Graz (1970)

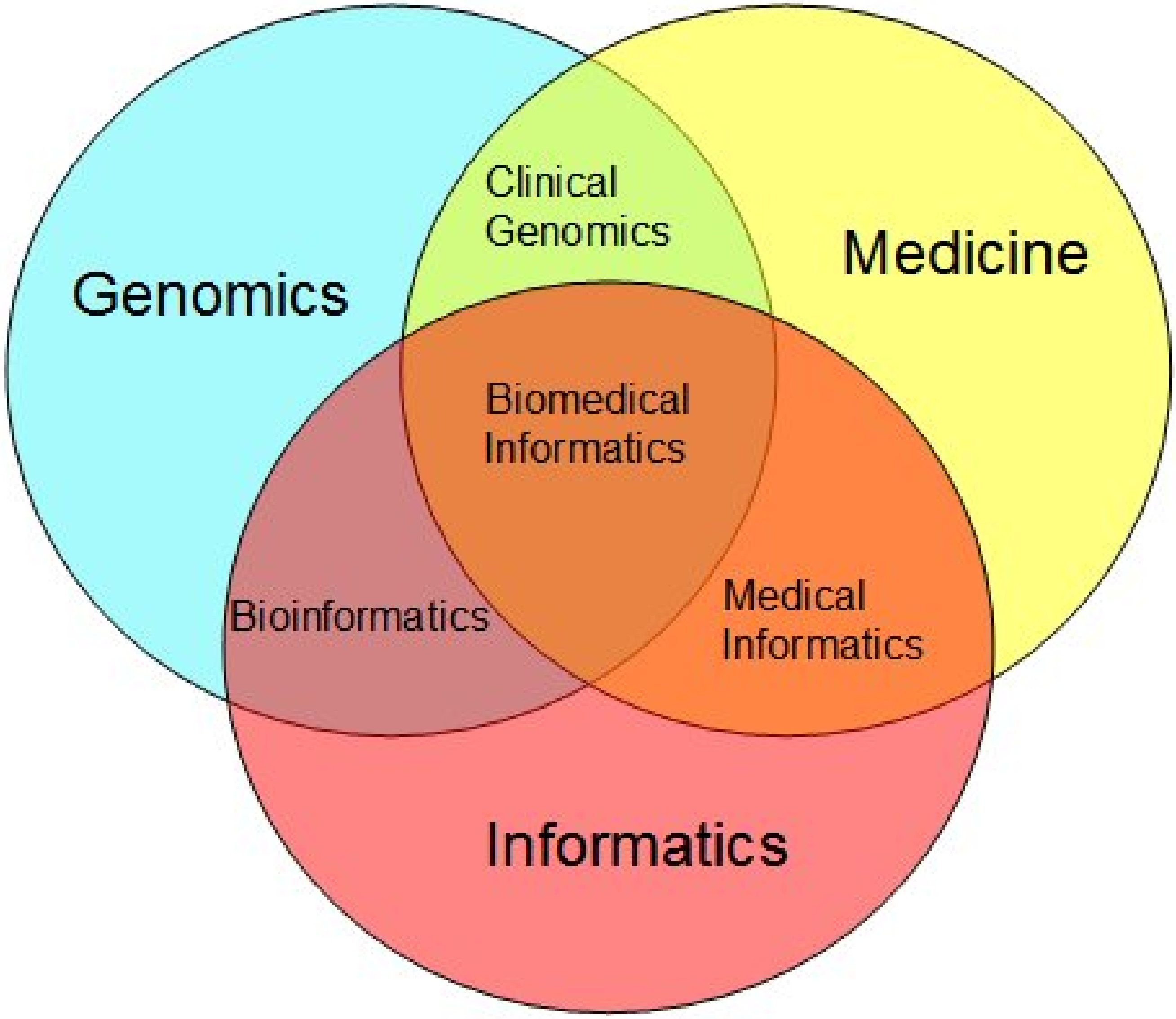
- 1970+ Begin of **Medical Informatics**
  - Focus on data acquisition, storage, accounting (typ. “EDV”)
  - The term was first used in 1968 and the first course was set up 1978
- 1985+ Health Telematics
  - Health care networks, Telemedicine, CPOE-Systems etc.
- 1995+ Web Era
  - Web based applications, Services, EPR, etc.
- 2005+ Ambient Era
  - Pervasive & Ubiquitous Computing
- 2010+ Quality Era – **Biomedical Informatics**
  - Information Quality, Patient empowerment, individual molecular medicine, End-User Programmable Mashups

INFORMATICS PROFESSIONALS. LEADING THE WAY.

