

Andreas Holzinger

KNOWLEDGE DISCOVERY AND INTERACTIVE INTELLIGENT VISUALIZATION OF BIOMEDICAL DATA

Challenges in Human-Computer Interaction & Biomedical Informatics

Rome, 26th July, 2012

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Graz University Hospital

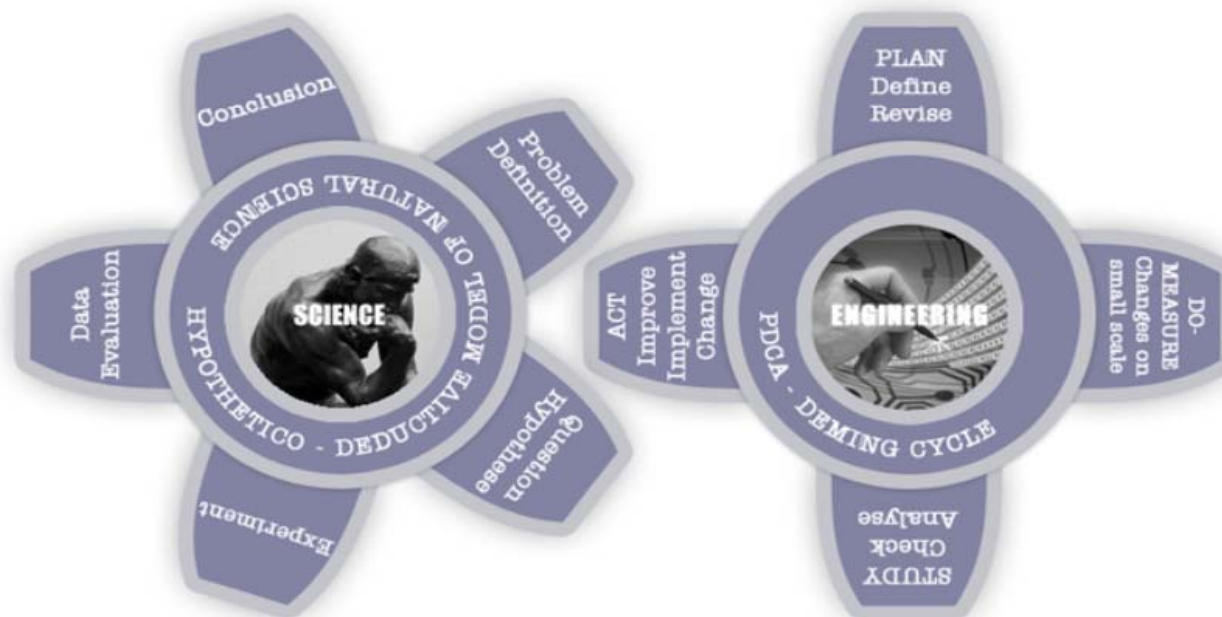


enjoy thinking
taming information
support knowledge

hci4all.at



Science is to test ideas - Engineering is to put these ideas into practice



VISION: Let us together, today, make information technology of tomorrow more usable, enjoyable and accessible for all!

MISSION: Realize usable, enjoyable and accessible Interactive Multimedia Information Systems following Human-Centered Development.

METHOD: Combine the Hypothetico-Deductive-Model (Natural Science) with the PDCA-Deming-Cycle (Engineering).

Search

Student Projects

Efficient Text Input Methods for improved User Experience on Mobile Devices

Keywords

Text Input, Mobile Devices, Alternative Input Technologies, Human-Computer Interaction

Abstract

Mobile devices (iPhones, Smartphones, etc.) are tremendously successful and ubiquitously available in our daily living. However, Touch-based User Interfaces still have potential for improvement in order to ensure high productivity and a positive user experience – even at complex and hectic work places (e.g. medicine and health care). Issues of research and development are e.g. the improvement of classical user controls, including list views or tree views on such mobile touch-screens. Text input poses a [...]



GENOMICS AND BIOINFORMATICS GRAZ

[Research](#)[Software](#)[Services](#)[Databases](#)[Education](#)[People](#)

MEDICAL INFORMATICS [444.152, 2VO WS]

LECTURER

Assoc. Prof. Dr. Andreas Holzinger

DESCRIPTION

1. Introduction: Computer Science meets Life Sciences, challenges and future directions
2. Back to the future: Fundamentals of Data, Information and Knowledge
3. Structured Data: Coding, Classification (ICD, SNOMED, MeSH, UMLS)
4. Biomedical Databases: Acquisition, Storage, Information Retrieval and Use
5. Semi structured and weakly structured data (structural homologies)
6. Multimedia Data Mining and Knowledge Discovery
7. Knowledge and Decision: Cognitive Science and Human-Computer Interaction
8. Biomedical Decision Making: Reasoning and Decision Support
9. Intelligent Information Visualization and Visual Analytics
10. Biomedical Information Systems and Medical Knowledge Management
11. Biomedical Data: Privacy, Safety and Security
12. Methodology for Information Systems: System Design, Usability and Evaluation

- a) Informatics**
- b) Software Engineering**
- c) Mathematics**
- d) Other**



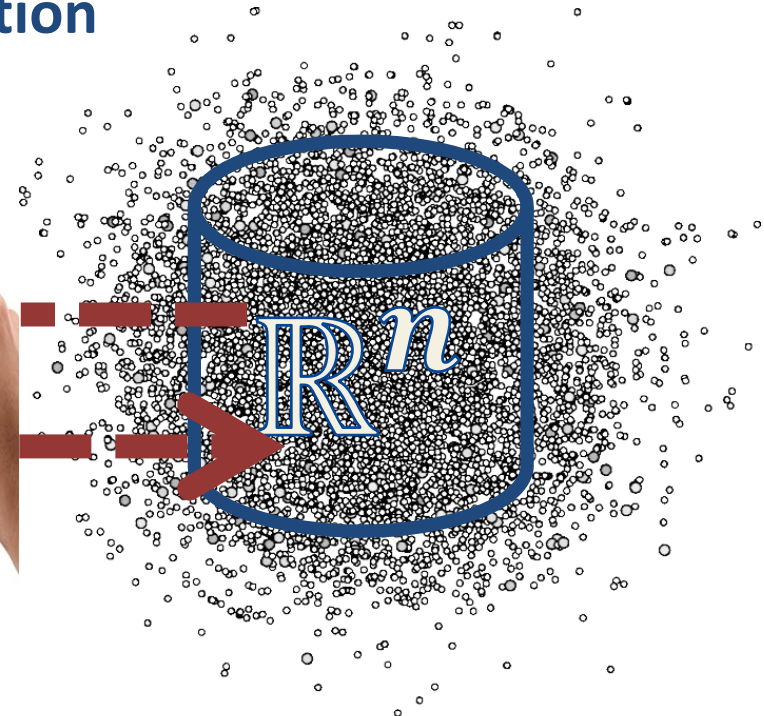
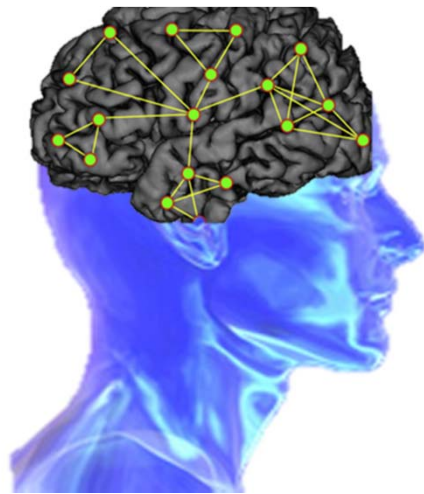
What is Human-Computer Interaction (HCI)?

Cognitive Space

Computational space

Perception

Visualization



Human intelligence

Machine intelligence

Human

Interaction

Computer

Human intelligence harnesses machine intelligence



- ***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. Simoncic (Eds.), *Information Quality in e-Health. Lecture Notes in Computer Science LNCS 7058* (pp. 711-714). Heidelberg, New York: Springer.

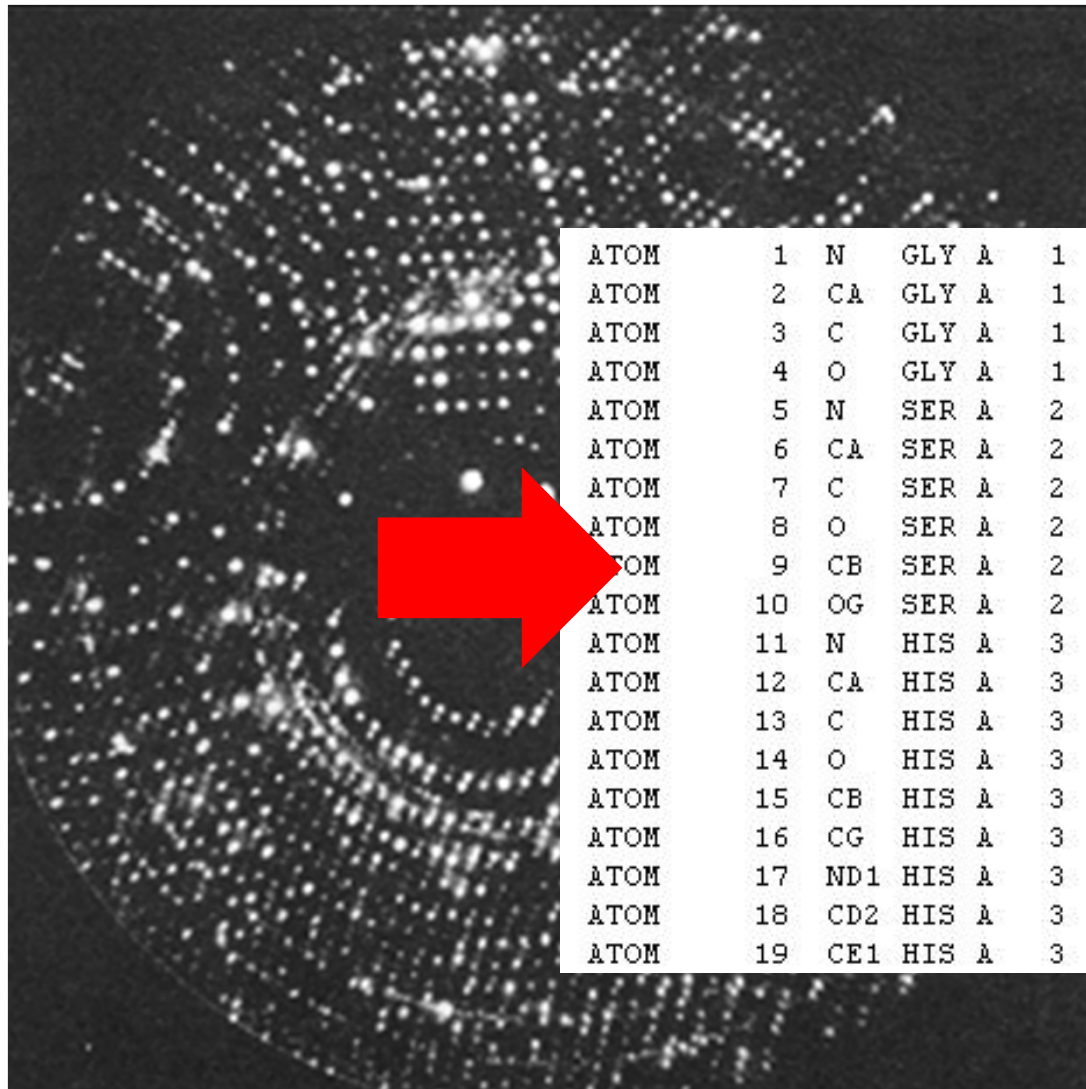
Between Hubble and Microscopes: How do data effect my life?



Russo (2011) Sky & Telescope Magazine

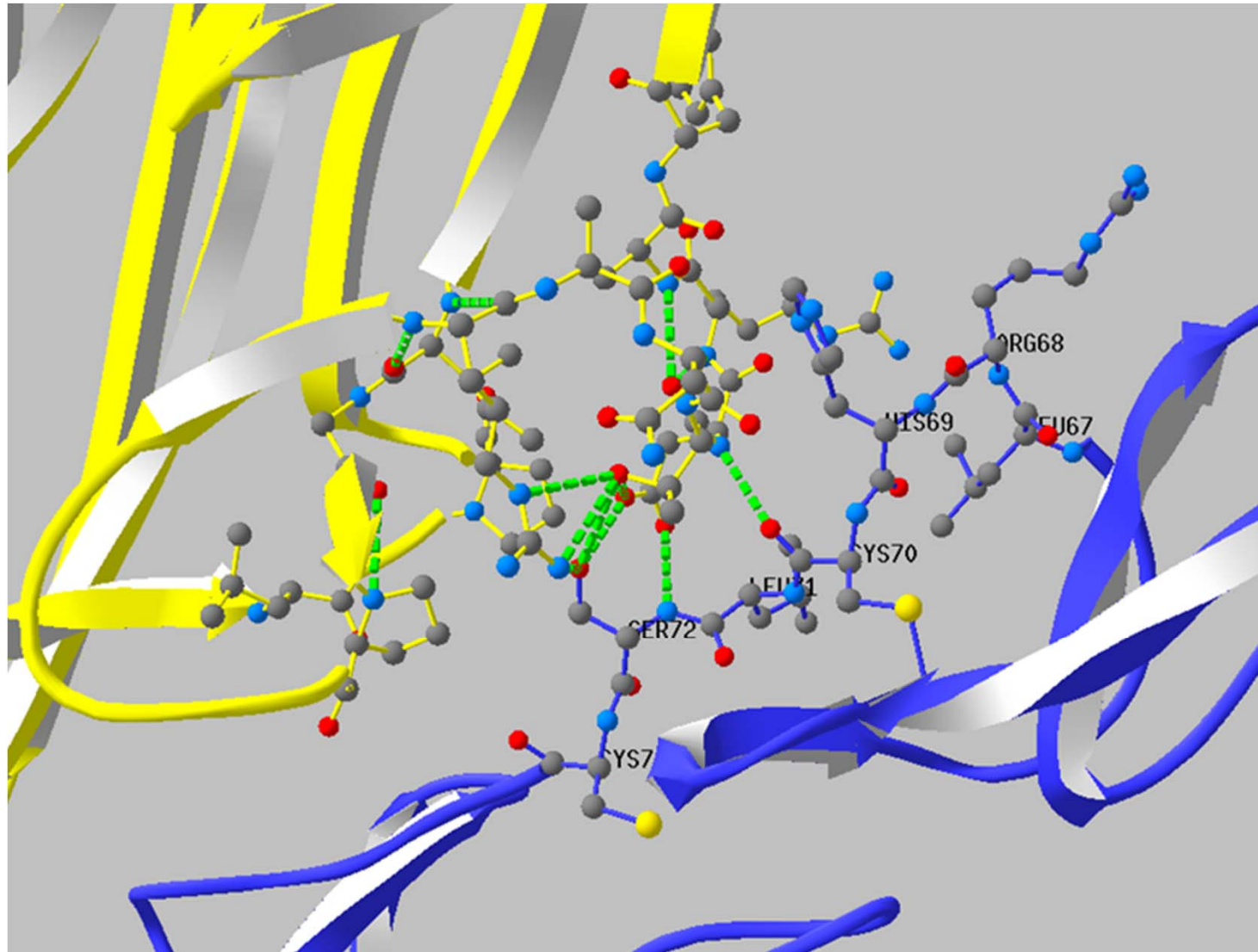


ESO, Atacama, Chile (2011)



