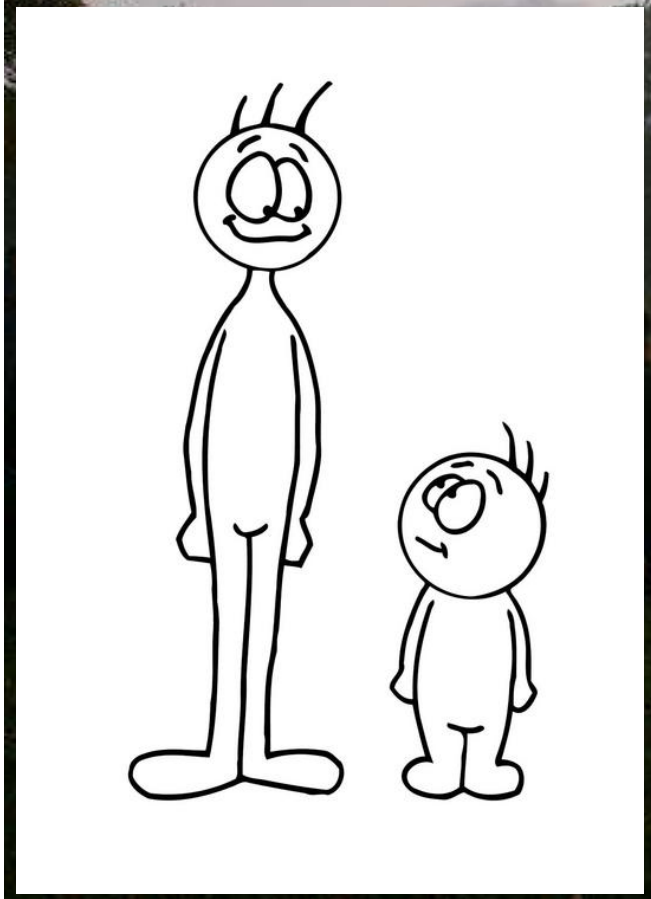
Where size matters…

Schönenberger group www.nanoelectronics.ch



Christian Schönenberger
Dep. für Physik & Swiss Nanoscience Institute
Universität Basel

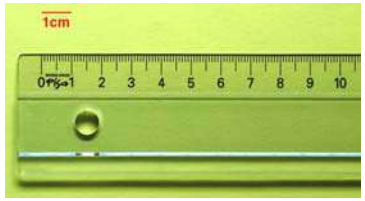
Where size matters…

ipod **Nano**, introduced by Apple in 2005

→ why was it called **"Nano"** ?

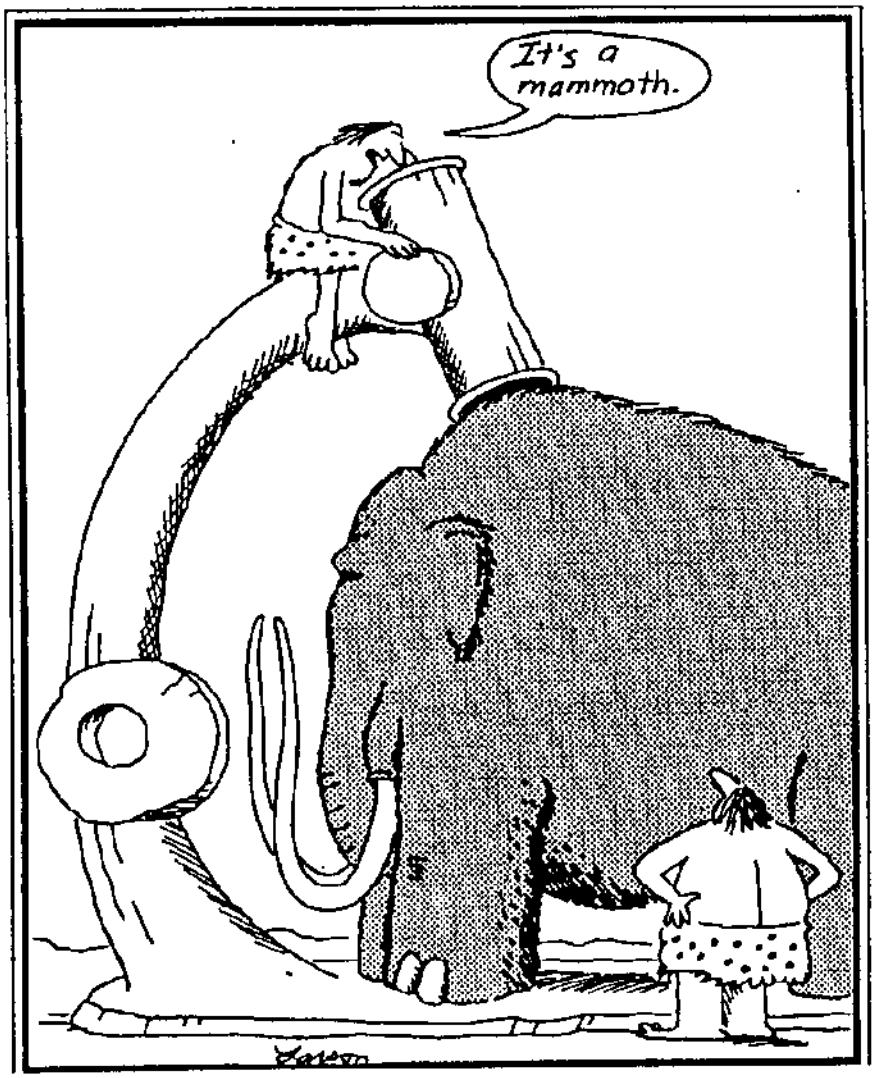
What is nano ?

Nanometer (a length scale)



„Nano“ (νανος**)**

- One **nanometer** is a **billions of a meter, a millions of a millimeter**
- It is about five times the size of an atom
- A **hundred-thousand times** smaller than a human hair



Early microscope

What is nano ?