- ***Biomedical informatics*** **(BMI) is the interdisciplinary field that studies and pursues the effective use of biomedical data, information, and knowledge for scientific problem solving, and decision making, motivated by efforts to improve human health**

Shortliffe, E. H. (2011). Biomedical Informatics: Defining the Science and its Role in Health Professional Education. In A. Holzinger & K.-M. Simonic (Eds.), *Information Quality in e-Health. Lecture Notes in Computer Science LNCS 7058 (pp. 711-714). Heidelberg, New York: Springer.*

Slide 1-44: Computational Sciences meet Life Sciences



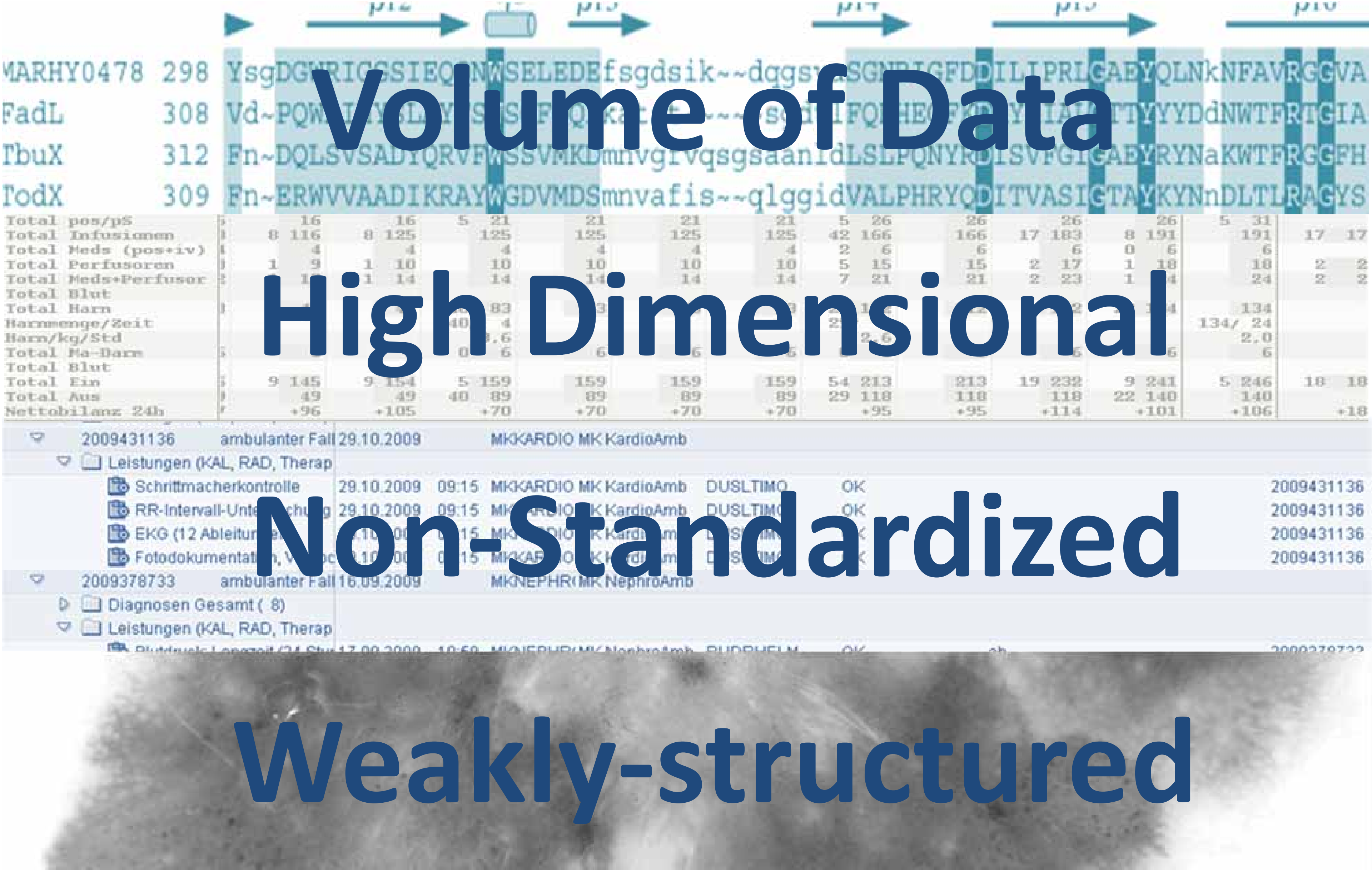
http://www.bioinformaticslaboratory.nl/twiki/bin/view/BioLab/EducationMIK1-2