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

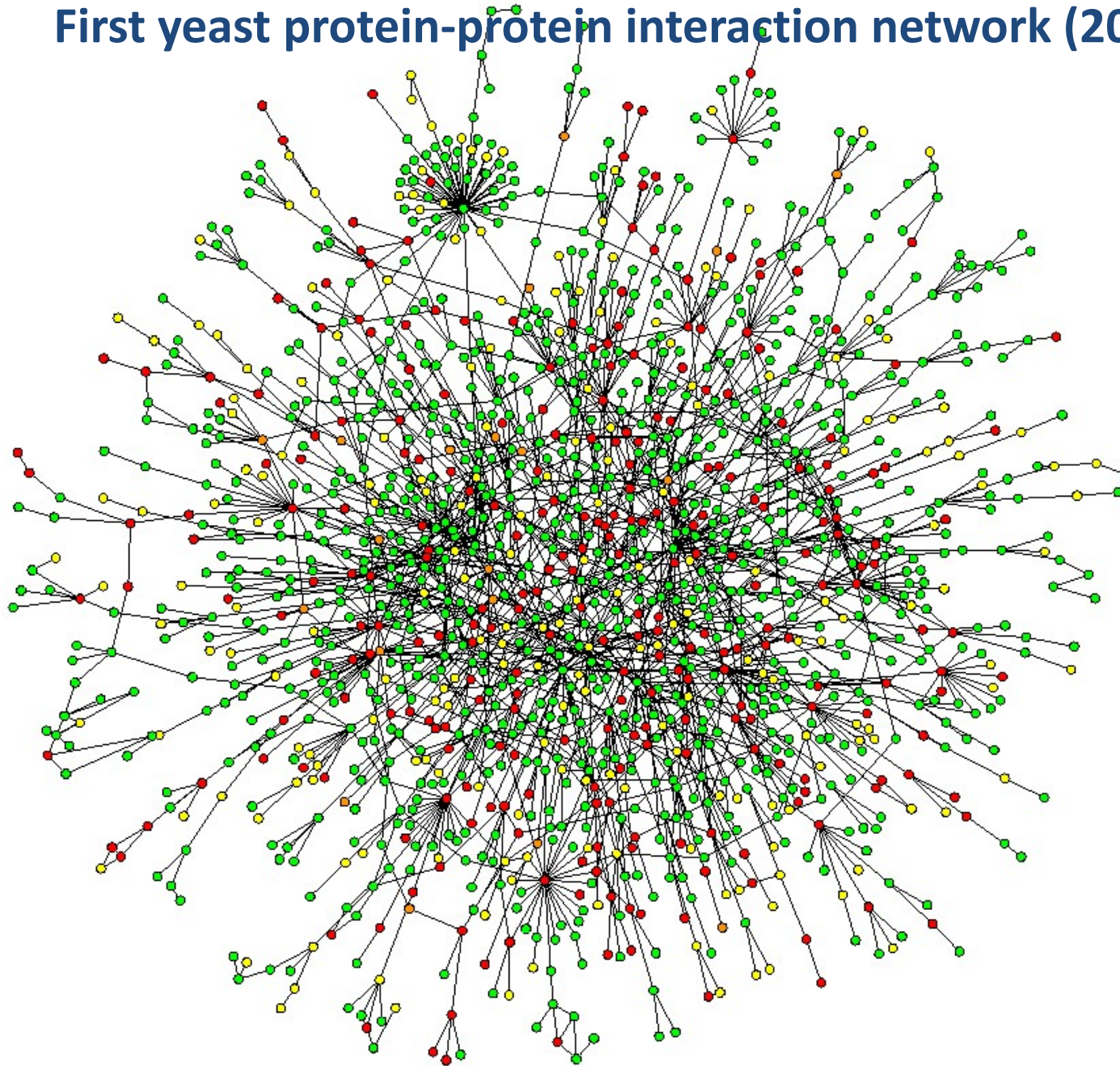
Wiltgen, M. & Holzinger, A. (2005) Visualization in Bioinformatics: Protein Structures with Physicochemical and Biological Annotations. In: *Central European Multimedia and Virtual Reality Conference. Prague, Czech Technical University (CTU)*, 69-74



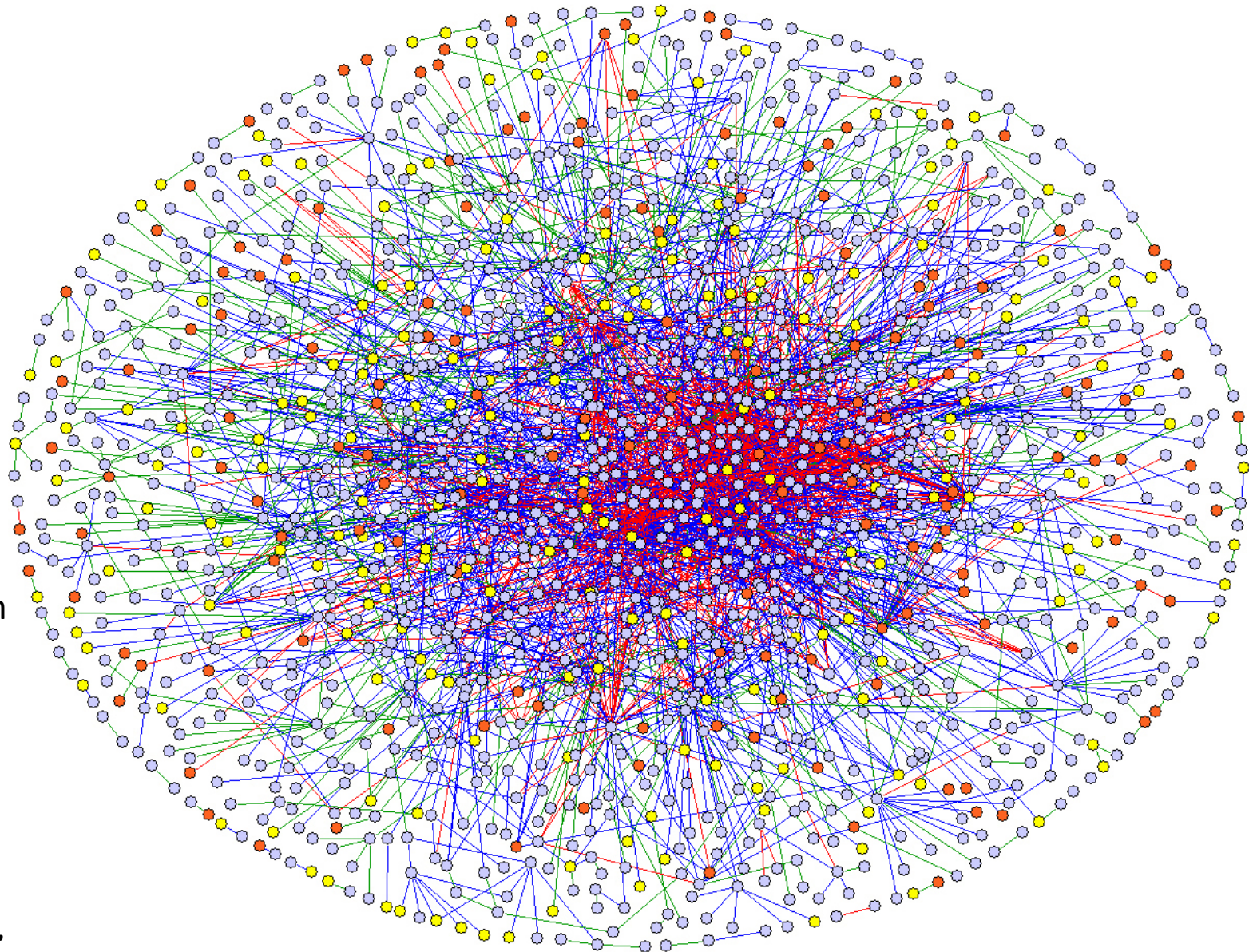
Wiltgen, M., Holzinger, A. & Tilz, G. P. (2007) Interactive Analysis and Visualization of Macromolecular Interfaces Between Proteins. In: *Lecture Notes in Computer Science (LNCS 4799)*. Berlin, Heidelberg, New York, Springer, 199-212.

First yeast protein-protein interaction network (2001)

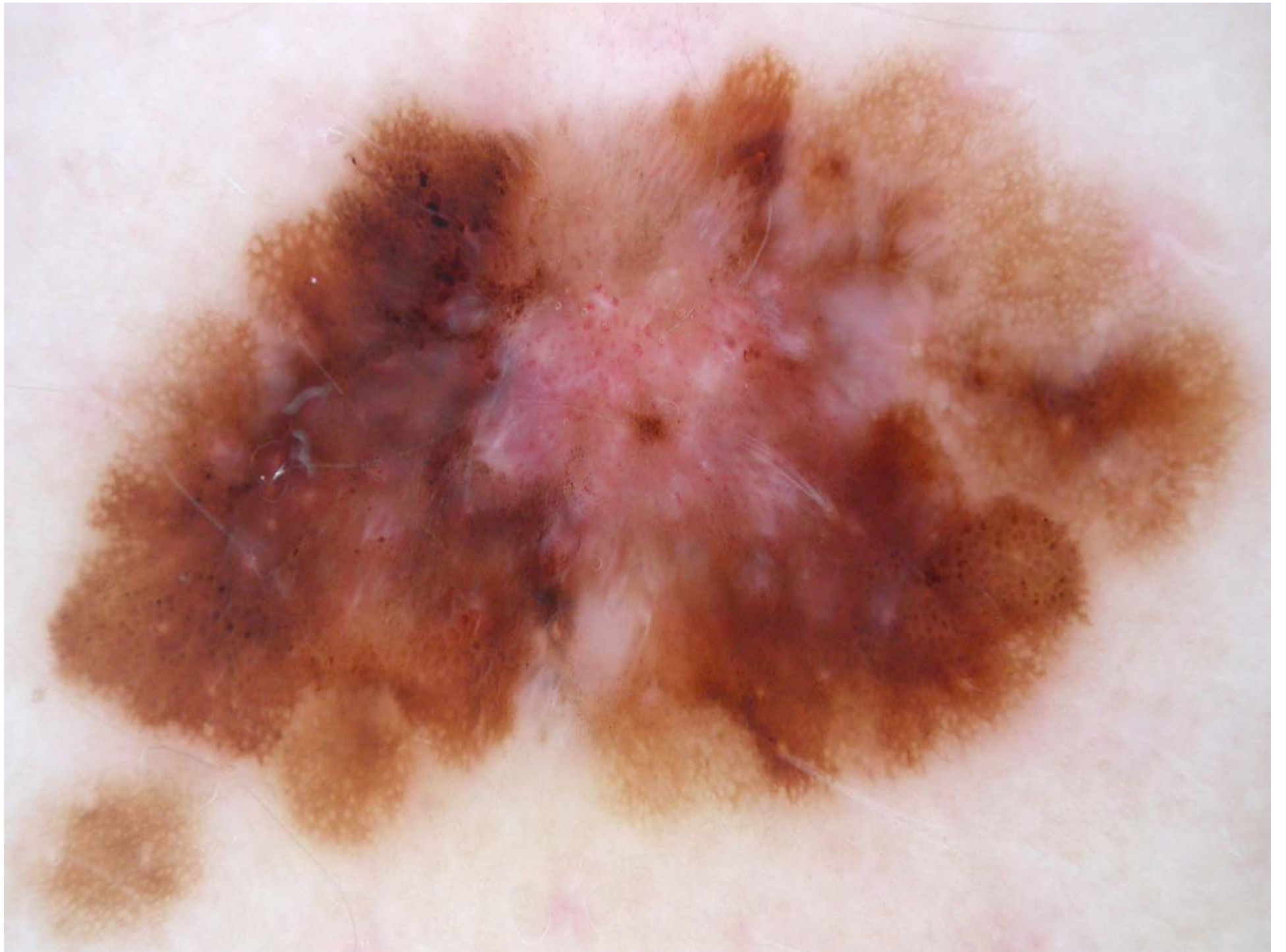
Nodes = proteins
Links = physical interactions
(bindings)
Red Nodes = lethal
Green Nodes = non-lethal
Orange = slow growth
Yellow = not known



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



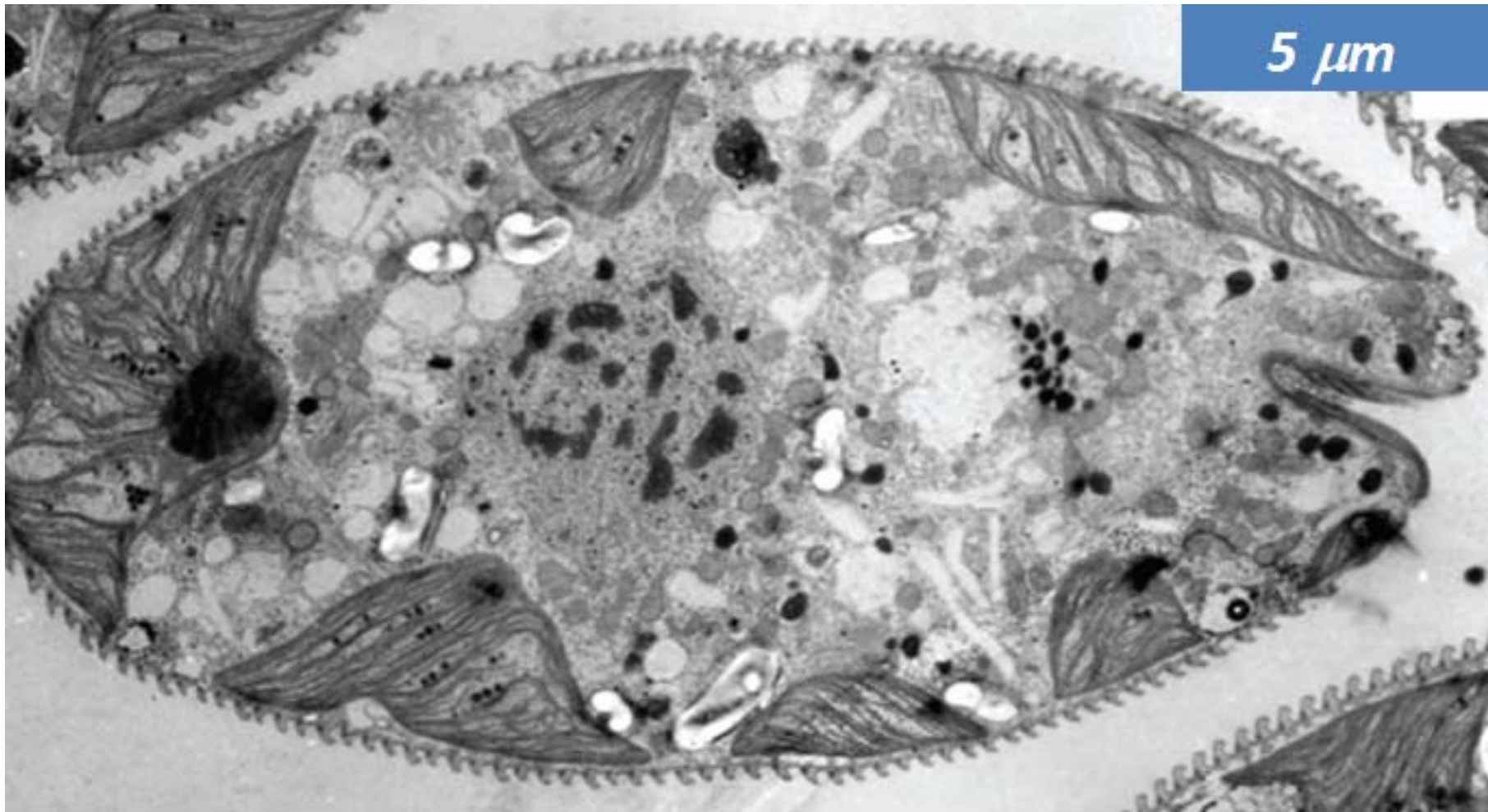
Stelzl, U. et al.
(2005) A Human
Protein-Protein
Interaction
Network: A
Resource for
Annotating the
Proteome. *Cell*,
122, 6, 957-968.



Who knows this person?