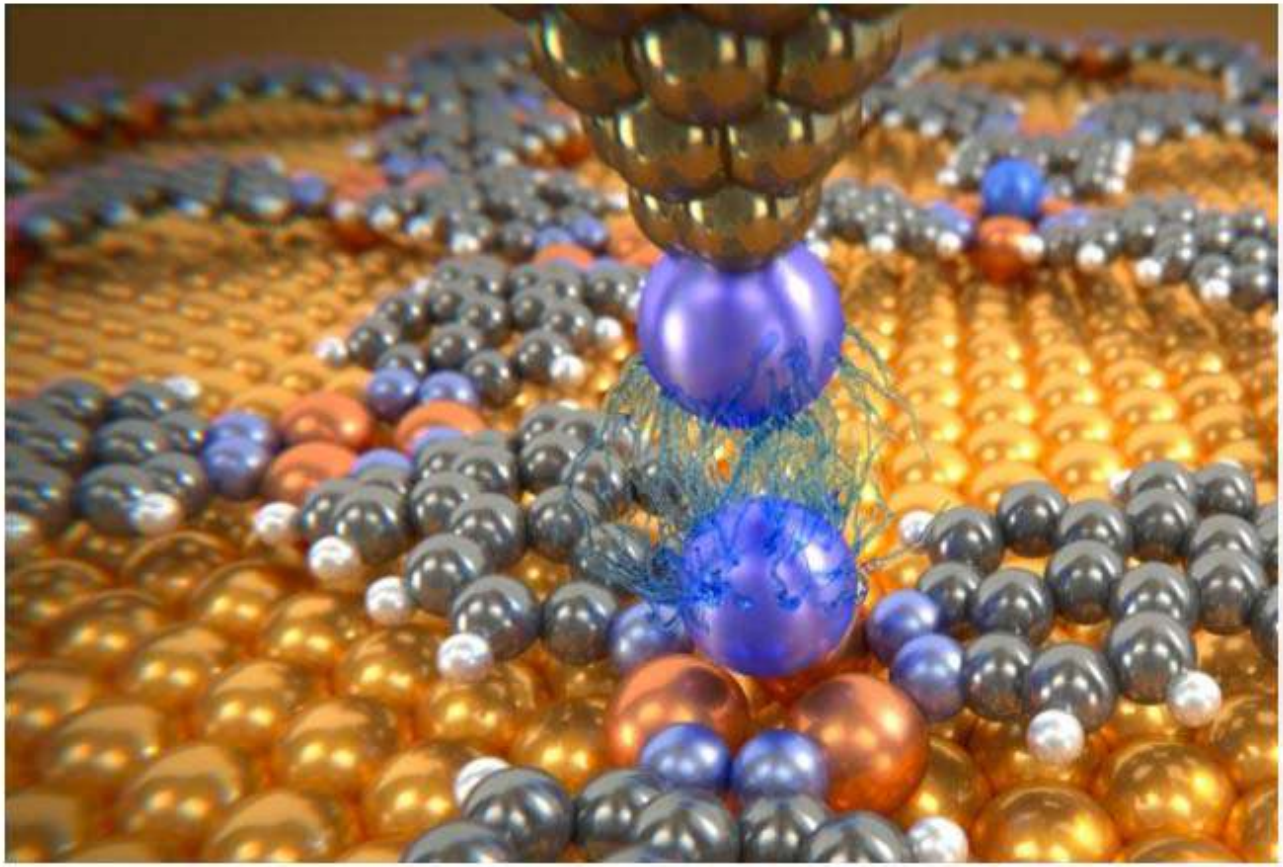
Schönenberger group www.nanoelectronics.ch

University of Basel

Swiss Nanoscience Institute

SNI SWISS NANOSCIENCE INSTITUTE
EINE INITIATIVE DER UNIVERSITÄT BASEL UND DES KANTONS AARGAU

News & Events | Research | Techtransfer | About Us | Study | Services | Media

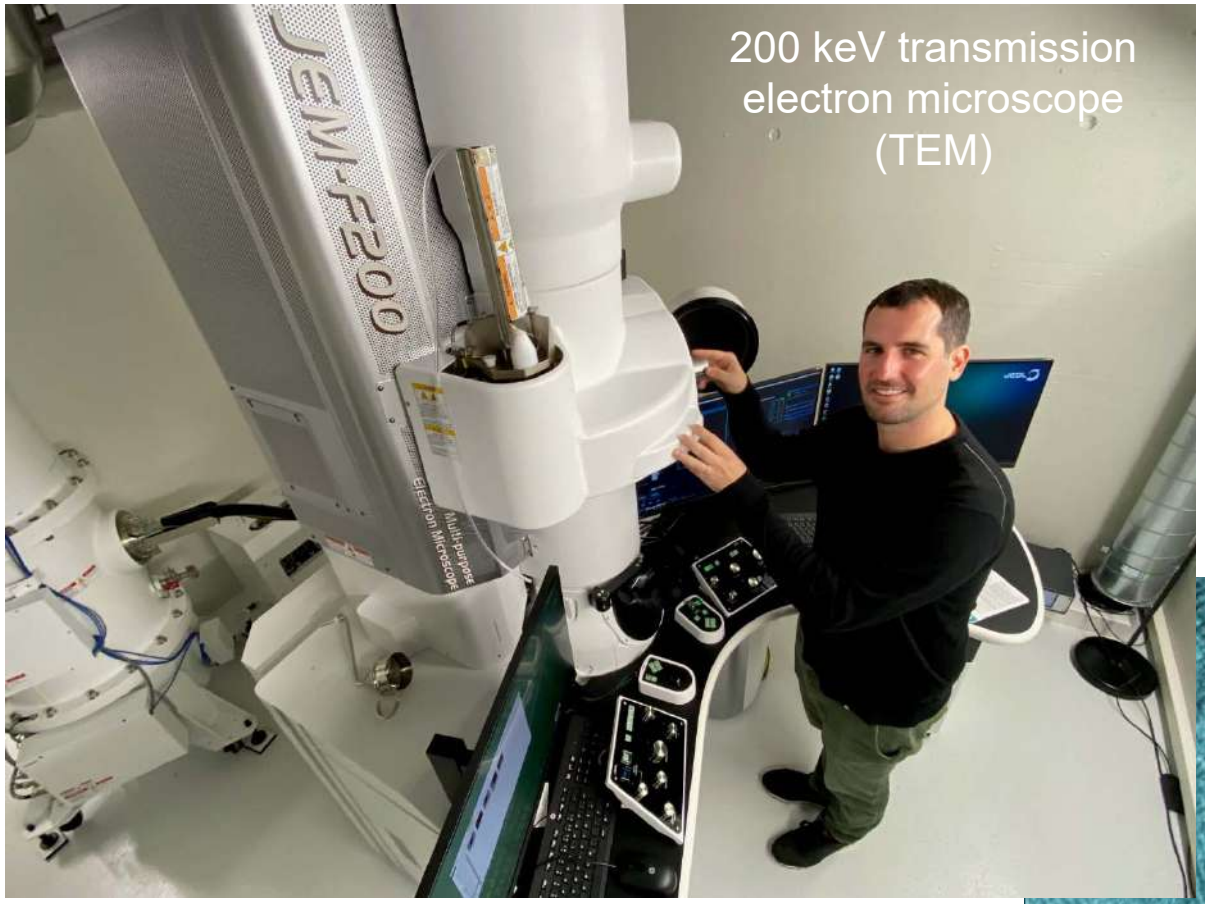


About Us

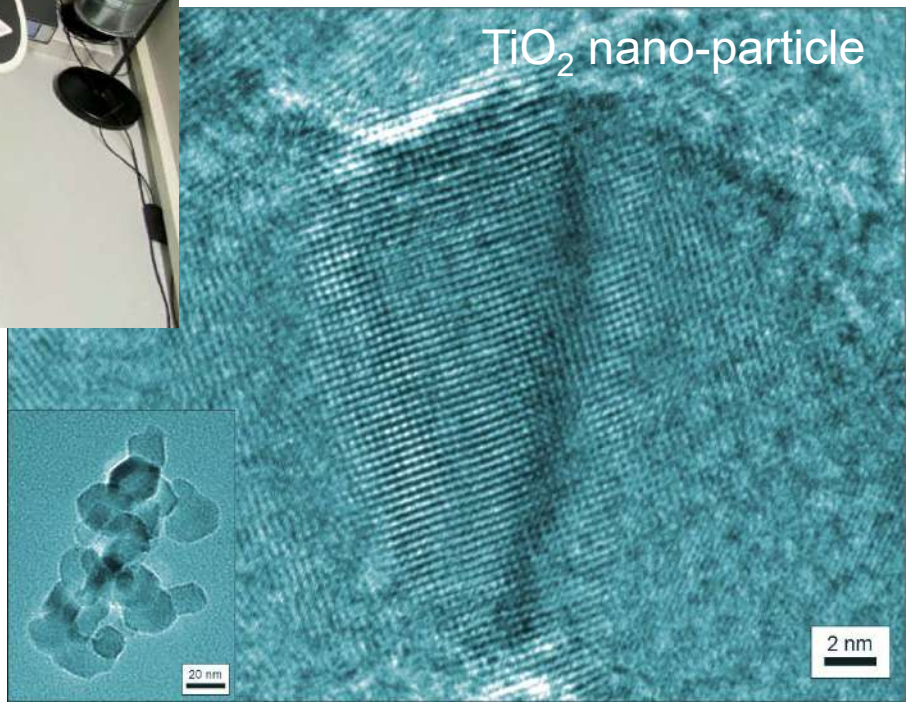
The Swiss Nanoscience Institute (SNI) at the University of Basel is a center of excellence for nanosciences and nanotechnology. It emerged from the National Center of Competence in Research (NCCR) Nanoscale Science and was founded in 2006 by the University of Basel and the Swiss Canton Aargau in order to support research, education, and technology transfer in the nanosciences and in nanotechnology in Northwestern Switzerland. Through the high-tech strategy of the Canton of Aargau, in which nanotechnology is a key component in driving innovation support, the role of the SNI is even more important in connecting industry with cutting-edge research.