Our central hypothesis:
Information bridges this gap

Holzinger, A. & Simonic, K.-M. (eds.) 2011. *Information Quality in e-Health. Lecture Notes in Computer Science LNCS 7058, Heidelberg, Berlin, New York: Springer.*

Holzinger, A. & Simonic, K.-M. (Eds.) (2011) *Information Quality in e-Health. Lecture Notes in Computer Science LNCS 7058, Heidelberg, New York, Springer.*

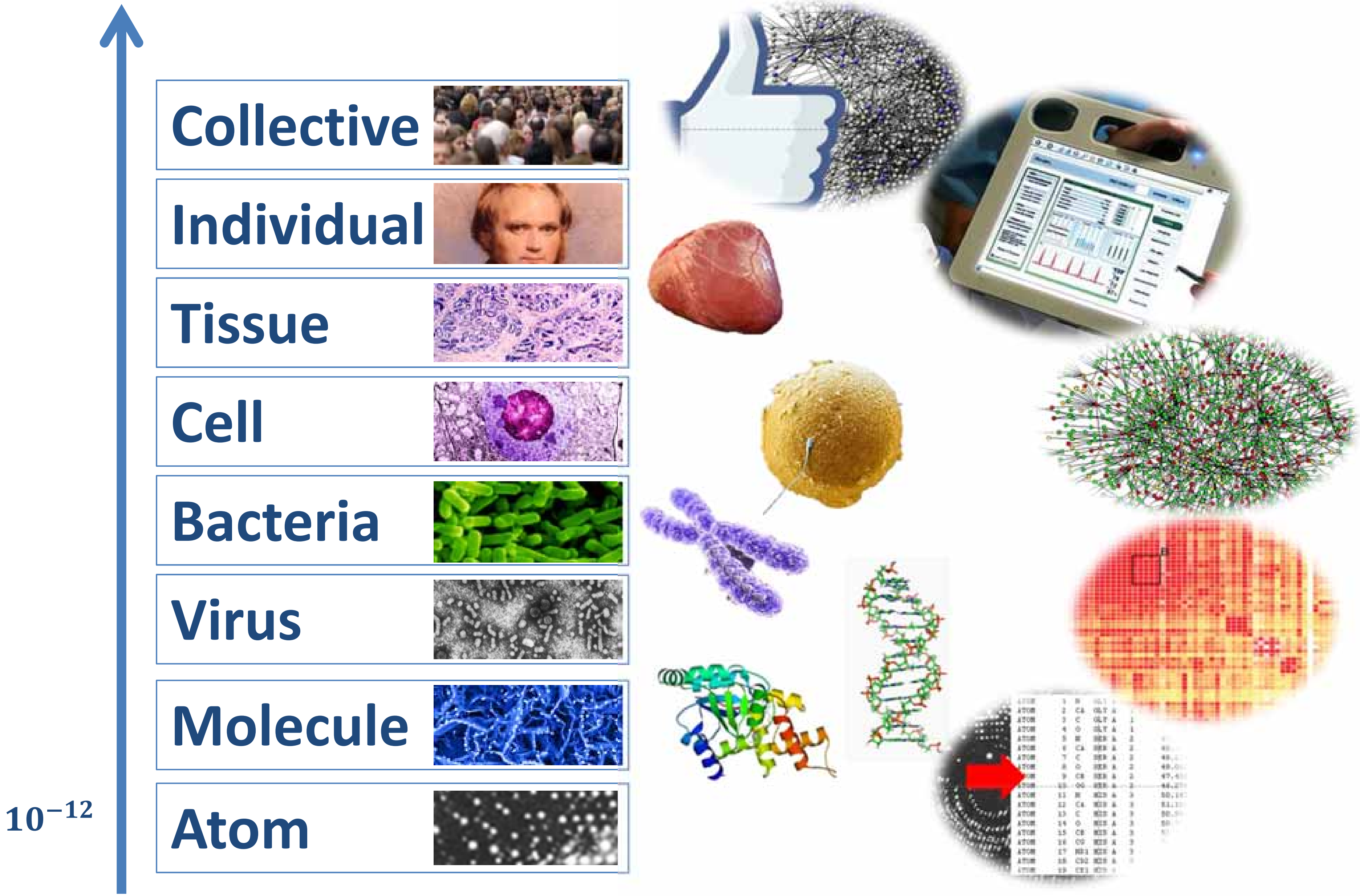

Where is the problem in building this bridge



Holzinger, A. (2011) Weakly Structured Data in Health-Informatics. In: *INTERACT 2011, Lisbon, IFIP, 5-7.*