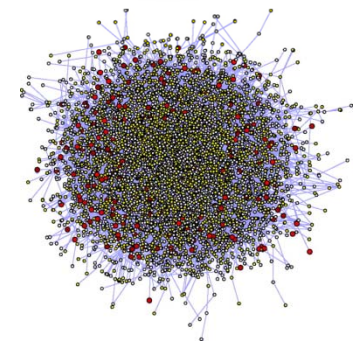


$$\left(-\frac{\hbar^2}{2m} \Delta + U(\vec{r}, t) \right) \psi(\vec{r}, t) = i\hbar \frac{\partial}{\partial t} \psi(\vec{r}, t)$$



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

- to reproduce
- to grow
- to evolve
- to self-replicate
- to generate energy
- to utilize energy
- **to process information**

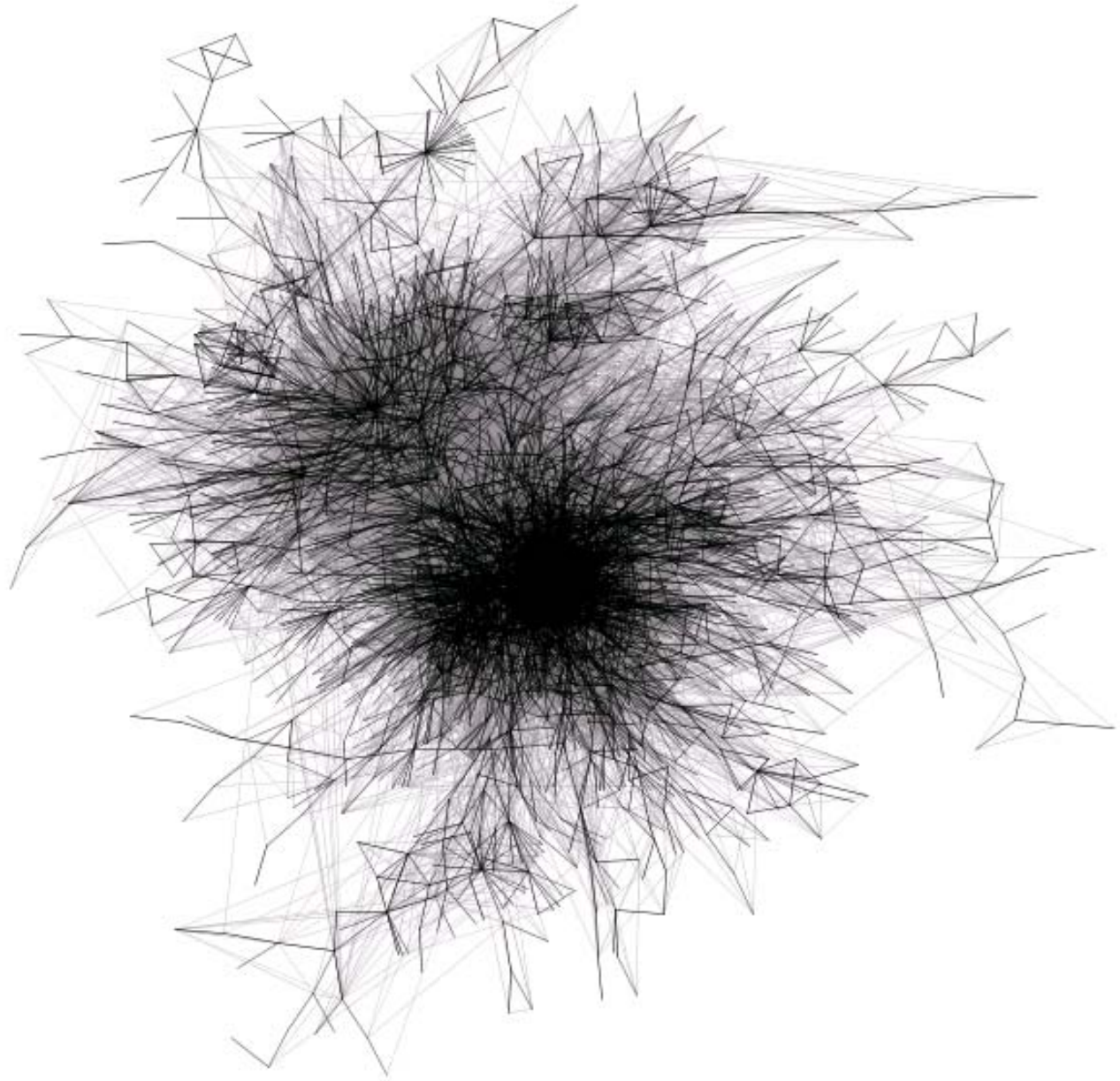


Schrödinger, E. (1944) *What Is Life? The Physical Aspect of the Living Cell*.
Dublin, Dublin Institute for Advanced Studies at Trinity College.

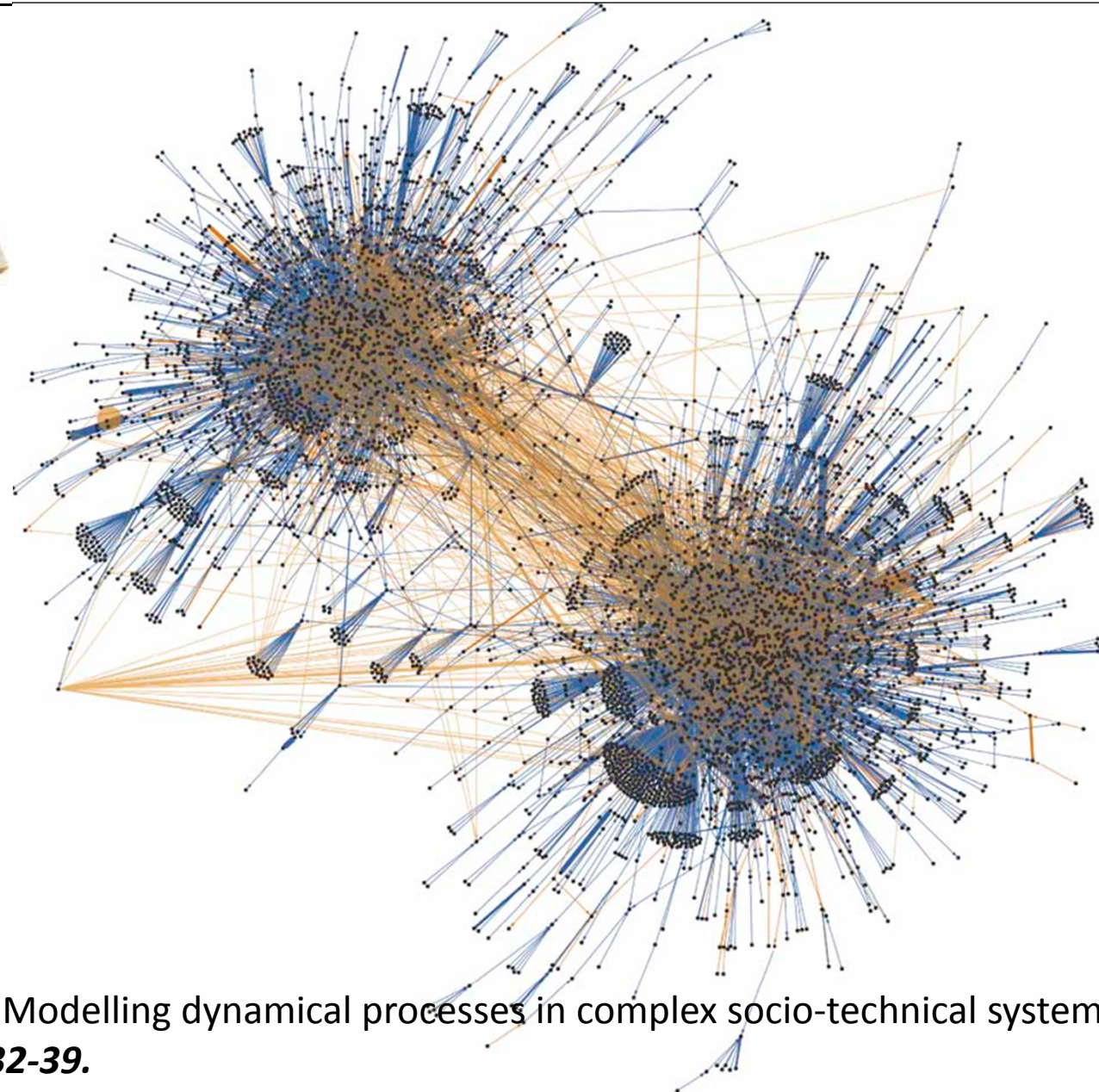
How do people interact?

**How do they find their
leaders?**

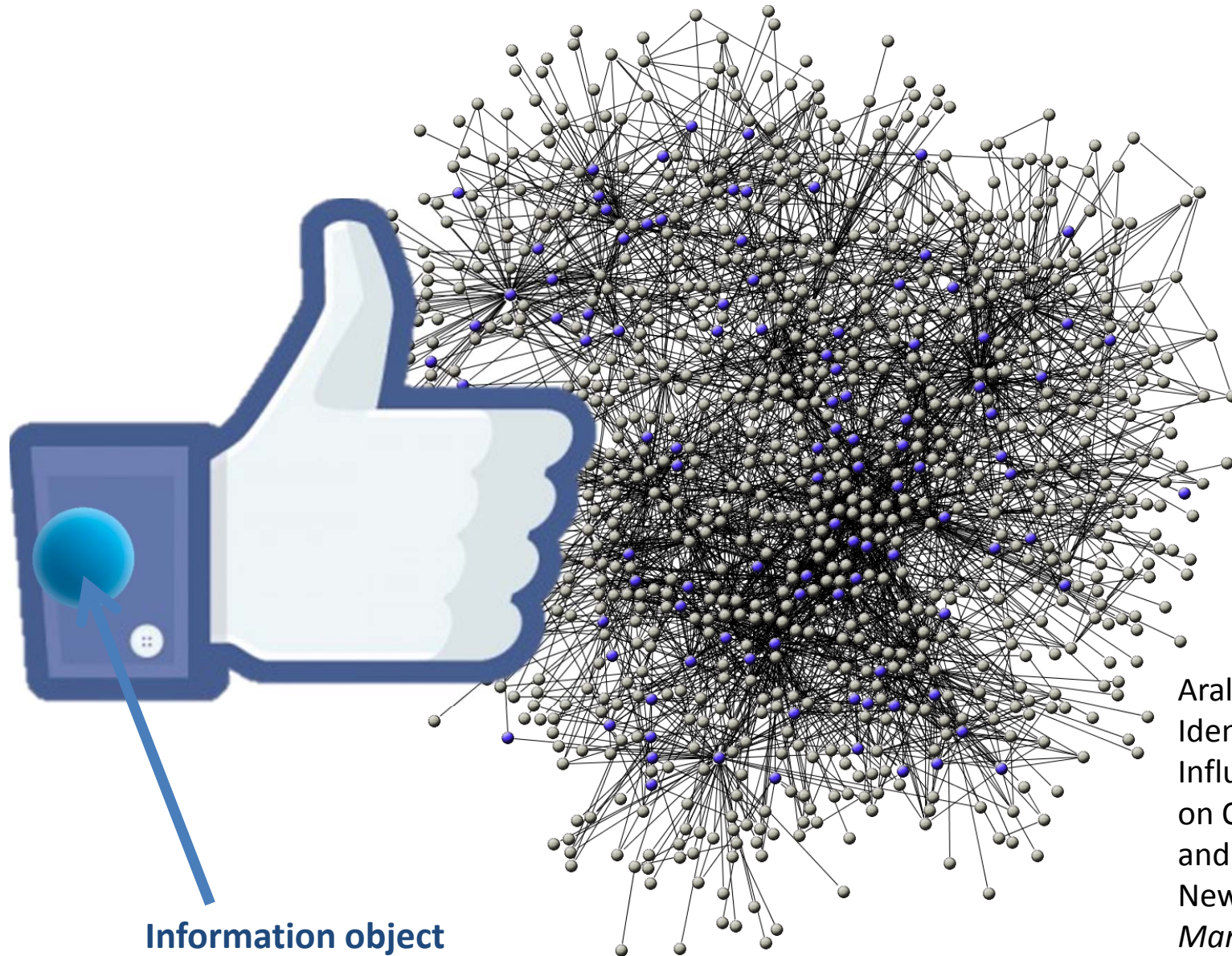
**How do groups get together
to solve a problem?**



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



Vespignani, A. (2012) Modelling dynamical processes in complex socio-technical systems. *Nature Physics*, 8, 1, 32-39.



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

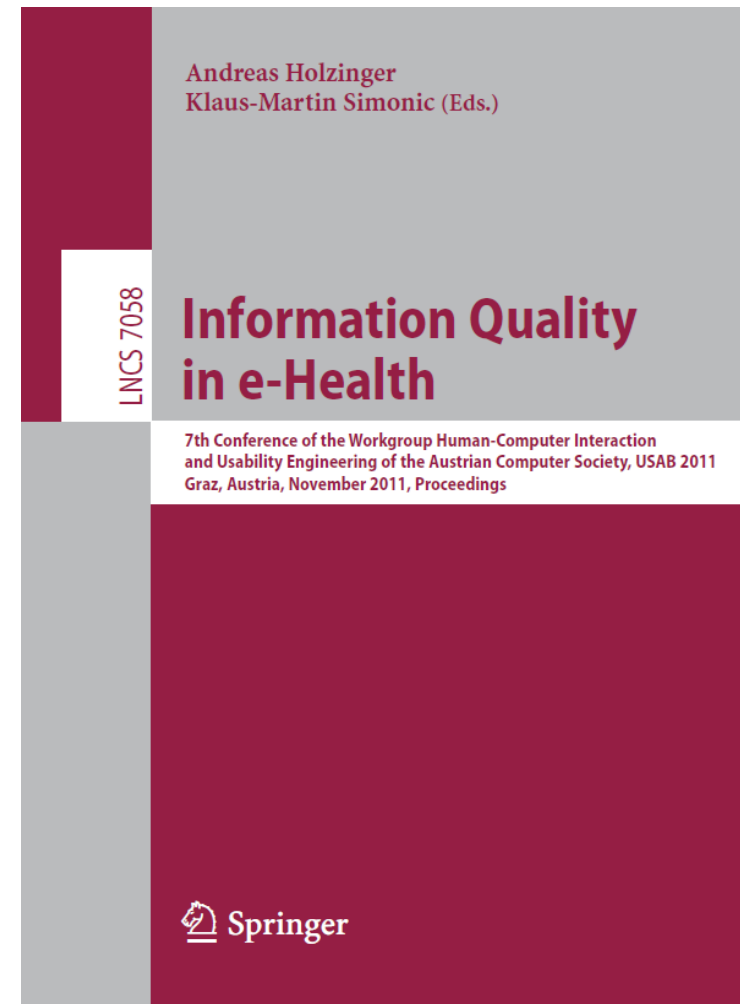
**Now, what is so specific
in the medical area?**



Our central hypothesis: Information bridges this gap

Simonic, K.-M. & Holzinger, A. (2010) Zur Bedeutung von Information in der Medizin. *OCG Journal*, 35, 1, 8.

Modern information
management can
bridge the hiatus theoreticus,
the gap between (scientific)
knowledge and its application



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

Knowledge Discovery

NoE Information
Clinical Routine Retrieval
Information Quality
Visualization Workflow
Security eHealth Perception
Pathways Patient Empowerment
Graz Accessibility
Safety Austria
Decision Making Education
Privacy

Now, what is so specific on medical data?

	Datum	Zeit	OE	Kurzbez.	VMA	Status	Klass.	erg. Bez.	Dokum...	Fall
2010018065	17.11.1953									
2010018065	13.01.2010			MKKARDIO MK KardioAmb						
Leistungen (KAL, RAD, Therap										
EKG (12 Ableitungen)	13.01.2010	08:00	MKKARDIO MK KardioAmb	DUSLTIMO	OK					2010018065
RR-Intervall-Untersuchung	13.01.2010	08:00	MKKARDIO MK KardioAmb	DUSLTIMO	OK					2010018065
Schrittmacherkontrolle	13.01.2010	08:00	MKKARDIO MK KardioAmb	DUSLTIMO	OK					2010018065
2010002197	04.01.2010			CK RAD TFC Transp						
Diagnosen Gesamt (3)										
2009494995	20.12.2009			MEDANGIO Med Angio						
Diagnosen Gesamt (14)										
Leistungen (KAL, RAD, Therap										
Becken-u. Beinarteriografie	22.12.2009	16:36	RKVIRADB RKVI Raum B	STANMELI	OK		PTA			2009494995
Laufbandergometrie	21.12.2009	08:30	MEDANGIO MK Angio Amb	BRANDR	OK					2009494995
Erstuntersuchung Status	21.12.2009	08:30	MEDANGIO MK Angio Amb	BRANDR	OK					2009494995
2009453621	17.11.2009			CKTXIMC CK TX IMC						
Diagnosen Gesamt (12)										
Leistungen (MEL) (2)										
Physioth. i.R.1 stat. Aufenth	23.11.2009	08:05	CKPHYSIO CK Physio	BEITWALT	OK					2009453621
Organbiop., Bildwandlerge	17.11.2009	08:12	CKTXOP CK TX OP	SCHWMICH	OK		Organbiopsie - Bildwandler			2009453621
Leistungen (KAL, RAD, Therap										
2009431136	29.10.2009			MKKARDIO MK KardioAmb						
Leistungen (KAL, RAD, Therap										
Schrittmacherkontrolle	29.10.2009	09:15	MKKARDIO MK KardioAmb	DUSLTIMO	OK					2009431136
RR-Intervall-Untersuchung	29.10.2009	09:15	MKKARDIO MK KardioAmb	DUSLTIMO	OK					2009431136
EKG (12 Ableitungen)	29.10.2009	09:15	MKKARDIO MK KardioAmb	DUSLTIMO	OK					2009431136
Fotodokumentation, Videoc	29.10.2009	09:15	MKKARDIO MK KardioAmb	DUSLTIMO	OK					2009431136
2009378733	16.09.2009			MKNEPHR MK NephroAmb						
Diagnosen Gesamt (8)										
Leistungen (KAL, RAD, Therap										
Blutdruck: Langzeit (24 Stun	17.09.2009	10:59	MKNEPHR MK NephroAmb	RUDRHELM	OK		ab			2009378733
Blutdruck: Langzeit (24 Stun	16.09.2009	12:02	MKNEPHR MK NephroAmb	RUDRHELM	OK		an			2009378733
2009187546	21.04.2009			CKGMIÜ CK GM IÜ						
Diagnosen Gesamt (5)										
Leistungen (KAL, RAD, Therap										
Fotodokumentation, Videoc	29.04.2009		MKKARDIO MK KardioAmb	PITTHEID	OK					2009187546
EKG (12 Ableitungen)	29.04.2009	08:49	MKKARDIO MK KardioAmb	PITTHEID	OK					2009187546
RR-Intervall-Untersuchung	29.04.2009	08:49	MKKARDIO MK KardioAmb	PITTHEID	OK					2009187546
Schrittmacherkontrolle	29.04.2009	08:49	MKKARDIO MK KardioAmb	PITTHEID	OK					2009187546
EKG (12 Ableitungen)	23.04.2009	10:43	MKKARDIO MK KardioAmb	KOBEINGR	OK					2009187546
RR-Intervall-Untersuchung	23.04.2009	10:43	MKKARDIO MK KardioAmb	KOBEINGR	OK					2009187546
Konsil FA	21.04.2009	10:22	NKKONS NK FA Konsil	LANNMICH	OK					2009187546