Microscopes allow to see atoms

Schönenberger group www.nanoelectronics.ch



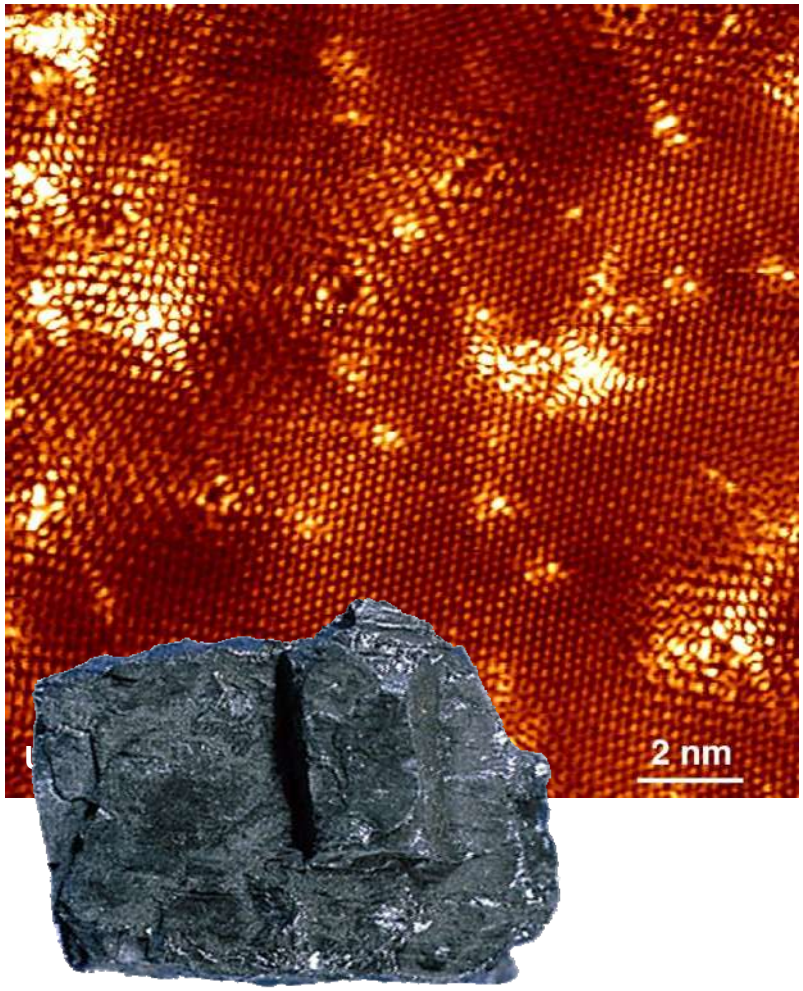
200 keV transmission electron microscope (TEM)



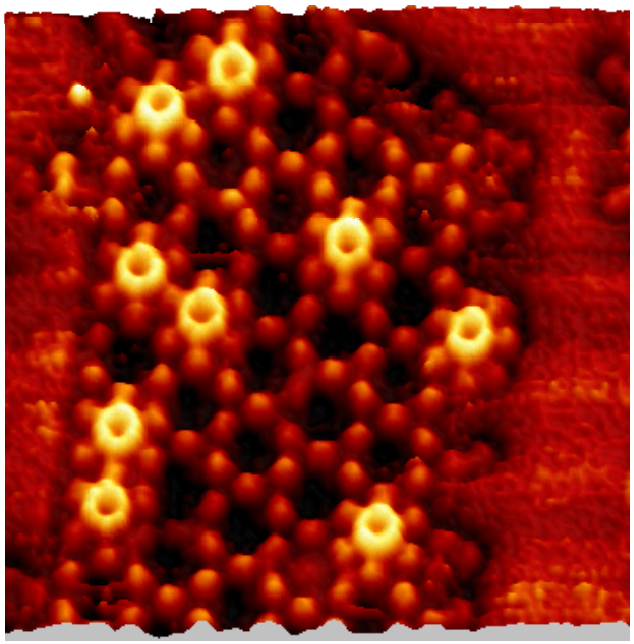
TiO_2 nano-particle

Microscopes allow to see atoms

atoms on the surface of “coal” (graphite)