scientific
neuroscience
provide
models
results
storage
databases
change
information
climate
science
sharing
research
analysis
researchers
visualization
many
human
access
data
knowledge
example
challenges
brain
community
health
new


HBR.ORG
Harvard Business Review
OCTOBER 2012
The Big Idea
The True Measures of Success
Michael J. Mauboussin
International Business
10 Rules for Managing Global Innovation
Keeley Wilson and Yves L. Doz
Leadership
What Ever Happened To Accountability?
Thomas E. Ricks
GETTING CONTROL OF
BIG DATA
How vast new streams of information are changing the art of management
PAGE XX


Collective
Individual
Tissue
Cell
Bacteria
Virus
Molecule
Atom
10^{-12}

Open Problems and Future Challenges

Slide 1-50 A list of grand challenges by Sittig (1994)

- 1. A unified controlled medical vocabulary (CMV);
- 2. A complete computer-based patient record that could serve as a regional/national/multinational resource and a format to allow exchange of records between systems;
- 3. The automatic coding of free-text reports, patient histories, discharge abstracts, etc.;
- 4. Automated analysis of medical records, yielding
  - a) the expected (most common) clinical presentation and course and the degree of clinical variability for patients with a given diagnosis;
  - b) the resources required in the care of patients compared by diagnosis, treatment protocol, clinical outcome, location, and physician;
- 5. A uniform, intuitive, anticipating user interface;
- 6. The human genome project;
- 7. A complete three-dimensional, digital representation of the body, including the brain, with graphic access to anatomic sections, etc.;
- 8. Techniques to ease the incorporation of new information management technologies into the infrastructure of organizations so that they can be used at the bedside or at the research bench;
- 9. A comprehensive, clinical decision support system.

Slide 1-51 An update of the list – 20 years later

- Grand new challenges from today's perspective include:
- 10. Closing the gap between Science and Practice
- 11. Data fusion and data integration in the clinical workplace
- 12. To provide a trade-off between Standardization and Personalization
- 13. An intuitive, unified and universal, adaptive and adaptable user interface
- 14. Integrated interactive Knowledge Discovery Methods particularly for the masses of still "unstructured data"
- 15. Mobile solutions for the bedside and the clinical bench
- A consequence of 14 and 15 will be the vision of "Watson" on the Smartphone. This goal was announced by IBM for the year 2020. The problem involved are the massive unstructured clinical data sets [1]

1. Holzinger, A., Stocker, C., Ofner, B., Prohaska, G., Brabenetz, A., & Hofmann-Wellenhof, R. (2013). Combining HCI, Natural Language Processing, and Knowledge Discovery - Potential of IBM Content Analytics as an assistive technology in the biomedical domain Springer Lecture Notes in Computer Science LNCS 7947 (pp. 13-24). Heidelberg, Berlin, New York: Springer.

The next big issue …


nature International weekly journal of science

Journal home > Archive > Books and Arts > Opinion > Full Text

Journal content
- Journal home
- Advance online publication
- Current issue
- Nature News
- Archive
- Supplements
- Web focuses
- Podcasts
- Videos
- News Specials

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- Online submission
- Nature Awards
- Nature history

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- Advertising
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- Authors & referees

NPG resources
- Gateways & databases

Books and Arts

Nature **464**, 680 (1 April 2010) | doi:10.1038/464680a; Published online 31 March 2010