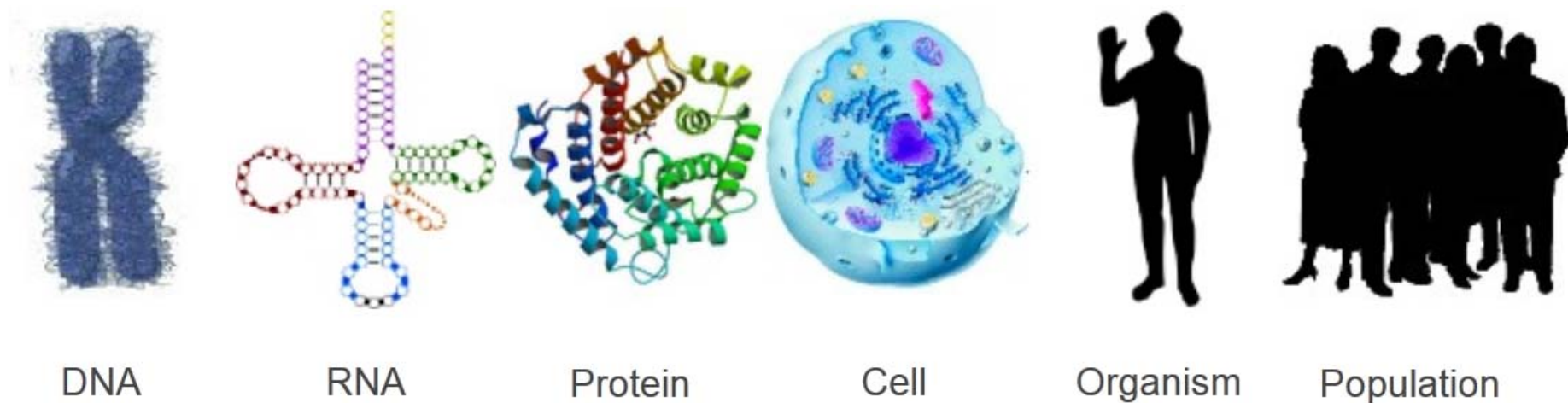
Amount

Level of Structure

Standardization

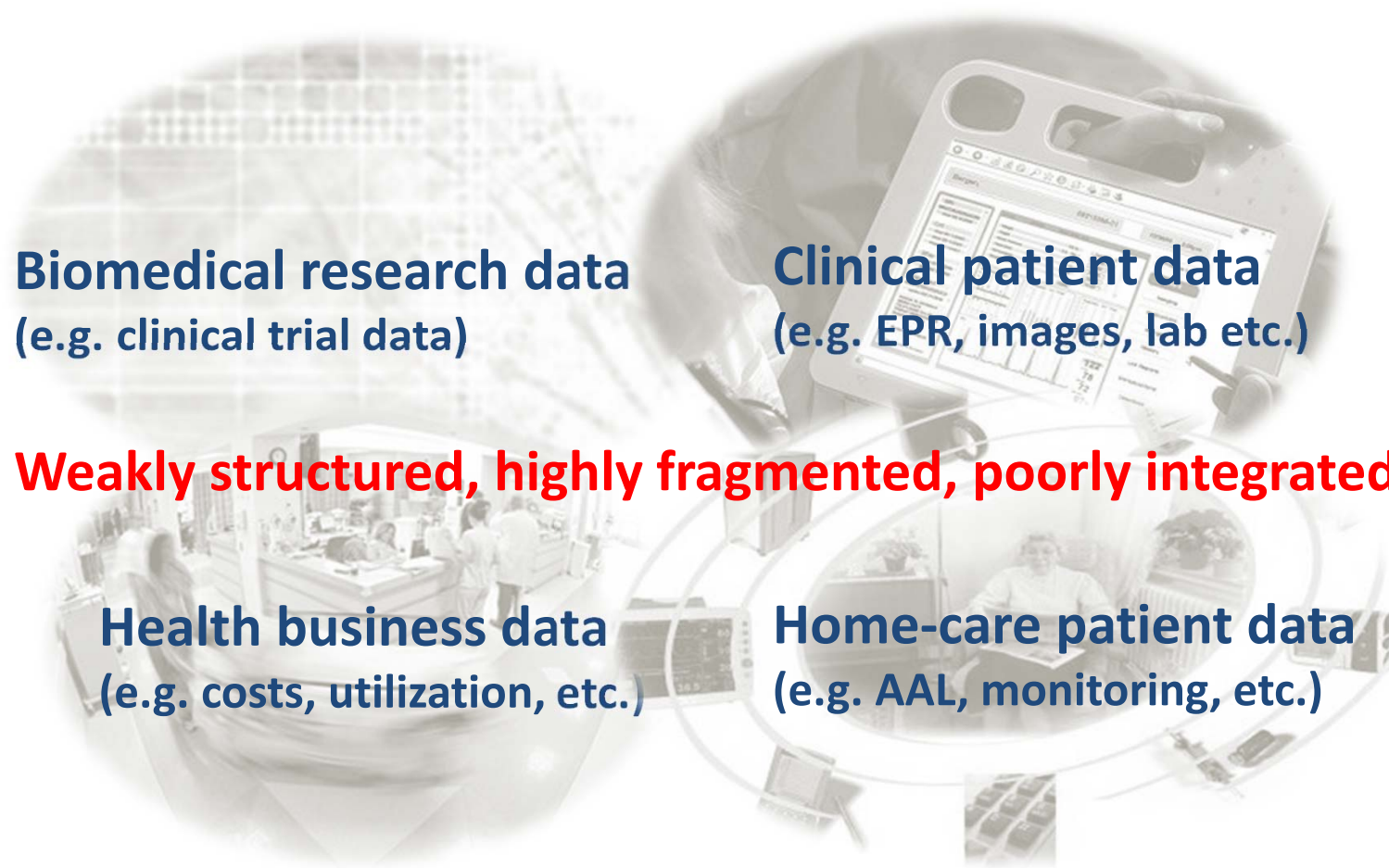
Complexity

Complex heterogeneous data in various structural dimensions



The behavior of a cell is the consequence of complex interactions between its numerous constituents, including DNA, RNA, proteins ...

<http://www.expasy.org/>



Biomedical research data
(e.g. clinical trial data)

Clinical patient data
(e.g. EPR, images, lab etc.)

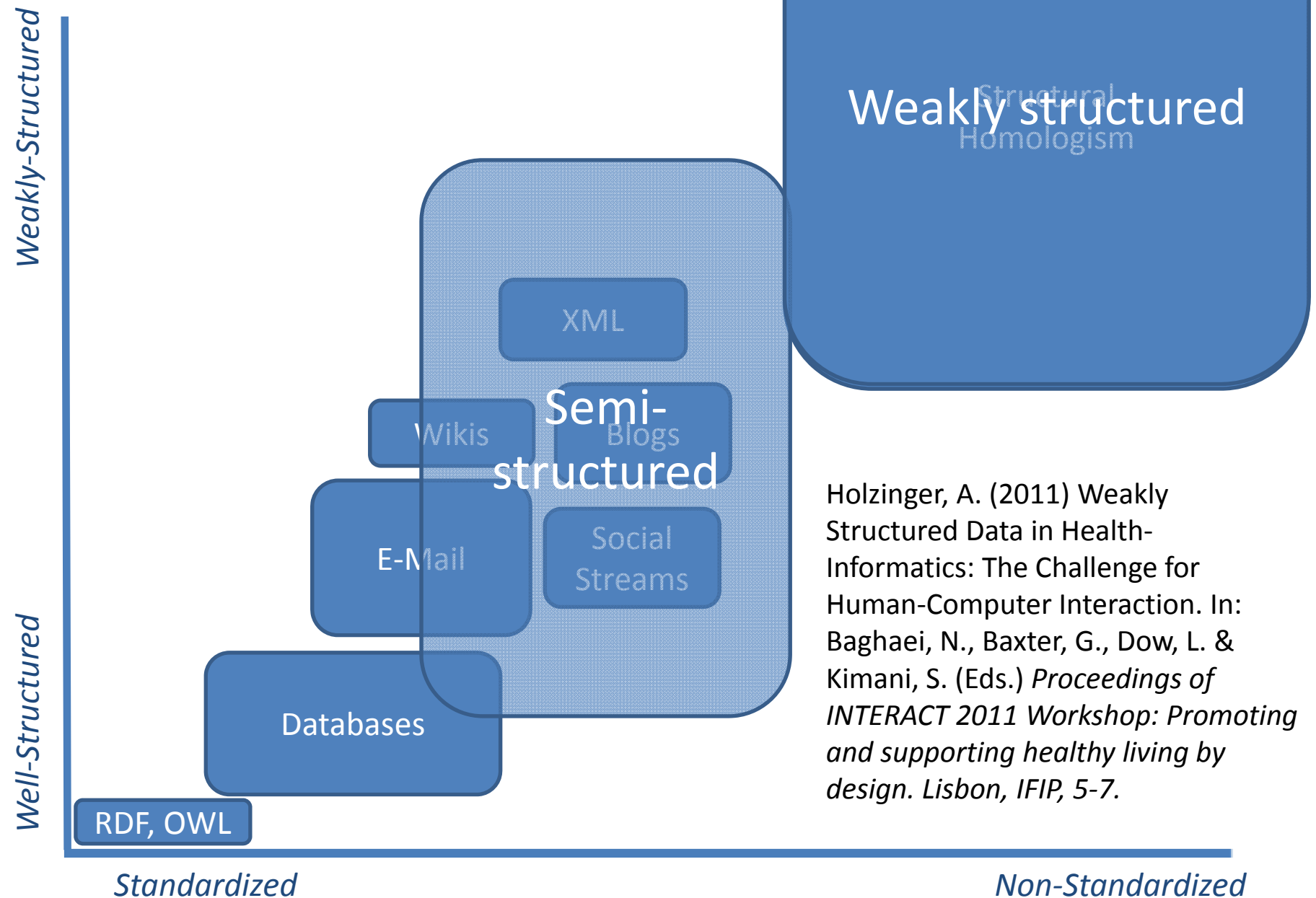
Weakly structured, highly fragmented, poorly integrated

Health business data
(e.g. costs, utilization, etc.)

Home-care patient data
(e.g. AAL, monitoring, etc.)

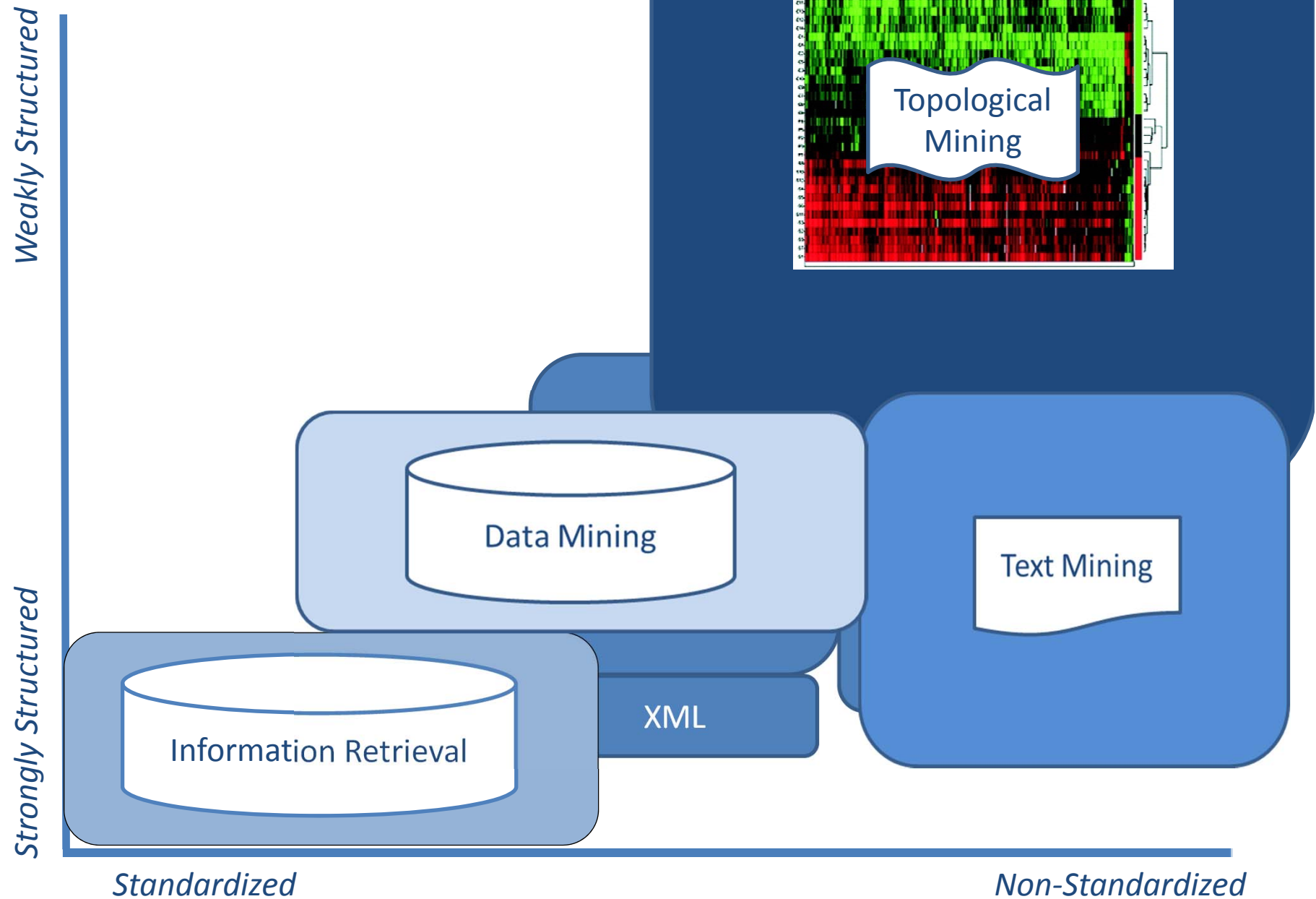
Manyika, J., Chui, M., Brown, B., Bughin, J., Dobbs, R., Roxburgh, C. & Byers, A. H. (2011) *Big data: The next frontier for innovation, competition, and productivity*. Washington (DC), McKinsey Global Institute.