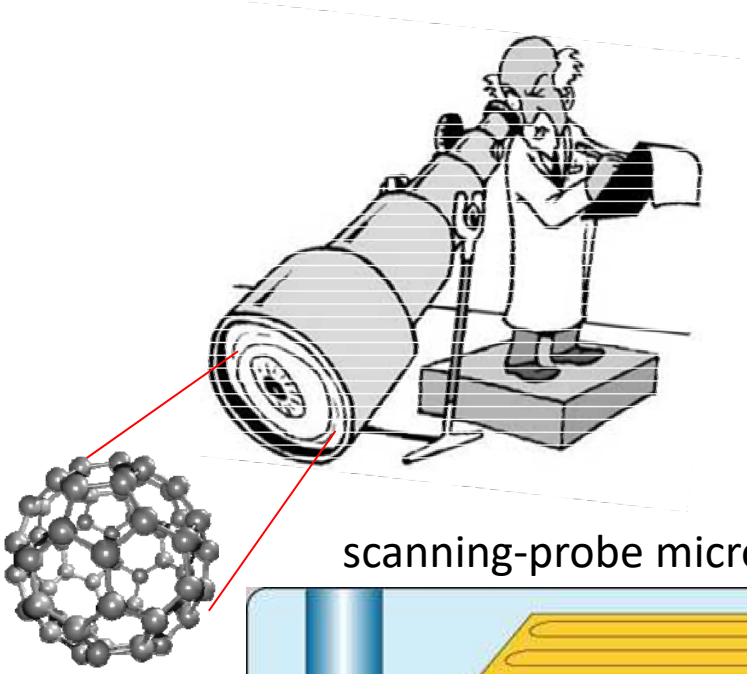


molecules on a surface

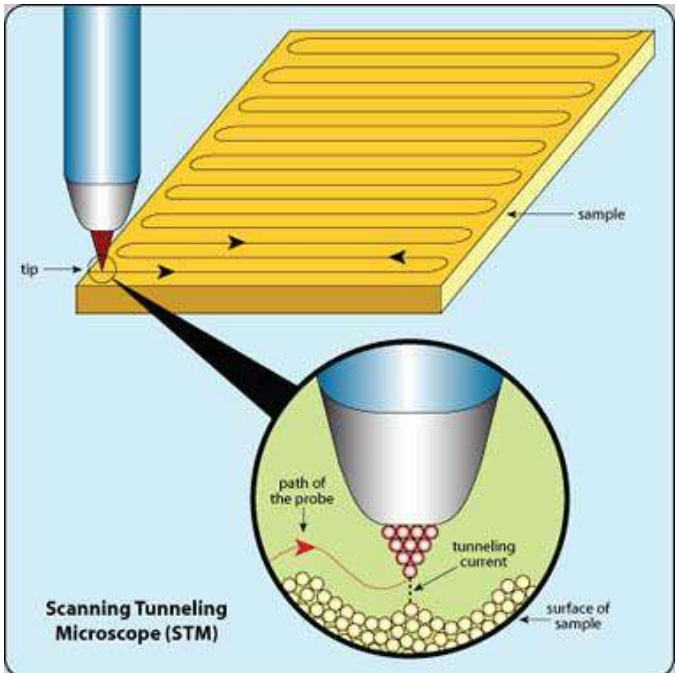


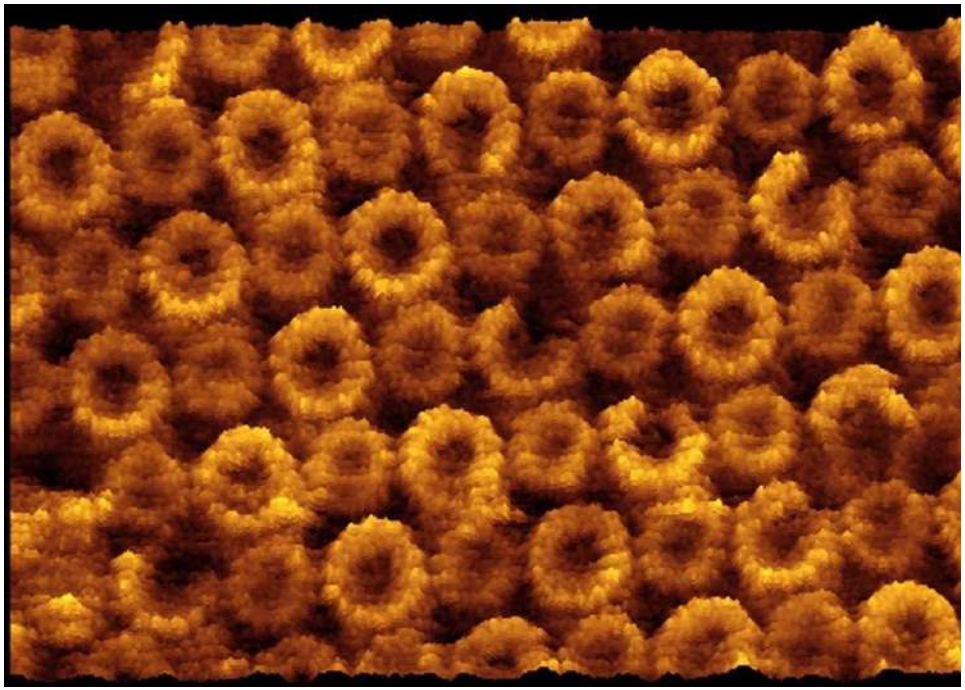
Microscopes allow to see atoms

Schönenberger group www.nanoelectronics.ch



scanning-probe microscope





membrane proteins

The visionary

Schönenberger group www.nanoelectronics.ch

Plenty of Room at the Bottom

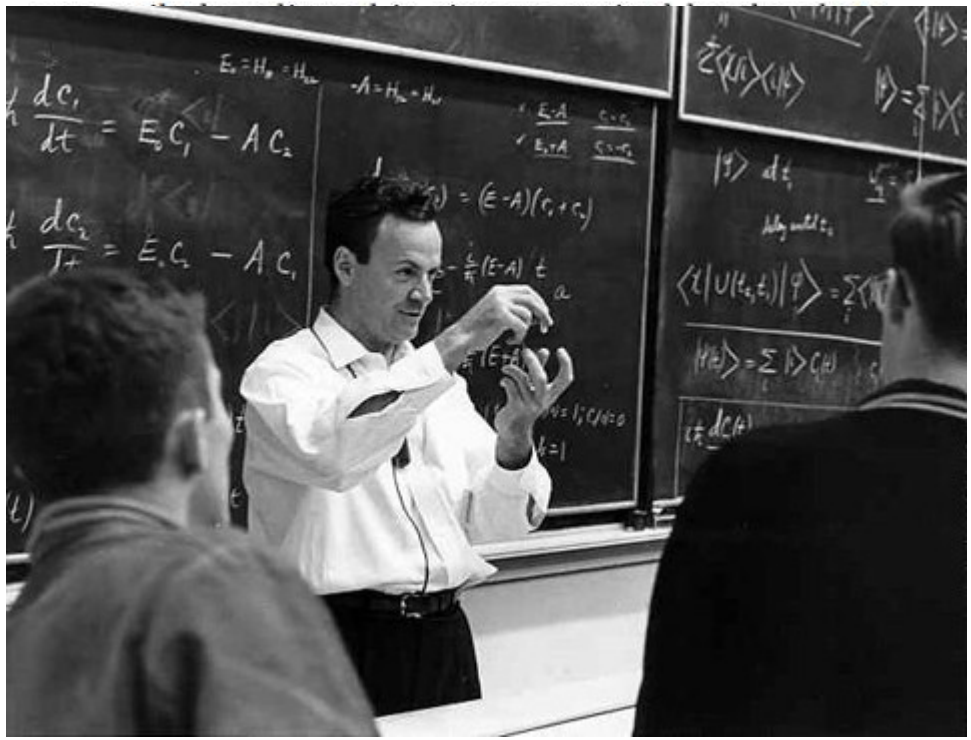
Richard P. Feynman
(Dated: Dec. 1959)

This is the transcript of a talk presented by Richard P. Feynman to the American Physical Society in Pasadena on December 1959, which explores the immense possibilities afforded by miniaturization.

I imagine experimental physicists must often look with envy at men like Kamerlingh Onnes, who discovered a field like low temperature, which seems to be bottomless and in which one can go down and down. Such a man is then a leader and has some temporary monopoly in a scientific adventure. Percy Bridgman, in designing a way to obtain higher pressures, opened up another new field and was able to move into it and to lead us all along. The development of ever higher vacuum was a continuing development of the same kind.

I would like to describe a field, in which little has been done, but in which an enormous amount can be done in principle. This field is not quite the same as the others in that it will not tell us much of fundamental physics (in the sense of, "What are the strange particles?") but it is more like solid-state physics in the sense that it might tell us much of great interest about the strange phenomena that occur in complex situations. Furthermore, a point that is most important is that it would have an enormous number of technical applications.