A reality check for personalized medicine

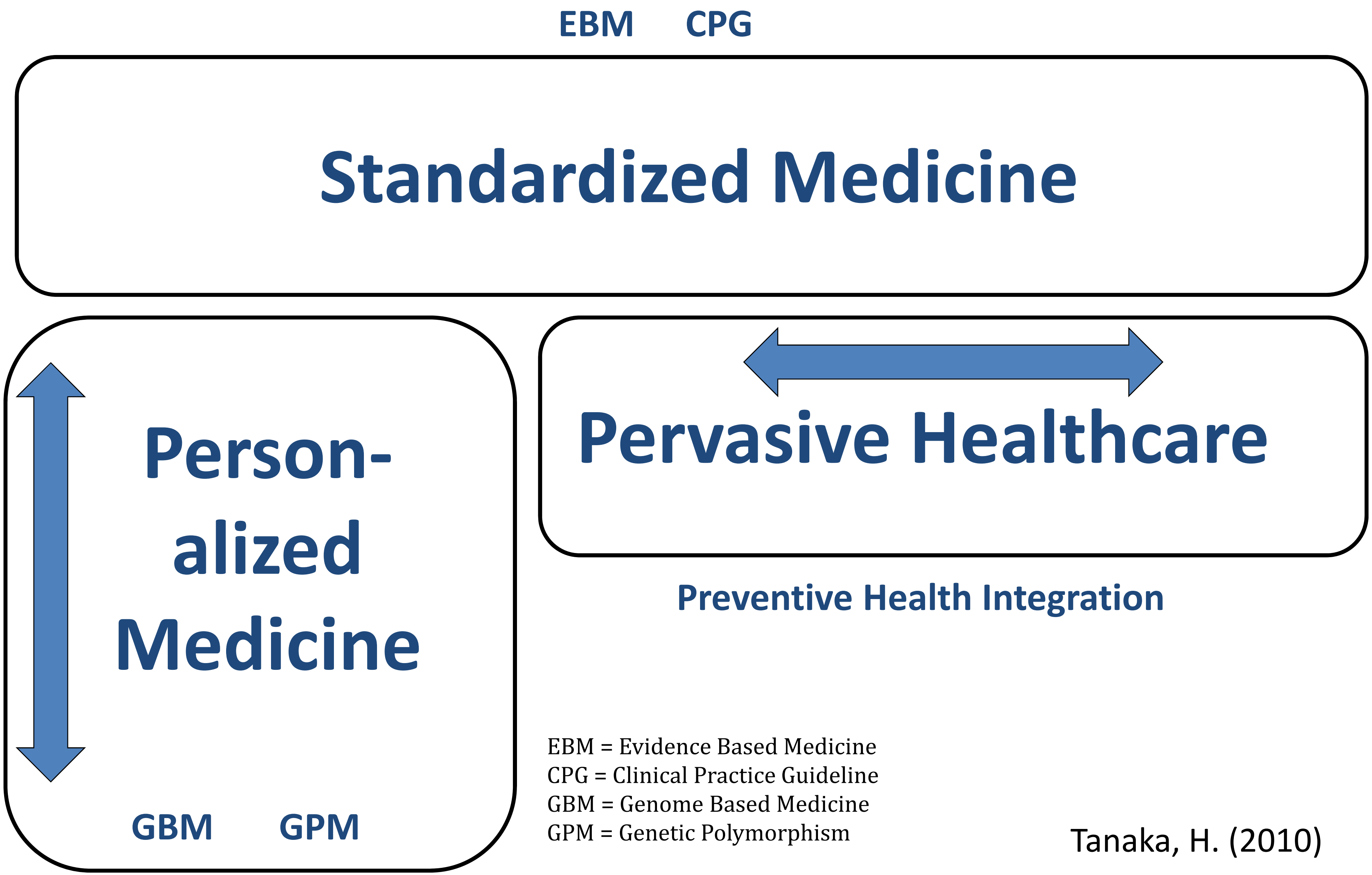
Muin J. Khoury[1], James Evans[2] & Wylie Burke[3]

Bringing genetic information into health care is welcome but its utility in the clinic needs to be rigorously reviewed, caution Muin J. Khoury, James Evans and Wylie Burke.

BOOK REVIEWED
Personal Genomics and Personalized Medicine
by Hamid Bolouri
Imperial College Press: 2010. 280 pp. £34