Standardization vs. Structurization



Holzinger, A. (2011) Weakly Structured Data in Health-Informatics: The Challenge for Human-Computer Interaction. In: Baghaei, N., Baxter, G., Dow, L. & Kimani, S. (Eds.) *Proceedings of INTERACT 2011 Workshop: Promoting and supporting healthy living by design. Lisbon, IFIP, 5-7.*

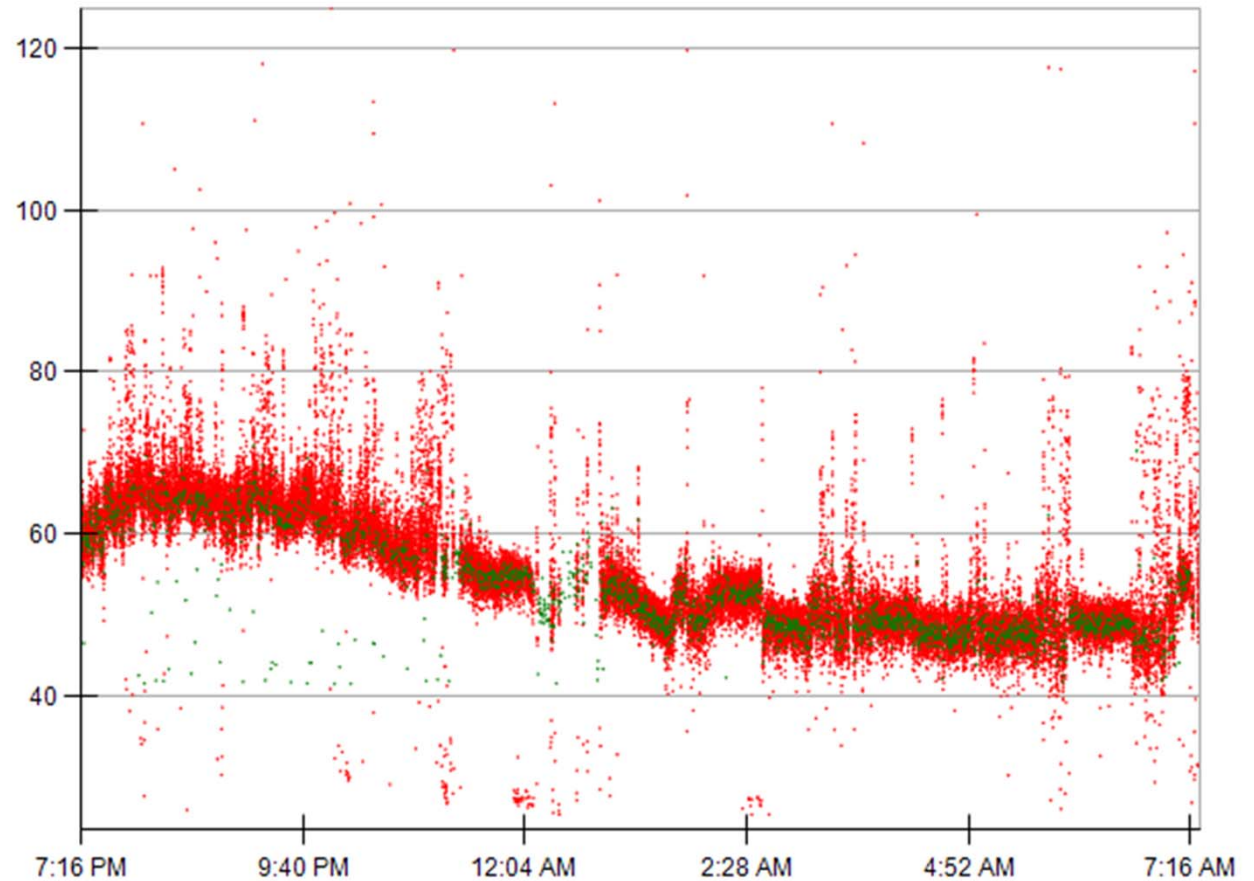
Methods for Mining ...



**Uncertainty
Incompleteness
Probable Information**



Example: Time Series Data



EU Project EMERGE (2007-2010)

Let: $\langle x_n \rangle = \{x_1, x_2, \dots, x_N\}$

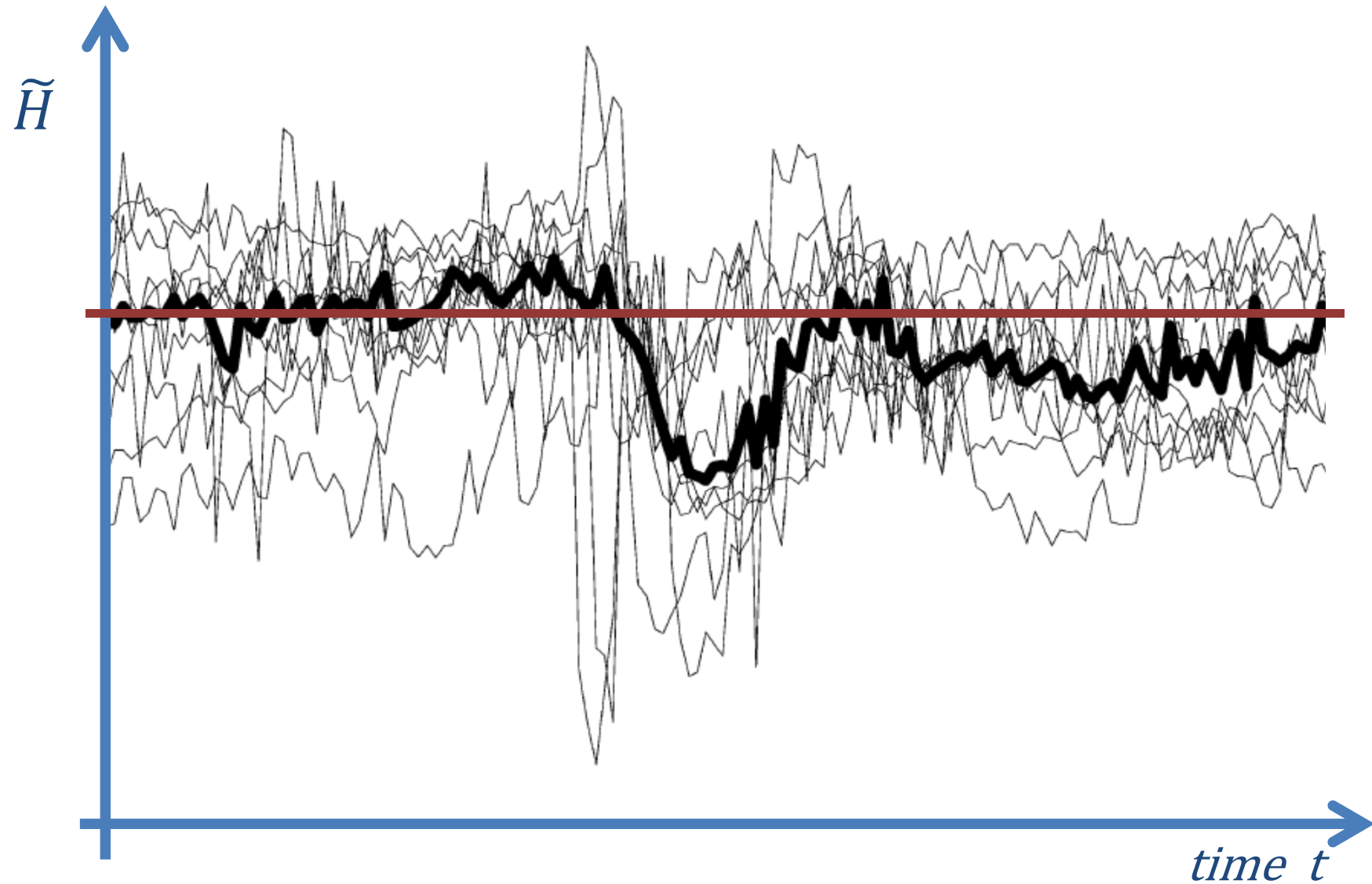
$$\vec{X}_i = (x_i, x_{(i+1)}, \dots, x_{(i+m-1)})$$

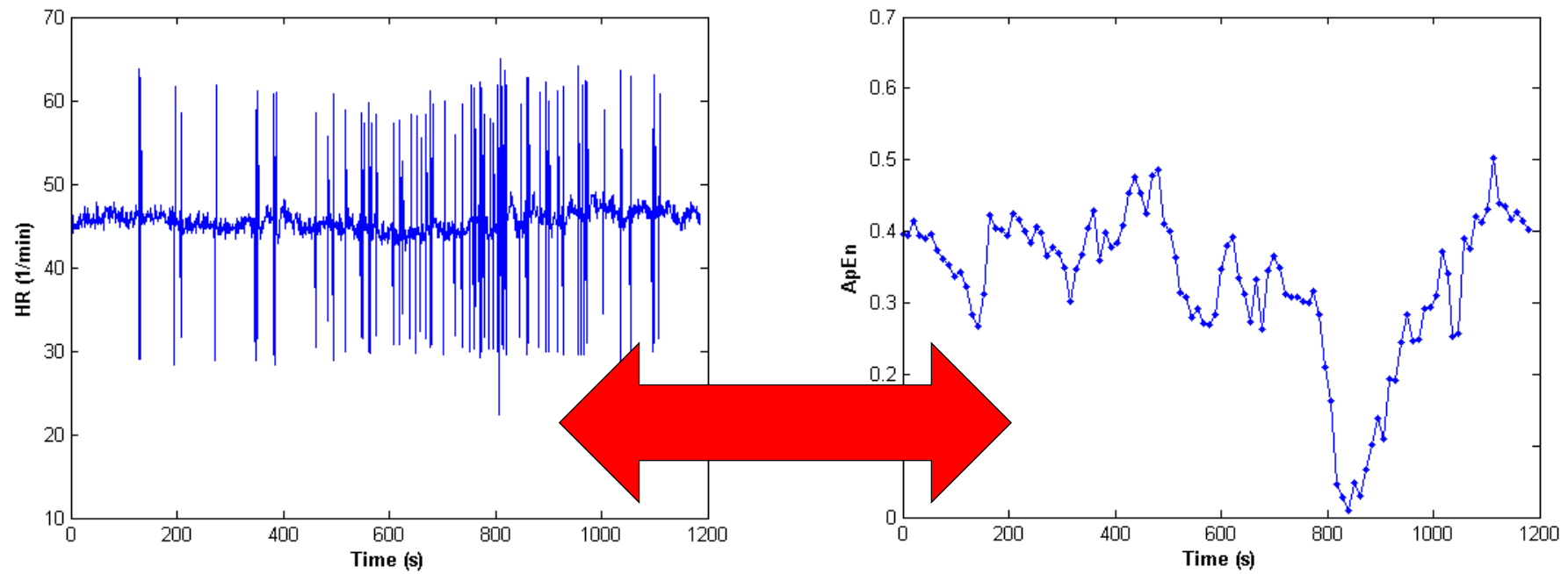
$$\|\vec{X}_i, \vec{X}_j\| = \max_{k=1,2,\dots,m} (|x_{(i+k-1)} - x_{(j+k-1)}|)$$

$$\tilde{H}(m, r) = \lim_{N \rightarrow \infty} [\phi^m(r) - \phi^{m+1}(r)]$$

$$C_r^m(i) = \frac{N^m(i)}{N - m + 1} \quad \phi^m(r) = \frac{1}{N - m + 1} \sum_{t=1}^{N-m+1} \ln C_r^m(i)$$

Pincus, S. M. (1991) Approximate Entropy as a measure of system complexity. *Proceedings of the National Academy of Sciences of the United States of America*, 88, 6, 2297-2301.





$\tilde{H}$...

- ... is robust against noise;
- ... can be applied to complex time series;
- ... is finite for stochastic, noisy, composite processes;
- ... values correspond directly to irregularities;

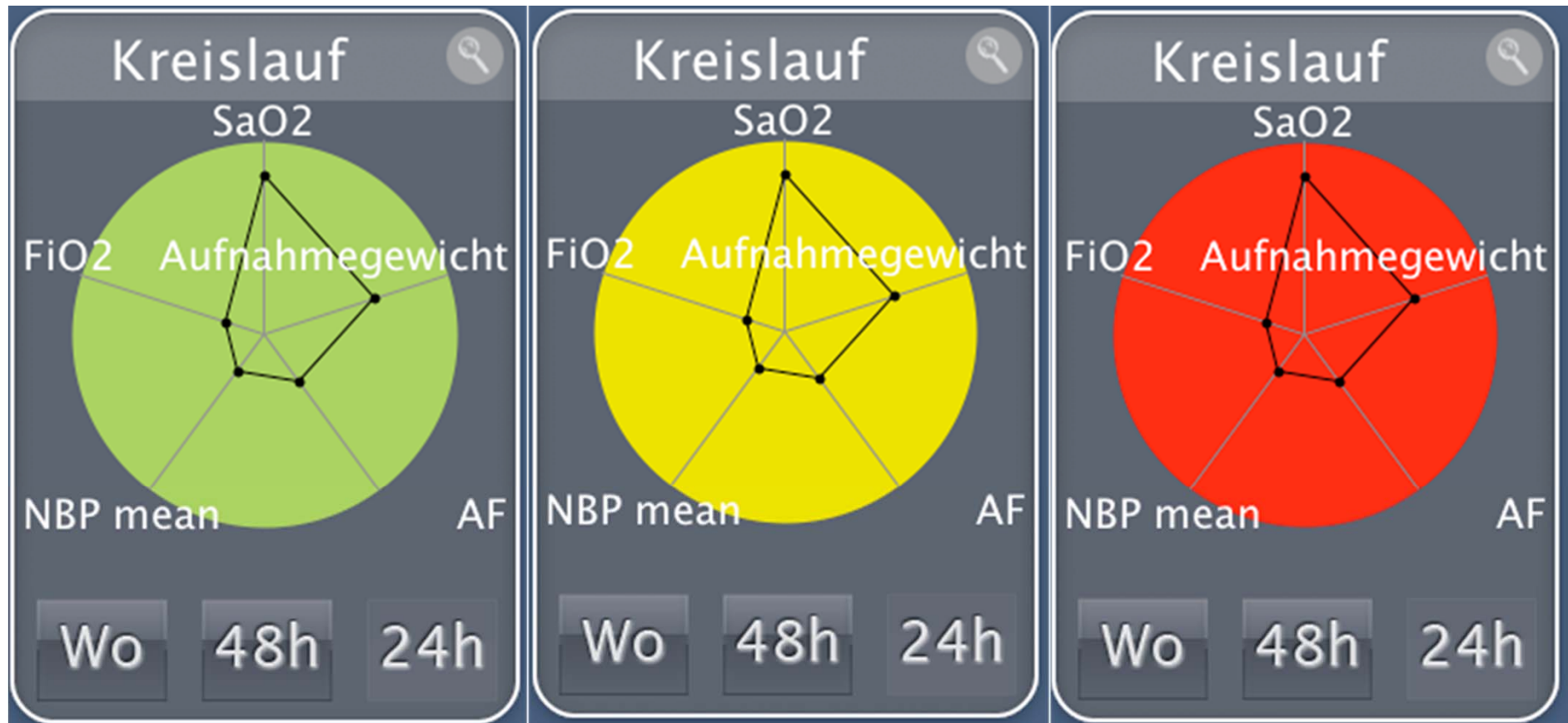
How can I use visual representations of abstract data to amplify the acquisition of knowledge?