What I want to talk about is the problem of manipulating and controlling things on a small scale

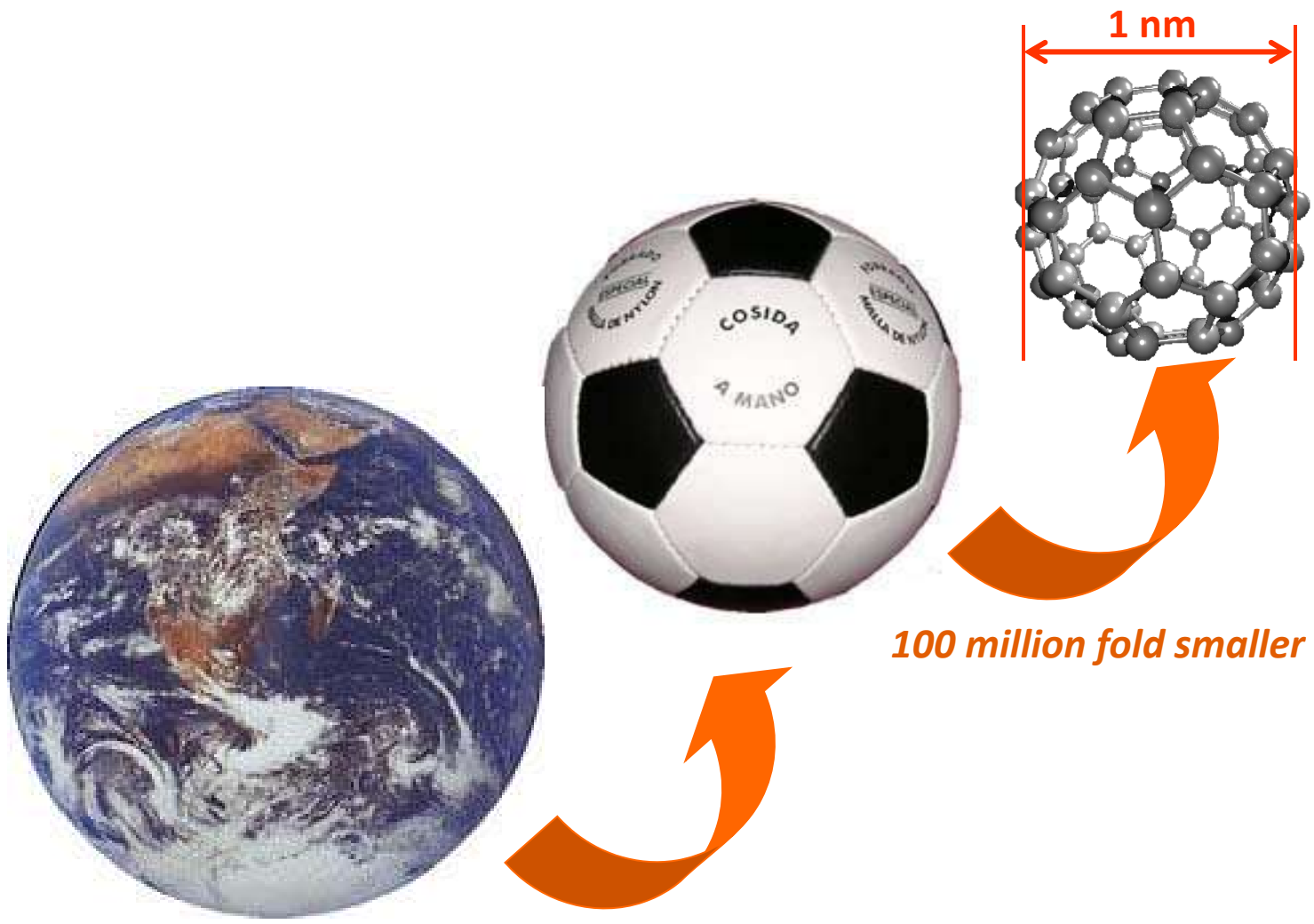


Imagination of a single-atom based technology: Nanoscience and Nanotechnology

SNI
SWISS NANOSCIENCE INSTITUTE
EINE INITIATIVE DER UNIVERSITÄT BASEL UND DES KANTONS AARGAU

UNI BASEL

One nanometer is indeed QUITE small



SNI
SWISS NANOSCIENCE INSTITUTE
EINE INITIATIVE DER UNIVERSITÄT BASEL UND DES KANTONS AARGAU

UNI BASEL

What is it good for?

Color by size

Schönenberger group www.nanoelectronics.ch

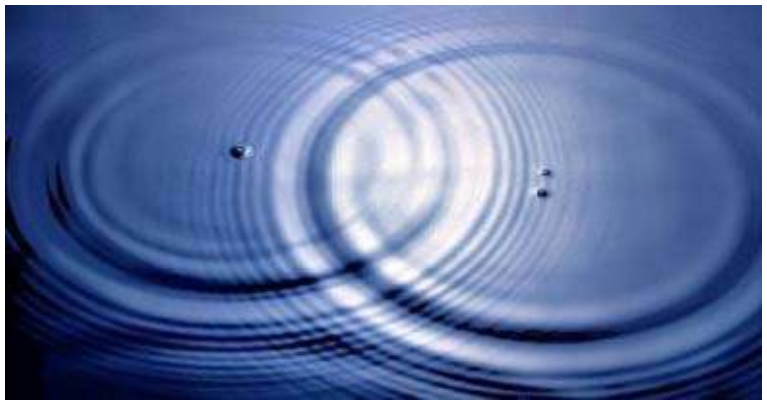
color, color, color

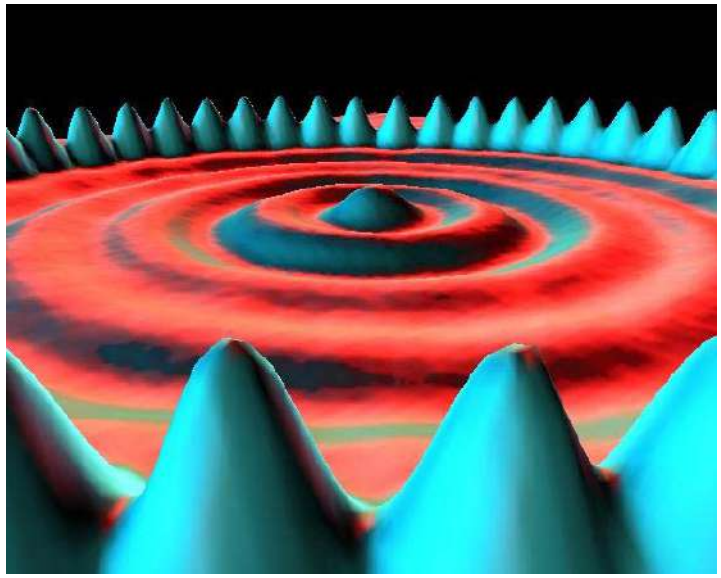
Schönenberger group www.nanoelectronics.ch

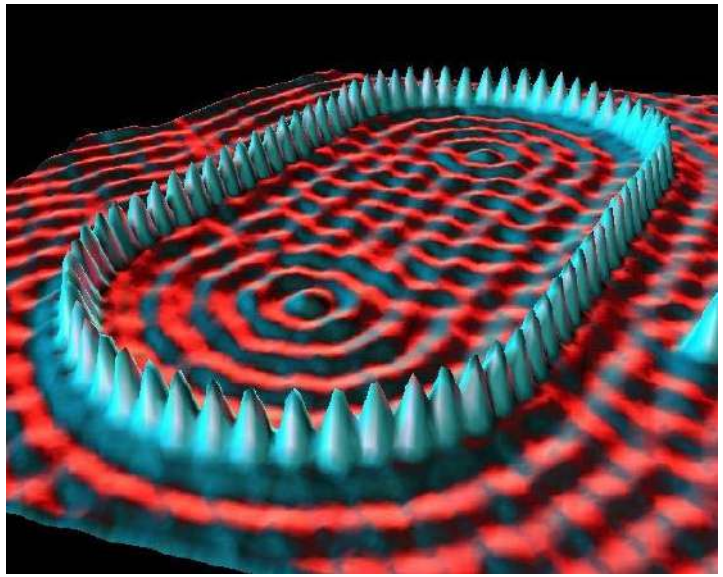
SNI
SWISS NANOSCIENCE INSTITUTE
EINE INITIATIVE DER UNIVERSITÄT BASEL UND DES KANTONS AARGAU