T. FLACH/STONE/GETTY

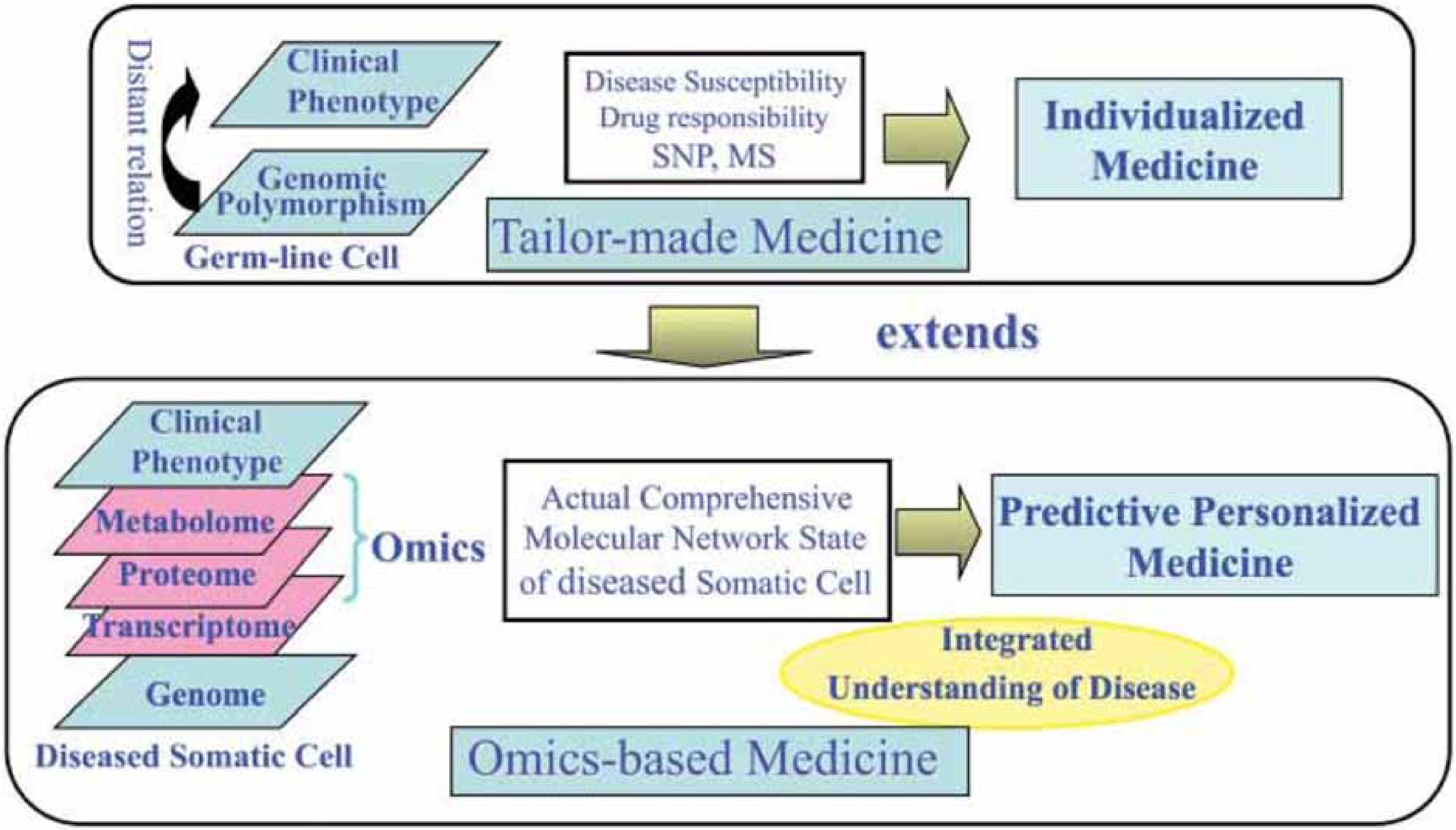
Genomic information: should it be treated in the same way as X-ray results?



EBM = Evidence Based Medicine
CPG = Clinical Practice Guideline
GBM = Genome Based Medicine
GPM = Genetic Polymorphism