X11 Applications Edit Window Help													
Krankenblatt Intensiv :													
Hauptmenü Aktionen Anzeige Bericht DATENEINGABE													
Zeit: 24 h Autom. Dokument. @15mi		21Mai05 0800	22Mai05 0800	23Mai05 0800	24Mai05 0800	25Mai05 0800	26Mai05 0800	27Mai05 0800	28Mai05 0800	29Mai05 0800	30Mai05 0800	31Mai05 0800	01Juni05 0800
Grafik Vital	A	ÄRZTLICHE VERORDNUNG											
	V	Tee Häufigkeit/Menge	1 * 8/ 1	* 8/ 1	* 8/ 1	* 8/ 1	* 8/ 1	* 8/ 1	* 8/ 1	* 8/ 1	* 8/ 1	* 8/ 1	* 8/ 1
Grafik Event	O	Nahrg.1: Verordnung	% * Preg5%	* Preg5%	* Preg5%	* Preg5%	* Preg5%	* Preg5%	* Preg5%	* Preg5%	* Preg5%	* Preg5%	* Preg5%
	R	Nahrung 1 Häufigk.	8 * 8	* 8	* 8	* 8	* 8	* 8	* 8	* 8	* 8	* 8	* 8
	S	Nahrung 1 Menge	0 * 3,0	* 4,0	* 6,0	* 8,0	* 10,0	* 10,0	* 12,0	* 15,0	* 18,0	* 20,0	* 24,0
Vital	P	PFLERGE											
	S	Sonde Ch.	0 * 4,0	* 4,0	* 4,0	* 4,0	* 4,0	* 5,0	* 5,0	* 5,0	* 5,0	* 5,0	* 5,0
	o	Sonde Lage/Marke	0 * Na 17,0	* Os 16,0	* Os 16,0	* Os 16,0	* Os 16,0	* Os 16,0	* Os 16,0	* Os 16,0	* Os 16,0	* Os 16,0	* Os 16,0
Visite	n	Sondierungsart	l * Manual	* Manual	* Manual	* Manual	* Manual	* Manual	* Manual	* Manual	* Manual	* Manual	* Manual
	d	ES-Wechsel:											
	e	Sondenprobe	v	* positiv	* positiv	* positiv	* positiv	* positiv	* positiv	* positiv	* positiv	* positiv	* positiv
Stat Labor	B	Glucose 33%		* 0,1									
	i	Nahrungsmenge	0 * 14,0	* 21,0	* 28,0	* 43,0	* 56,0	* 70,0	* 81,0	* 103,0	* 125,0	* 140,0	* 166,0
Respir	l	Nahrung pos (ml)			1,0								
Atmung	a	Nahrung pS (ml)	0 * 4,0	* 3,0	* 3,0	* 7,0	* 1,0	* 10,0	* 10,0	* 12,0	* 13,0	* 18,0	* 20,0
	n	Tee pS (ml)	0 * 1,0	* 1,0		* 1,0	* 1,0	* 1,0	* 11,0				
Medika	z	Trinkverhalten											
		Saugertyp											
	R	Restvolumen	S * nichts	* nichts	* nichts	* nichts	* nichts	* nichts	* nichts	* nichts	* nichts	* nichts	* nichts
Oral - Parent	V	Ma-Darm: RV	5 * 2,5	* 0,0	* 0,0	* 0,0							
		Enesis		* gespuck			* gespuck	* klein		* gespuck			
Bilanz	A	Bauch: Befund 1	l. * l.bläh	* gebläht	* l.bläh	* o.B.	* o.B.	* o.B.	* l.bläh	* o.B.	* l.bläh	* o.B.	* l.bläh
	b	Bauch: Befund 2	h * weich	* weich	* weich	* weich	* weich	* weich	* weich	* weich	* weich	* weich	* weich
	d	Bauch: Maßnahmen		* Spülung	* Massage	* Spülung	* Massage	* Massage	* Massage	* Massage	* Massage	* Massage	* Massage
Pflege	o	Massnahmen: Erfolg											
	S	Stuhl: Art	l	* Knollen		* normal	* normal	* Knollen	* normal		* normal	* normal	* normal
	t	Stuhl rectal: Menge	g	* genug		* genug	* wenig	* wenig	* wenig		* genug	* wenig	* genug
Kath/ Drains	u	Stuhl: Farbe	b	* grün		* braun	* grün						
	h	Stuhl: Konsistenz										* weich	* weich
	l	Haemocult	v	* positiv			* positiv						
Magen-Darm		letzter Stuhl am:	i	* 20 Mai	* 20 Mai	* 22 Mai	* 23 Mai	* 25 Mai	* 26 Mai	* 26 Mai	* 27 Mai	* 29 Mai	* 30 Mai
		letzter Stuhl um:	0	* 17/	* 17/	* 11/	* 5/	* 8/	* 5/	* 20/	* 20/	* 17/	* 23/
		Harn: Spontan	t	* Mtt	* Mtt	* Mtt	* 14,0	* Mtt	* Mtt	* Mtt	* Mtt	* Mtt	* Gr.
Hyg.													
Proben Aktion													
Tage													

Holzinger, A., Hoeller, M., Bloice, M. & Urlesberger, B. (2008). *Typical Problems with developing mobile applications for health care: Some lessons learned from developing user-centered mobile applications in a hospital environment.* ICE-B 2008, IEEE, 235-240.

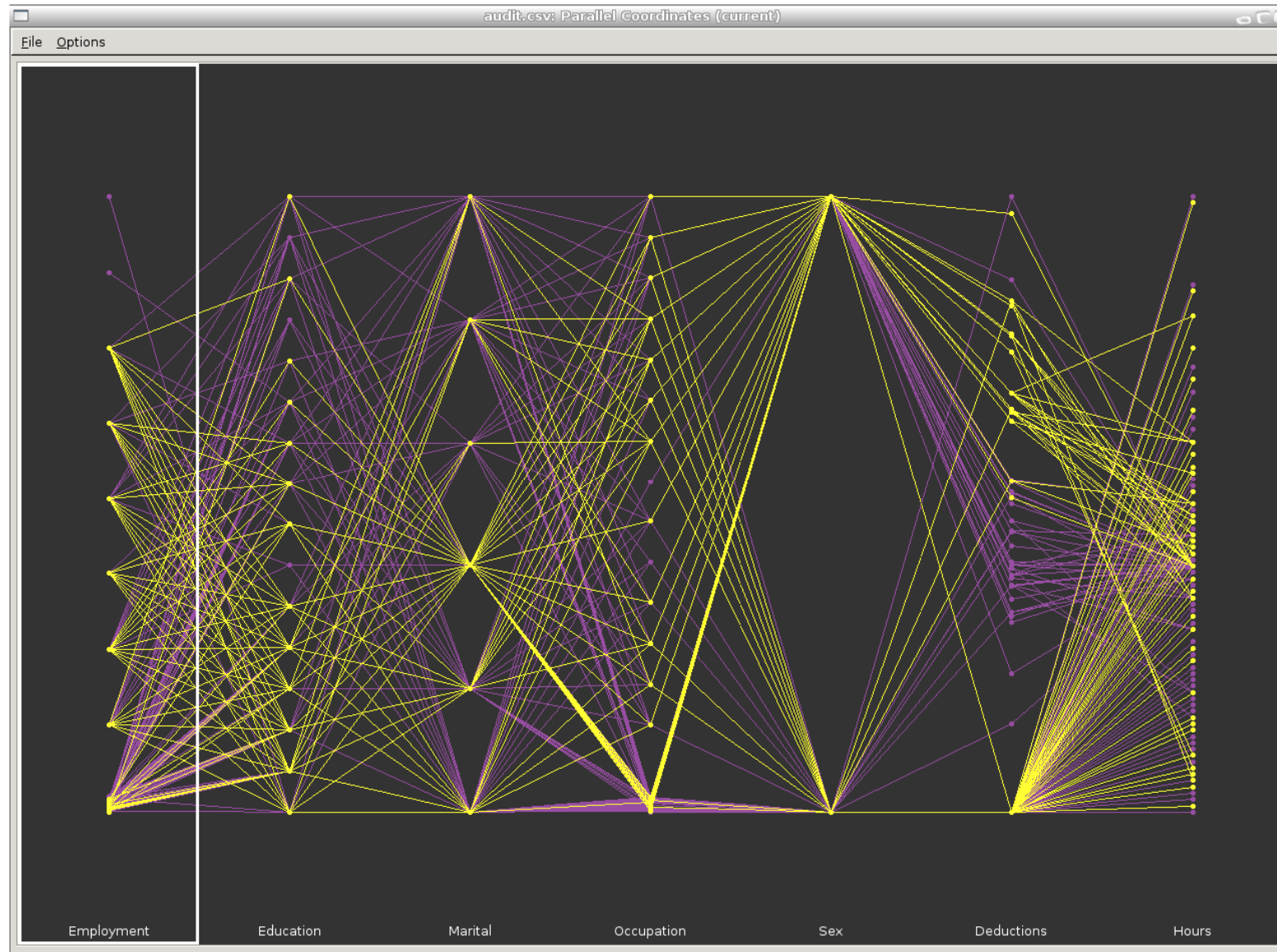
a.holzinger@hci4all.at

Rome, 2012



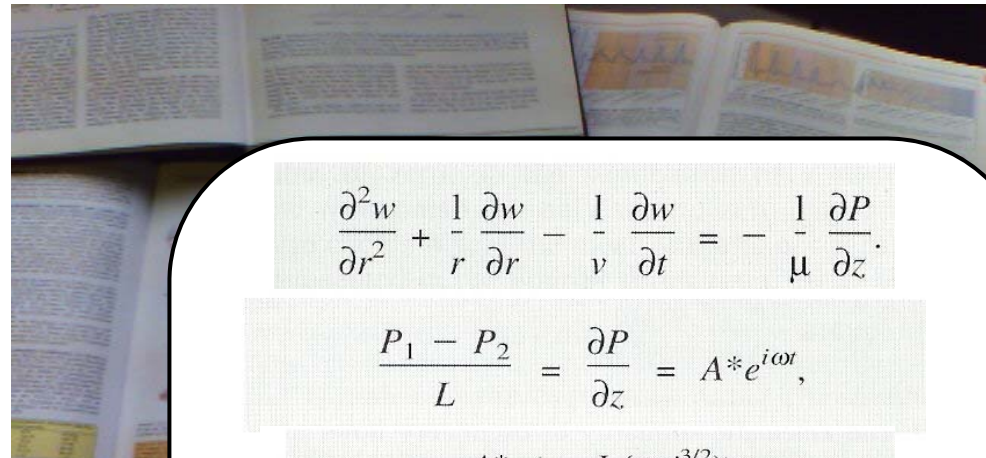
Holzinger, A., Hoeller, M., Bloice, M. & Urlesberger, B. (2008). *Typical Problems with developing mobile applications for health care: Some lessons learned from developing user-centered mobile applications in a hospital environment. ICE-B 2008, IEEE, 235-240.*

Example: Parallel Coordinates (Inselberg) in R



<http://datamining.togaware.com>

Example: Previous Knowledge of Medical Students ...



$$\frac{\partial^2 w}{\partial r^2} + \frac{1}{r} \frac{\partial w}{\partial r} - \frac{1}{v} \frac{\partial w}{\partial t} = - \frac{1}{\mu} \frac{\partial P}{\partial z}.$$

$$\frac{P_1 - P_2}{L} = \frac{\partial P}{\partial z} = A^* e^{i\omega t},$$

$$w = \frac{A^*}{i\omega\rho} \left(1 - \frac{J_0(\alpha y i^{3/2})}{J_0(\alpha i^{3/2})} \right) e^{i\omega t},$$

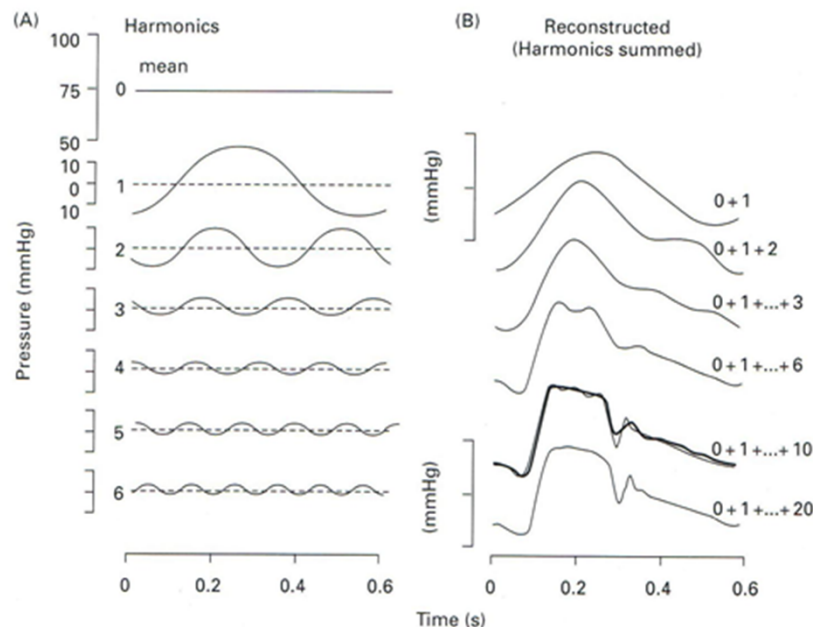
$$\alpha^2 = \frac{R^2 \omega \rho}{\mu} = \frac{R^2 \omega}{v}.$$

$$Q = \frac{\pi R^2 A^*}{i\omega\rho} \left(1 - \frac{2J_1(\alpha i^{3/2})}{\alpha i^{3/2} J_0(\alpha i^{3/2})} \right) e^{i\omega t},$$

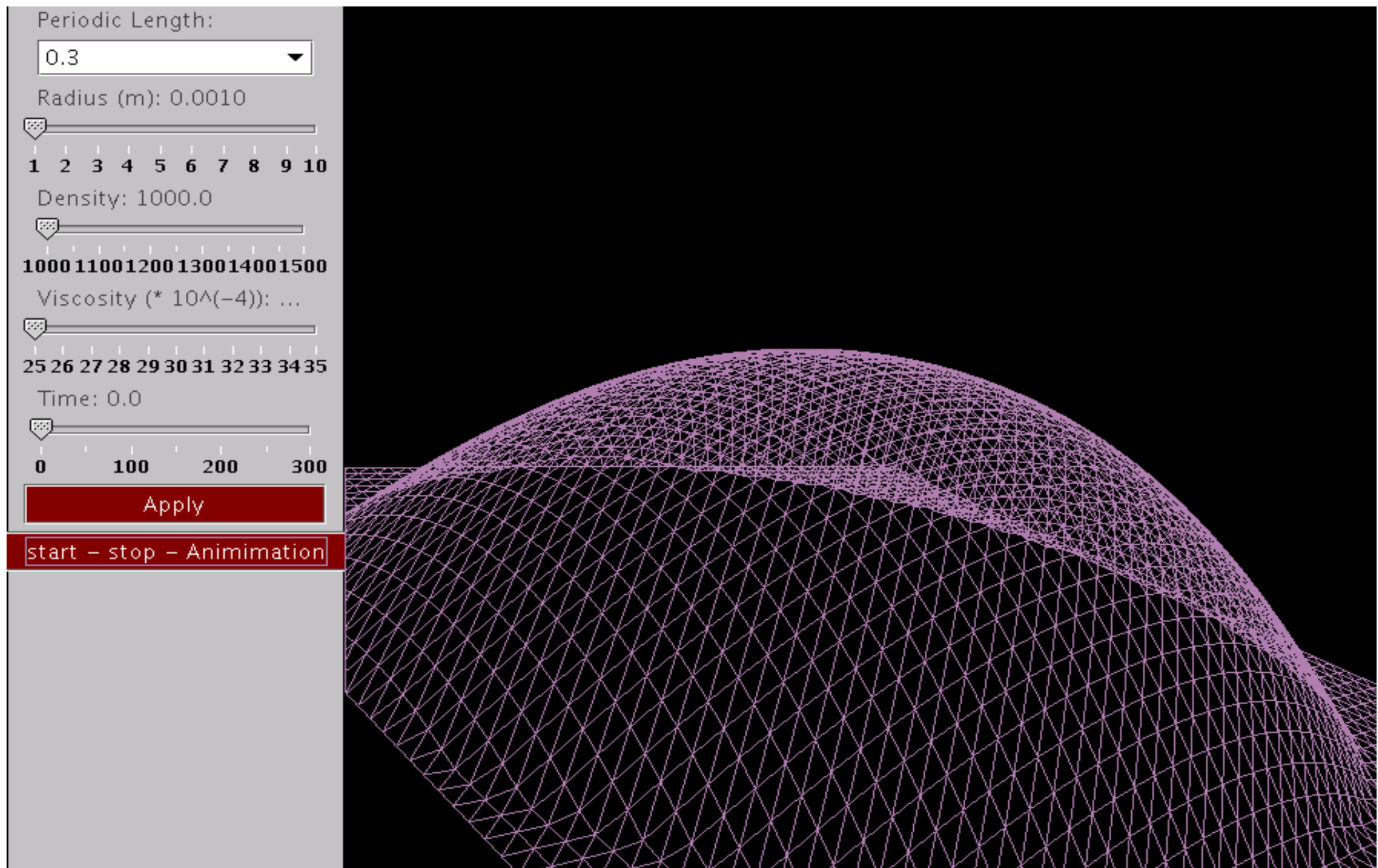
$$[1 - F_{10}] = M'_{10} e^{i\varepsilon_{10}}.$$

$$Q = \frac{\pi R^2}{\omega\rho} M M'_{10} \sin(\omega t - \phi + \varepsilon_{10}).$$