UNI BASEL

Small ... and different

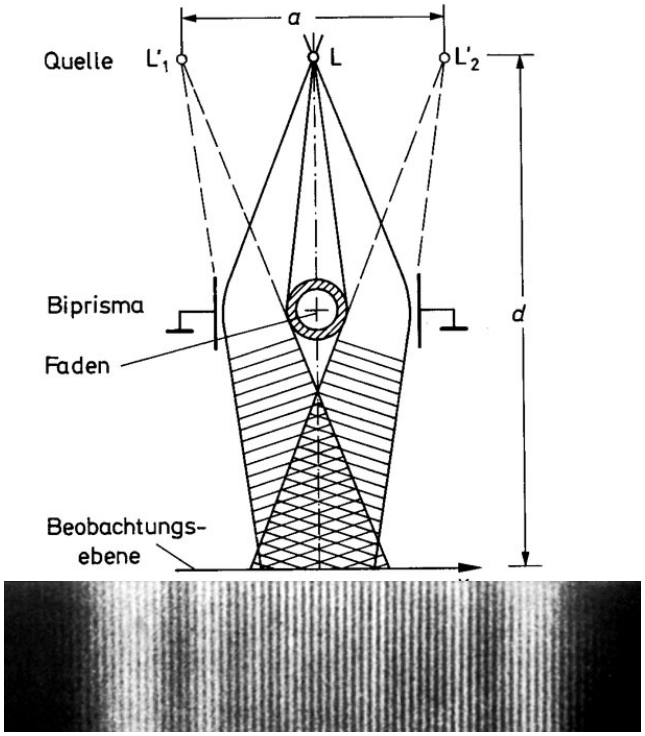




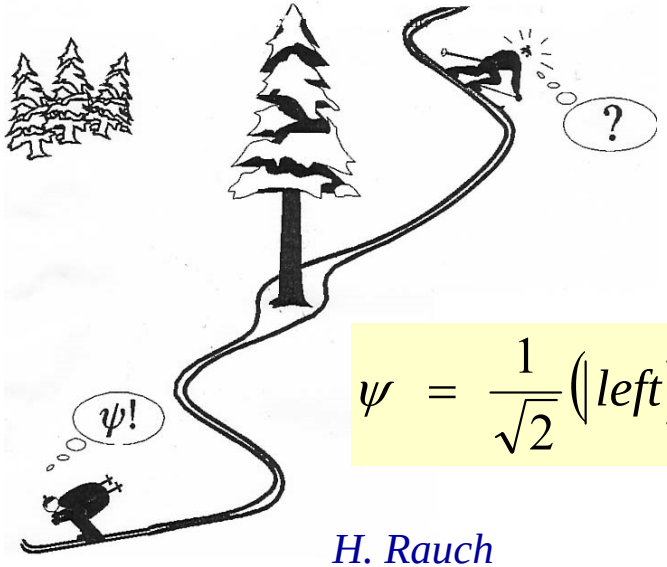


electrons do not necessarily have to be point particles, they can be behave as **waves: particle wave duality**

Small … and different

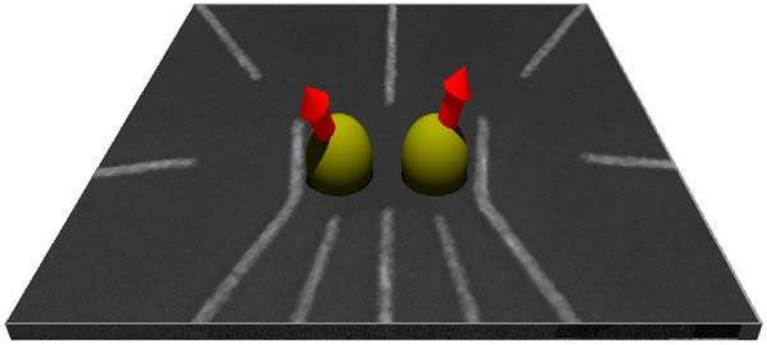


(Moellenstedt, Tonamura)

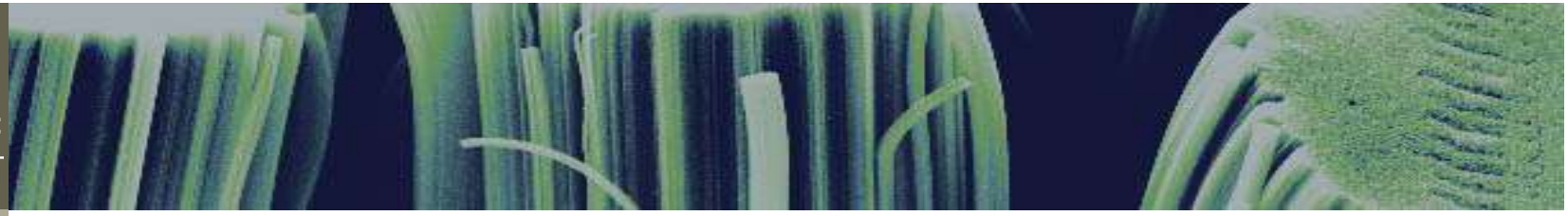


$$\psi = \frac{1}{\sqrt{2}}\left(|left\rangle + |right\rangle\right)$$

H. Rauch

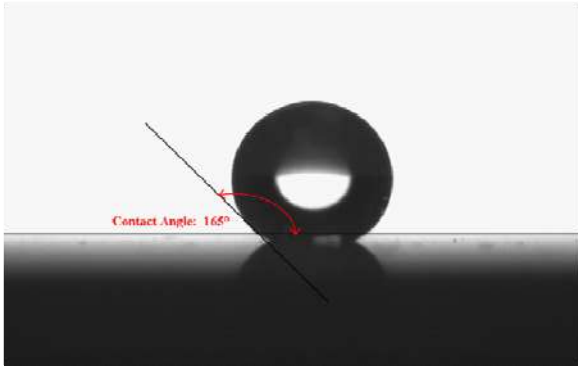


D. Zumbühl

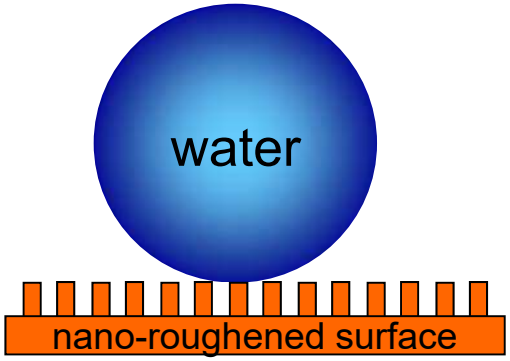


Hydrophobic Surfaces

hydrophob > 90°
superhydrophob > 150-160°



Typical hydrophobic coatings have a contact angle of around 120°. Larger ones can only be achieved through surface structures on the micrometer and nanometer scale