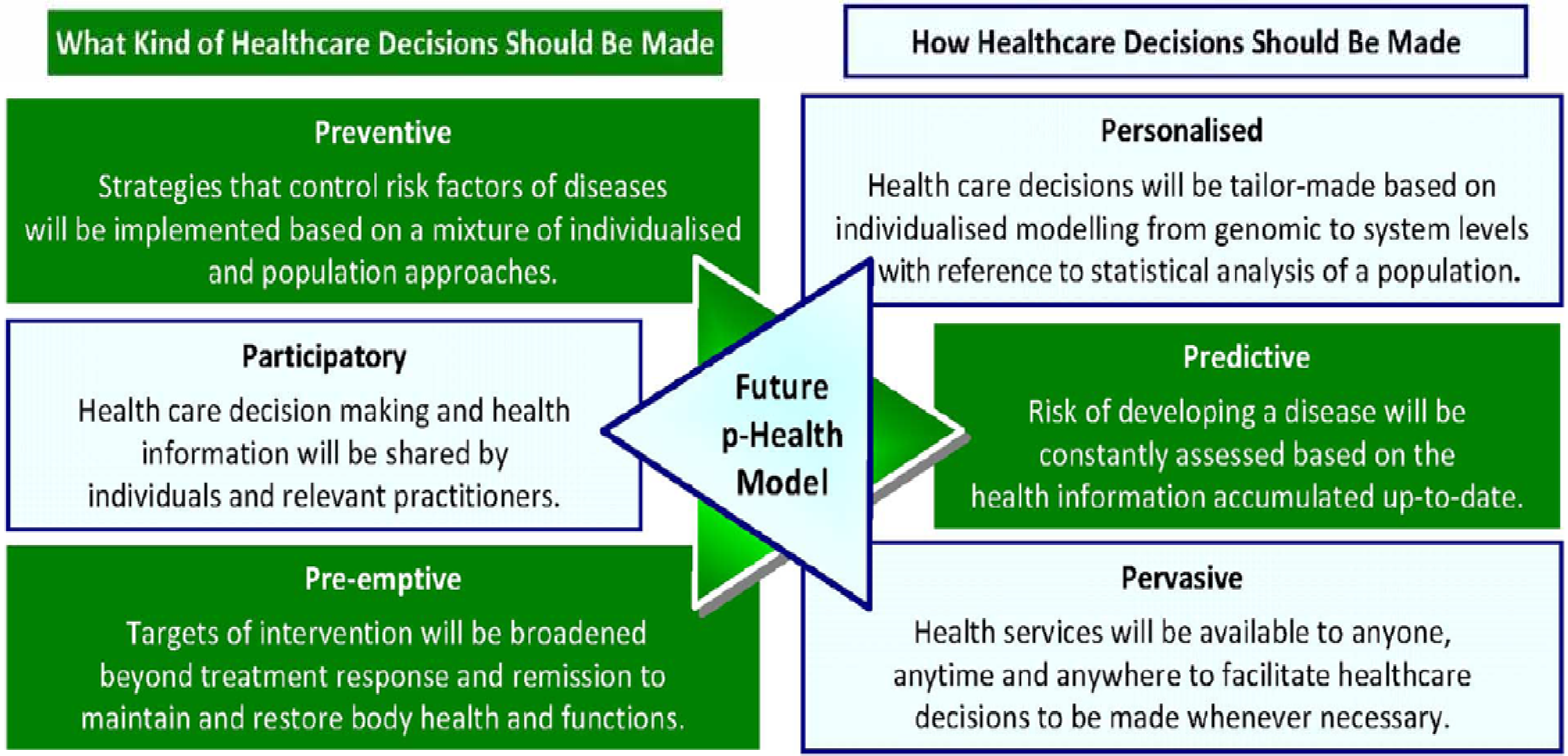
Tanaka, H. (2010)

Slide 1-53: Towards Personalized Medicine



Tanaka, H. (2010) Omics-based Medicine and Systems Pathology A New Perspective for Personalized and Predictive Medicine. *Methods of Information In Medicine, 49, 2, 173-185.*