$$Q = \frac{\pi R^2}{\omega\rho} M [1 - F_{10}] \sin(\omega t - \phi)$$

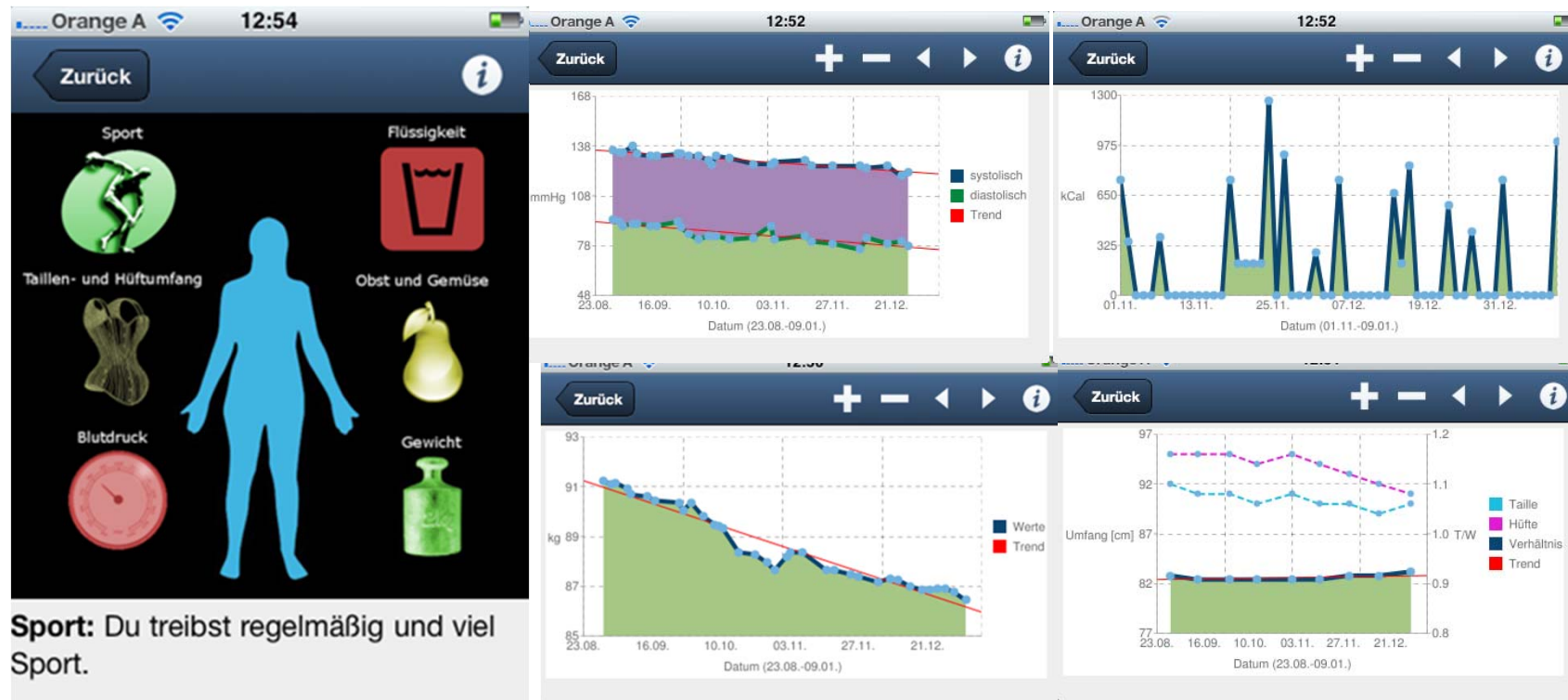


Holzinger, A., Kickmeier-Rust, M. D., Wassertheurer, S. & Hessinger, M. (2009) Learning performance with interactive simulations in medical education: Lessons learned from results of learning complex physiological models with the HAEMOdynamics SIMulator. *Computers & Education*, 52, 2, 292-301.

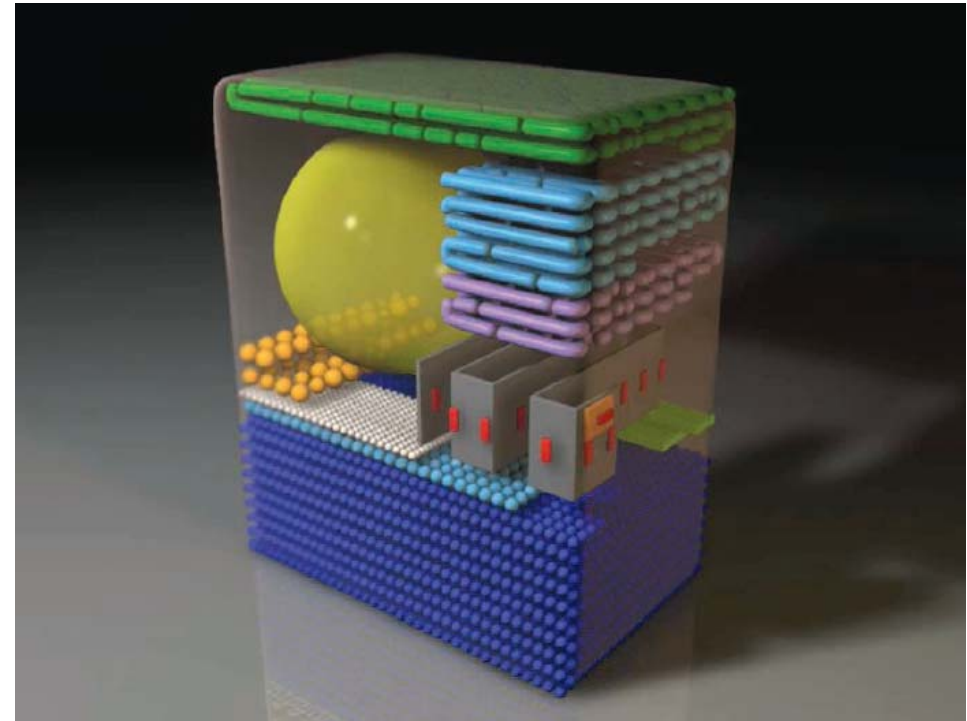
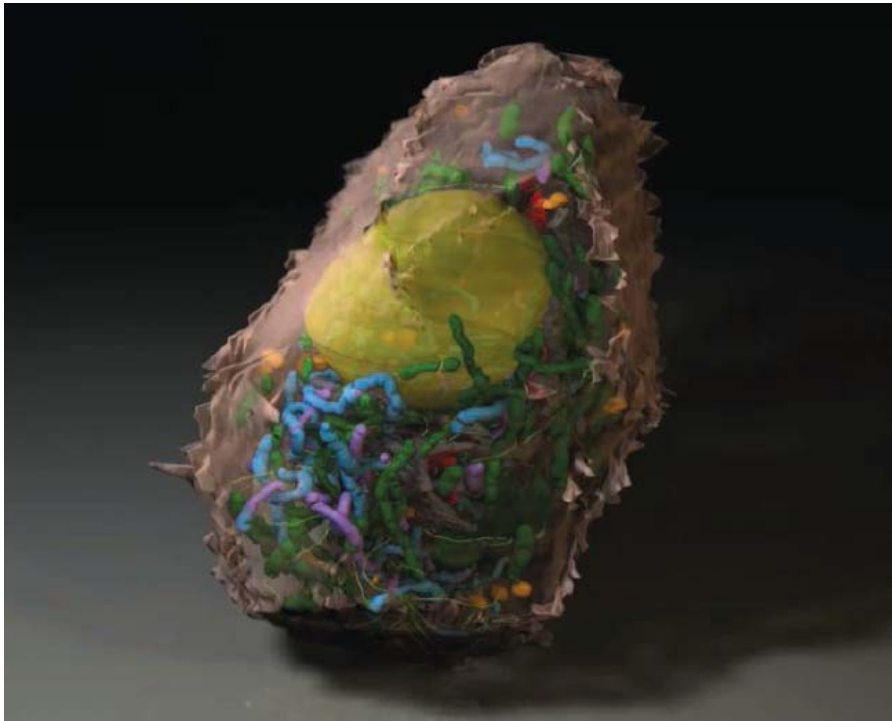


Holzinger, A., Kickmeier-Rust, M. D., Wassertheurer, S. & Hessinger, M. (2009) Learning performance with interactive simulations in medical education: Lessons learned from results of learning complex physiological models with the HAEMOdynamics SIMulator. *Computers & Education*, 52, 2, 292-301.

Data for health use ...



Holzinger, A., Dorner, S., Födinger, M., Valdez, A. C. & Ziefle, M. (2010) Chances of Increasing Youth Health Awareness through Mobile Wellness Applications. In: *Lecture Notes in Computer Science LNCS 6389. Berlin, Heidelberg, Springer, 71-81.*



- Green = mitochondria
- Dark Blue = mature insulin granules
- Light Blue = immature insulin granules
- Yellow = nucleus

Johnson, G. (2012) Rapid Visual Inventory & Comparison of Complex 3D Structures. *Science*, 335, 6068, 534-535. **February, 3, 2012**

Recent Example of Game Based Science Learning

Rank: 317 **Score: 2534**

Soloist Beginner Puzzle 8 (<150): Fruit Fly

► No conditions

Group Competition

#	Group Name	Score
1	Rice Biochemistry	9174
2	Team Commonwealth	9168
3	Ukraine	9088
4	Team Canada	9085
5	Firebird BioChem	9073
6	SETI.Germany	9030
7	Boinc.be	9001

Soloist Competition

#	Player Name	Current	Best
1	Mike Crunching for Physics	-	9242
2	weitzel	-	9235
3	ys719	-	9222
4	jmarkic	-	9211
5	kevin_karplus	-	9186
6	JINXter	-	9185
7	eb.eric	-	9183

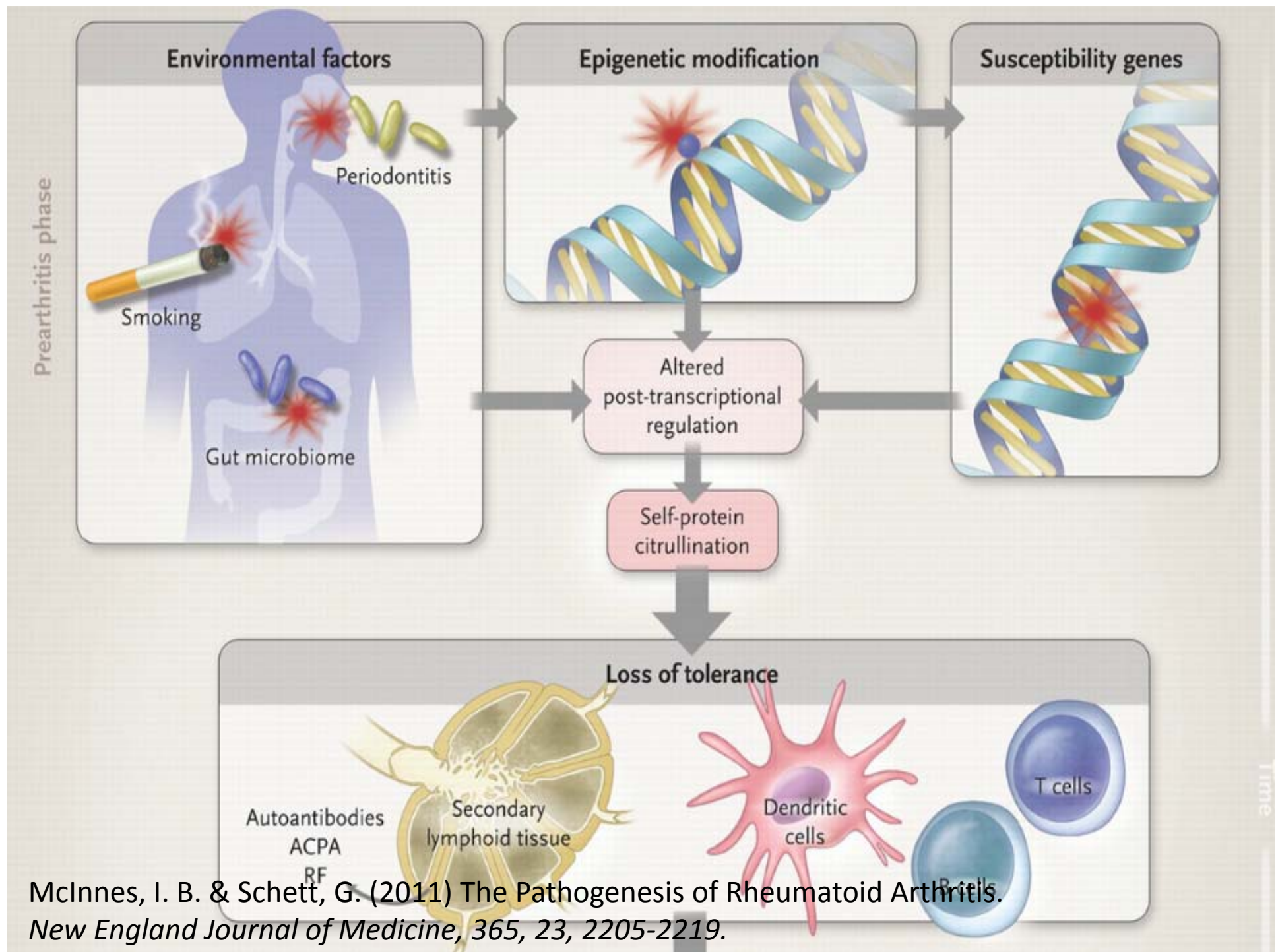
Actions: Shake Sidechains, Wiggle All, Wiggle Backbone, Wiggle Sidechains, Freeze Protein, Remove Bands, Disable Bands, Align Guide, Reset Structures, Reset Puzzle, Help, Glossary

Chat: Chat - Group, Chat - Puzzle, Chat - Global, Notifications

Cooper, S. et al.(2010) Predicting protein structures with a multiplayer online game. *Nature*, 466, 7307, 756-760.

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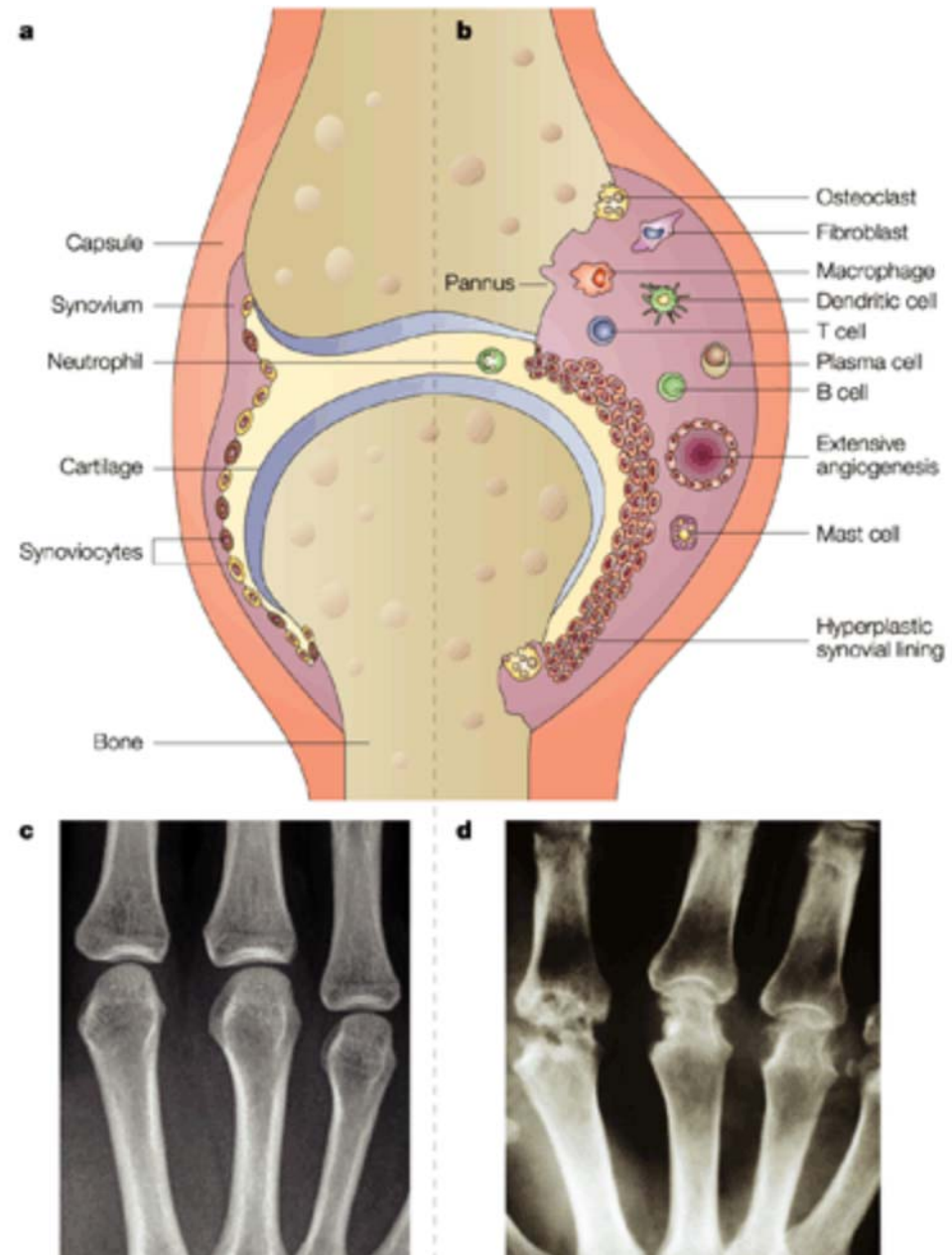


McInnes, I. B. & Schett, G. (2011) The Pathogenesis of Rheumatoid Arthritis. *New England Journal of Medicine*, 365, 23, 2205-2219.