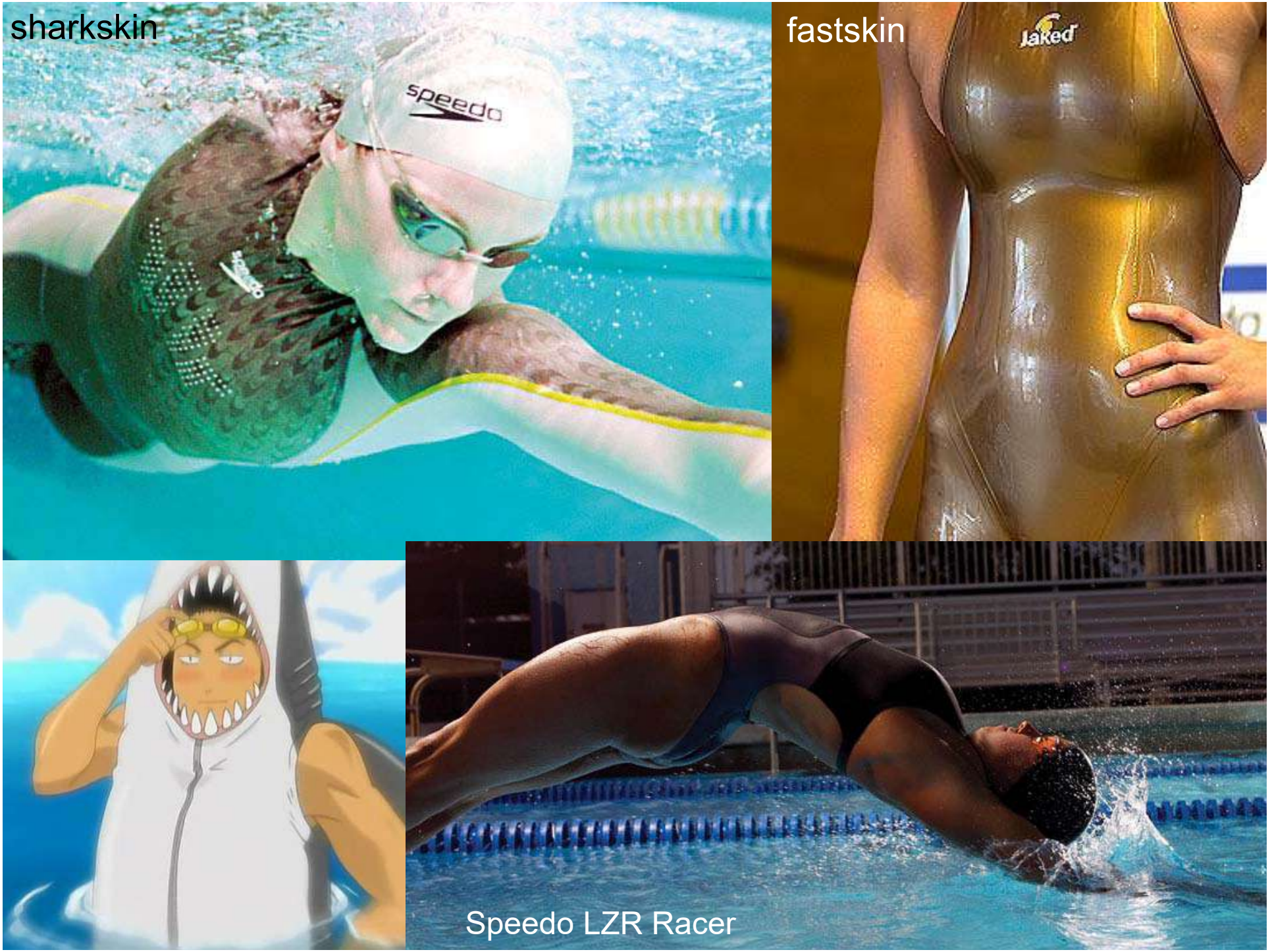


SNI
SWISS NANOSCIENCE INSTITUTE
EINE INITIATIVE DER UNIVERSITÄT BASEL UND DES KANTONS AARGAU

UNI BASEL

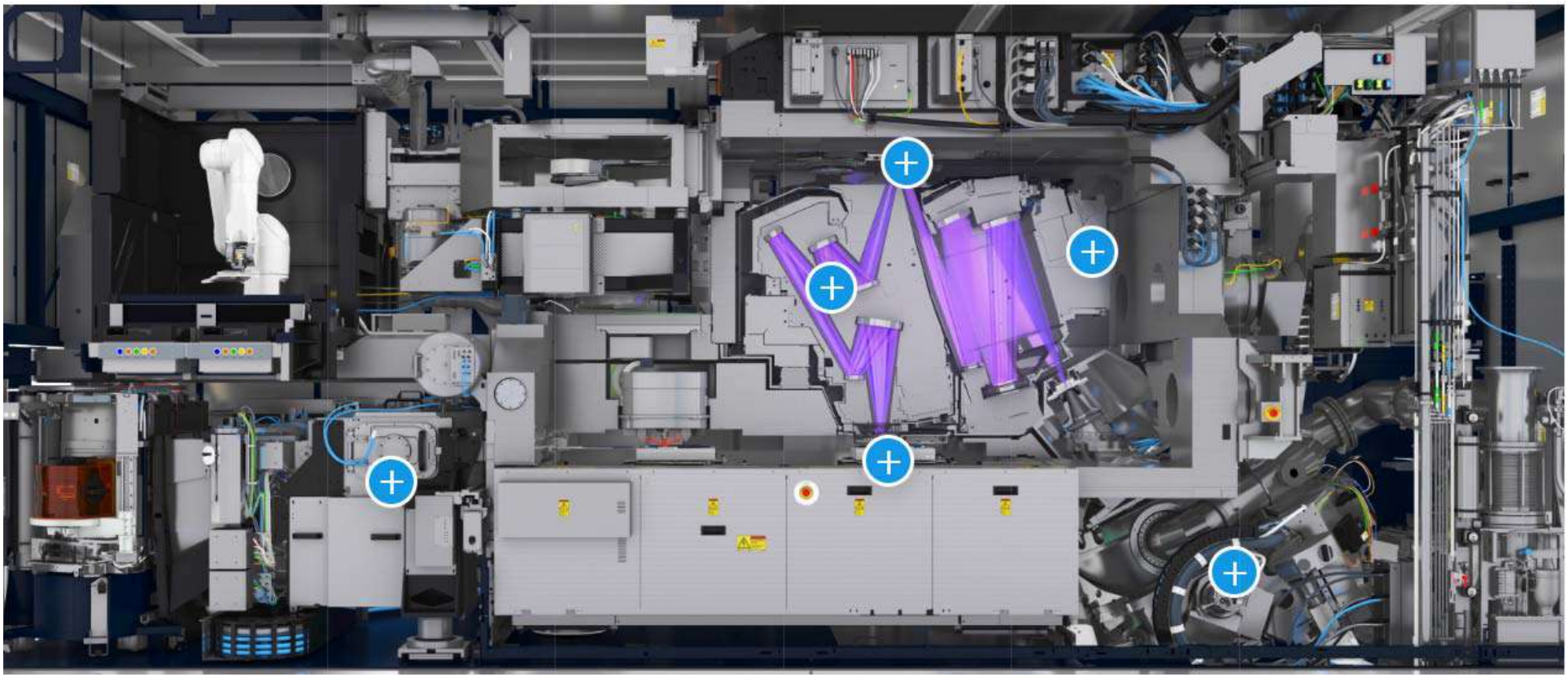
Hydrophobic treated textiles

Innovative fabrics
schoeller®
Switzerland


sharkskin
speedo
fastskin
Jaked
Speedo LZR Racer

Where size matters…

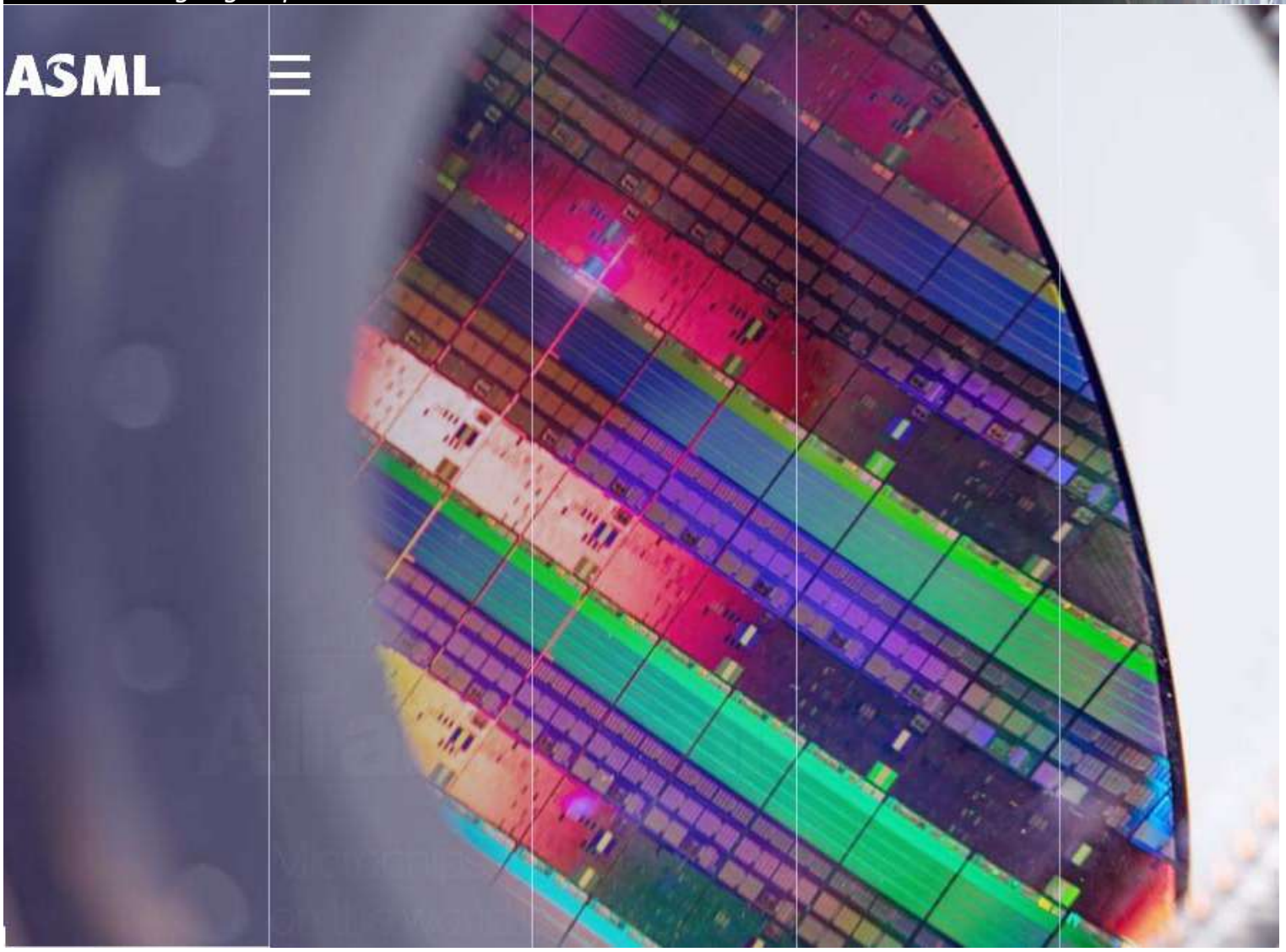
Where size matters…