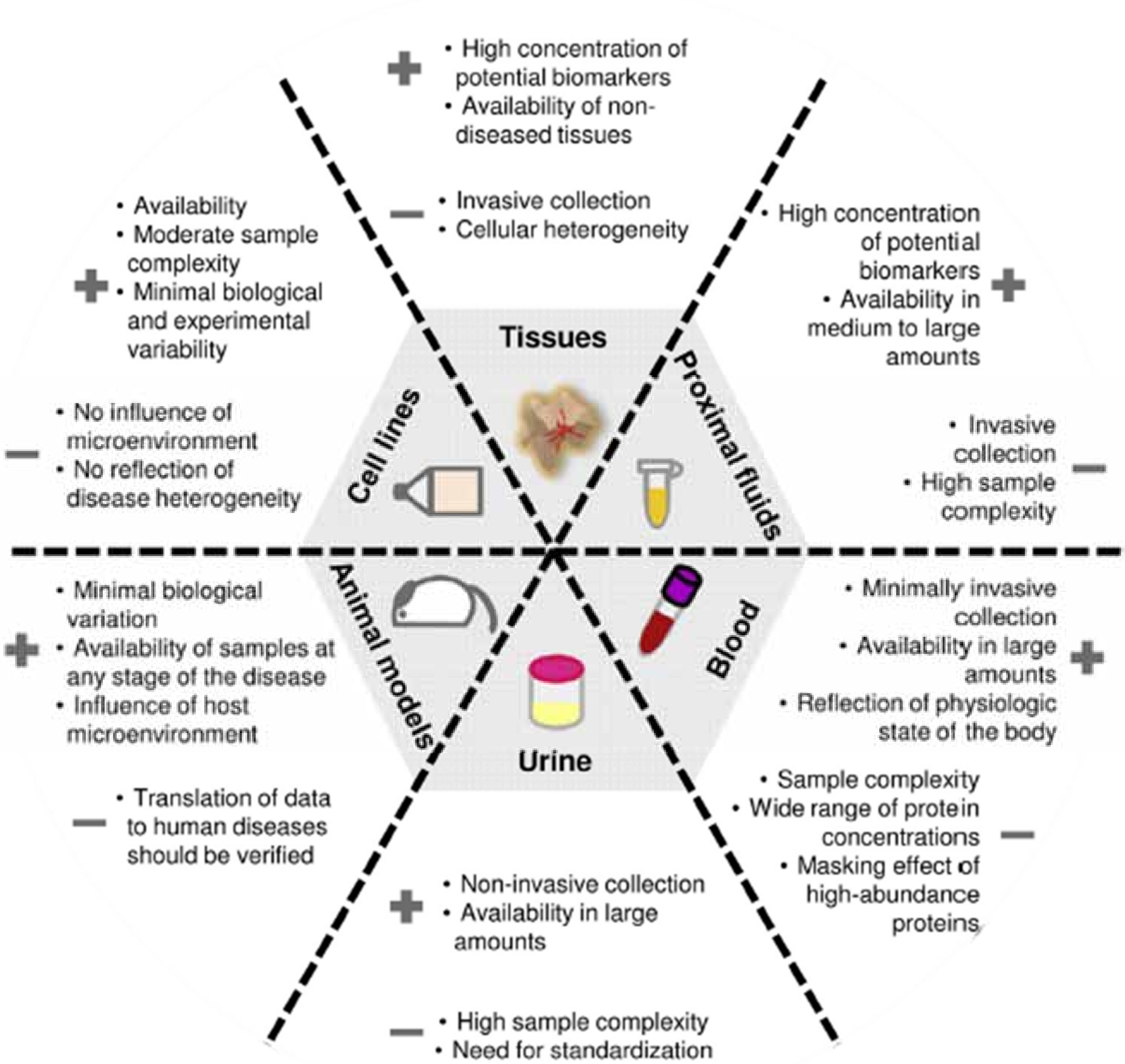
Slide 1-54: Future p-Health Model – A 6 P's paradigm



Zhang, Y. T. & Poon, C. C. Y. (2010) Editorial Note on Bio, Medical, and Health Informatics. *Information Technology in Biomedicine, IEEE Transactions on, 14, 3, 543-545.*

Slide 1-55: Proteomic Samples for Biomarker Discovery

Drabovich, A. P., Pavlou, M. P., Batruch, I. & Diamandis, E. P. 2013. Chapter 2 - Proteomic and Mass Spectrometry Technologies for Biomarker Discovery. *In: Haleem, J. I. & Timothy, D. V. (eds.) Proteomic and Metabolomic Approaches to Biomarker Discovery. Boston: Academic Press, pp. 17-37.*



nature

www.nature.com/nature

458 | Issue no. 7234 | 5 March 2009

What price health?

Thank you!

	computer.		
08	Biomarkers are measured molecules which indicate the presence of an abnormal condition within a patient, and can be a gene (e.g., SNP), protein (e.g., prostate-specific antigen), or metabolite.	❒ Yes ❒ No	2 total

	❒ d) ... heterogeneity and weak structurization of the available data.	
06	Part of the definition of Biomedical Informatics is the ... ❒ ... effective use of biomedical data. ❒ ... motivation to improve computational capacities. ❒ ... effort to expand the technological capabilities. ❒ ... motivation to improve human health.	4 total

02	The Von-Neumann Architecture is the fundamental computer organization structure of nearly all of our todays computing systems (e.g. in your PC, smartphone, microwave oven, car, etc.), please roughly sketch the Von Neumann Architecture and indicate the main parts:	1-28 1 each 6 total

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