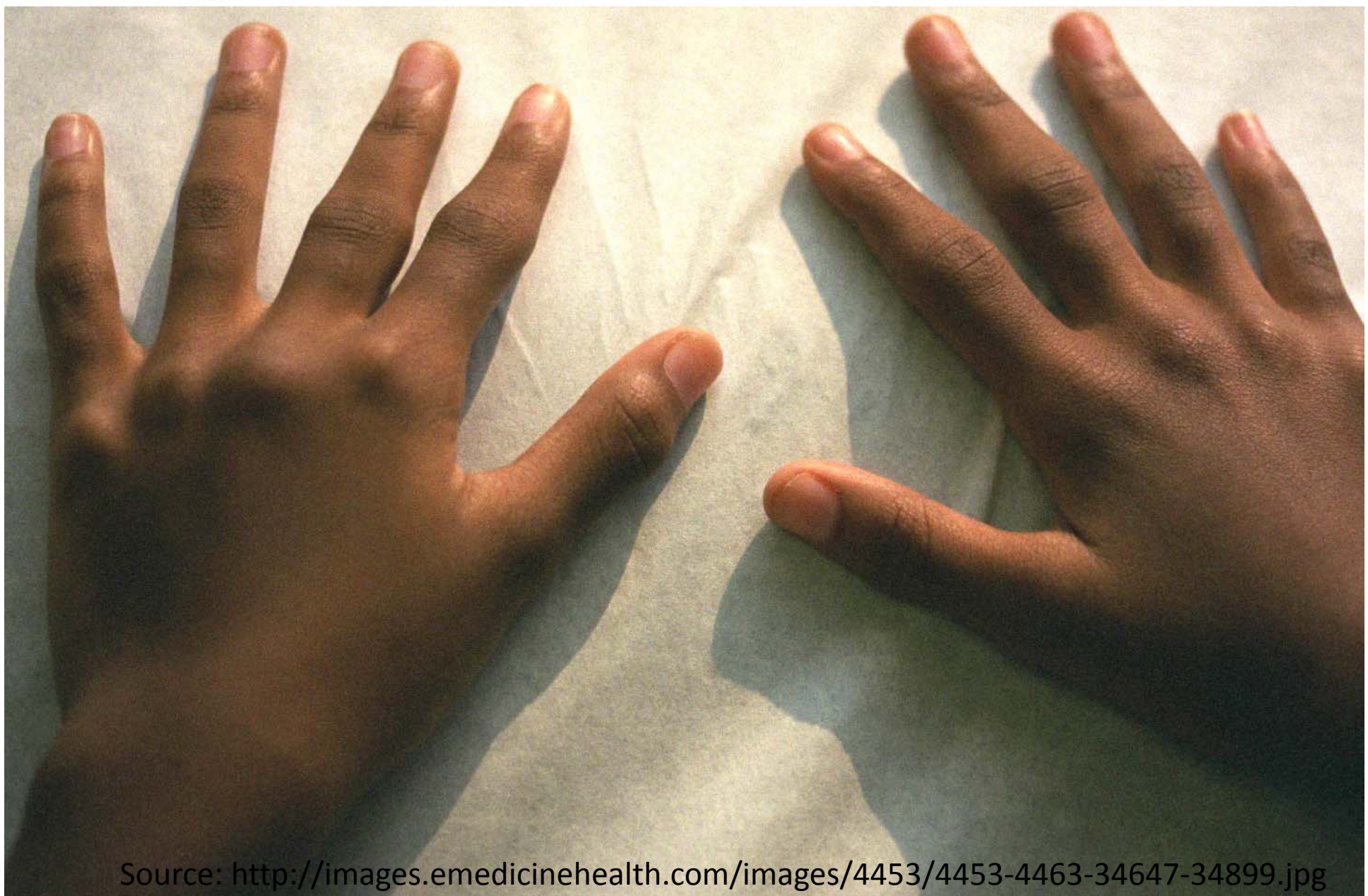
Chao, J., Parker, B. A. & Zvaifler, N. J. (2009) Accelerated Cutaneous Nodulosis Associated with Aromatase Inhibitor Therapy in a Patient with Rheumatoid Arthritis. *The Journal of Rheumatology*, 36, 5, **1087-1088**.

Destroys the joints ... medication can only slow down



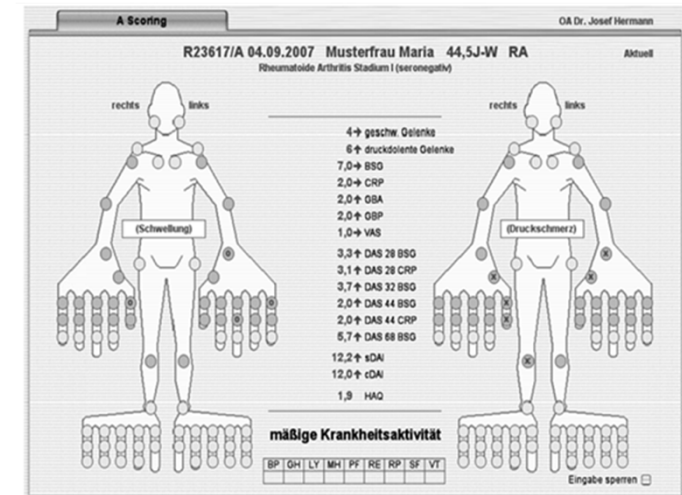
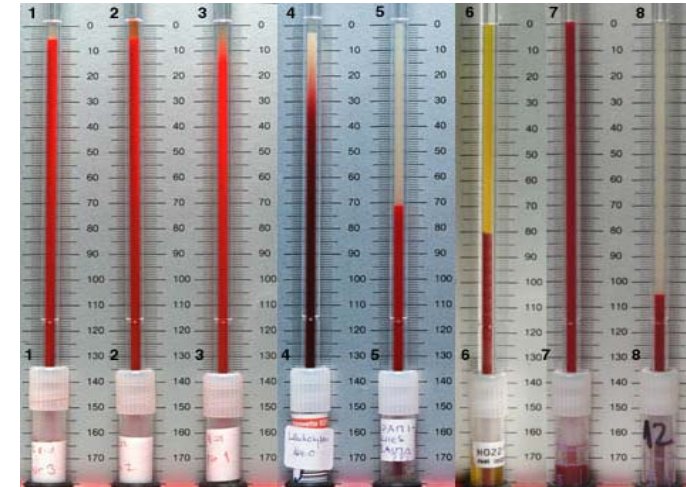
Smolen, J. S. & Steiner, G.
(2003) Therapeutic strategies
for rheumatoid arthritis.
Nature Reviews Drug Discovery,
2, 6, 473-488.

Even young people are affected ...



Source: <http://images.emedicinehealth.com/images/4453/4453-4463-34647-34899.jpg>

- 50+ Patients per day ~ 5000 data points per day ...
- Aggregated with specific scores (Disease Activity Score, DAS)
- Current patient status is related to previous data
- = convolution over time
- **⇒ time-series data**



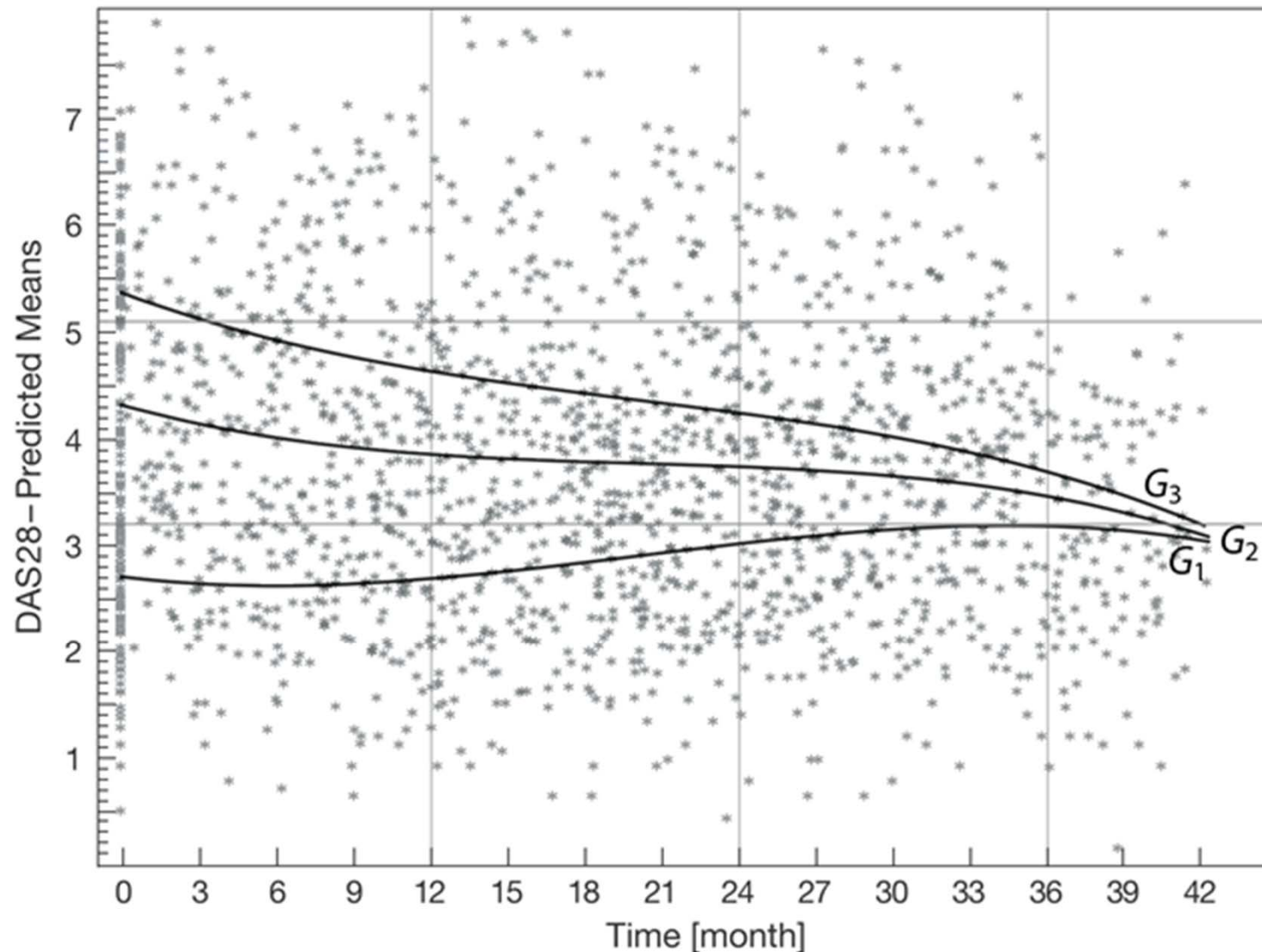
Simonic, K. M., Holzinger, A., Bloice, M. & Hermann, J. (2011). *Optimizing Long-Term Treatment of Rheumatoid Arthritis with Systematic Documentation. Pervasive Health - 5th International Conference on Pervasive Computing Technologies for Healthcare, Dublin, IEEE, 550-554.*

Let the observation times for subject i be $t_{i1}, t_{i2}, \dots, t_{i,n_i}$

$$y_i = X_i \beta + Z_i \gamma_i + \varepsilon_i$$

- X, Z ... corresponding design matrices
- Vector β ... Parameters which are shared by all people = general = fixed population effects
- Vector γ ... Parameters which are subject specific = individual = random effects

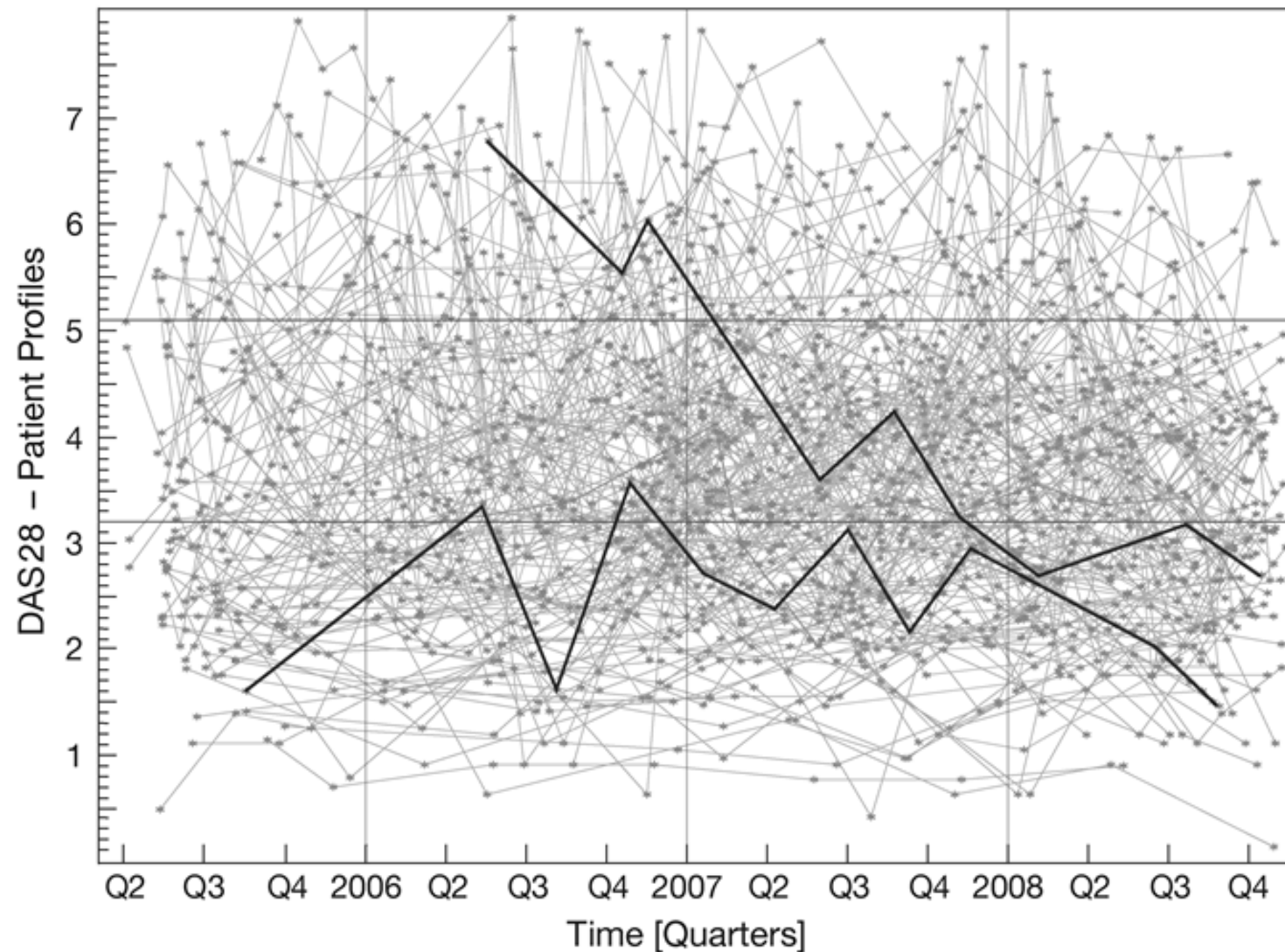
Simonic, K. M., Holzinger, A., Bloice, M. & Hermann, J. (2011). *Optimizing Long-Term Treatment of Rheumatoid Arthritis with Systematic Documentation. Pervasive Health - 5th International Conference on Pervasive Computing Technologies for Healthcare, Dublin, IEEE, 550-554.*



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Rome, 2012



Simonic, K. M., Holzinger, A., Bloice, M. D. & Hermann, J. (2012) A clinical information system to improve the outcome of Rheumatoid Arthritis treatment. *Journal of Health Informatics*, in print.



Our central hypothesis: Information bridges this gap

Simonic, K.-M. & Holzinger, A. (2010) Zur Bedeutung von Information in der Medizin. *OCG Journal*, 35, 1, 8.



See you in Vienna 2014