ASML = Advanced Semiconductor Materials Lithography
it is a sort of a “printer” to fabricate structures at the nanoscale

Where size matters…

Schönenberger group www.nanoelectronics.ch

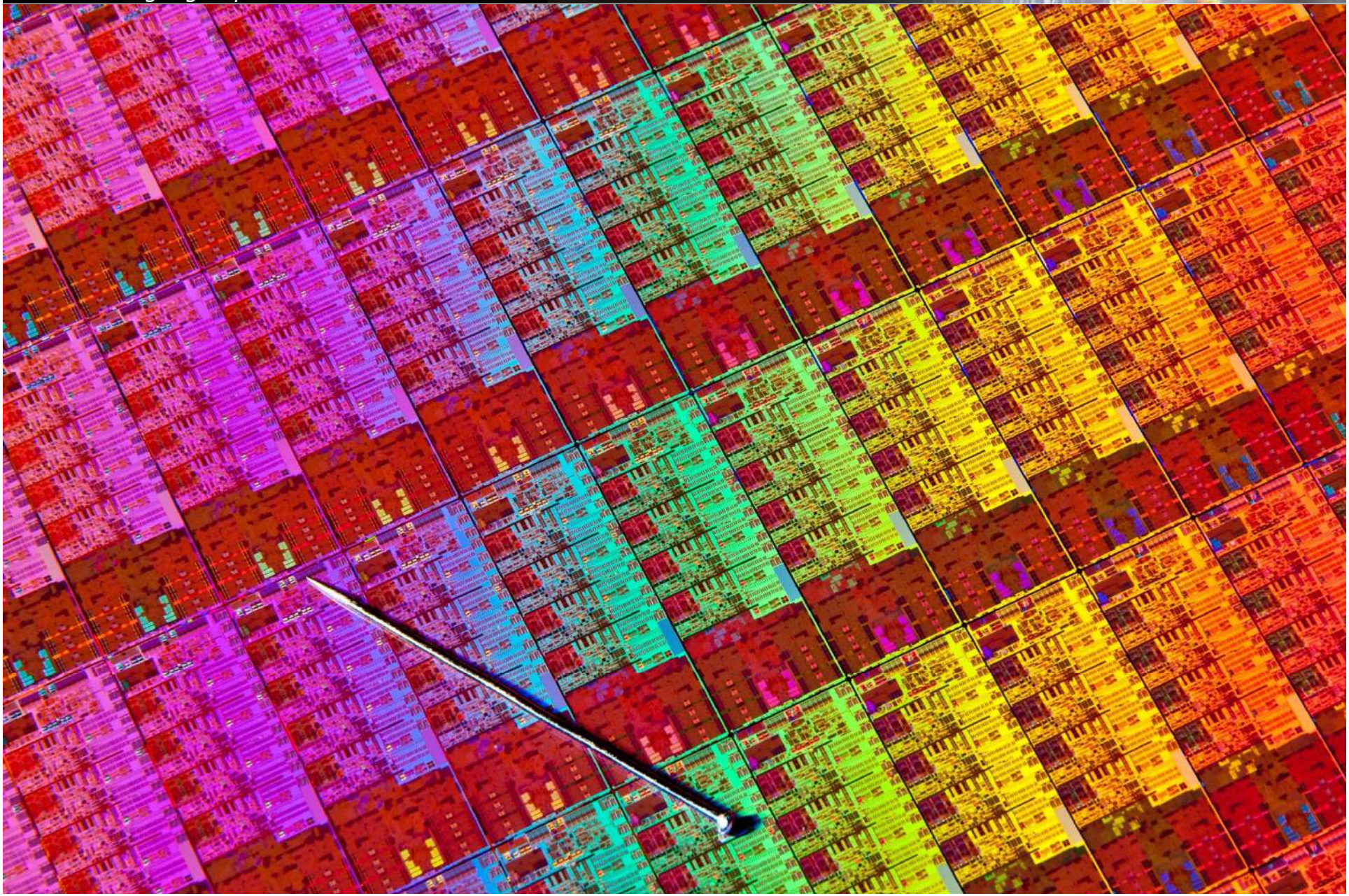


electronic **chips** with nanoscale dimensions

ASML = Advanced Semiconductor Materials Lithography
it is a sort of a “printer” to fabricate structures at the nanoscale

Modern processor chip

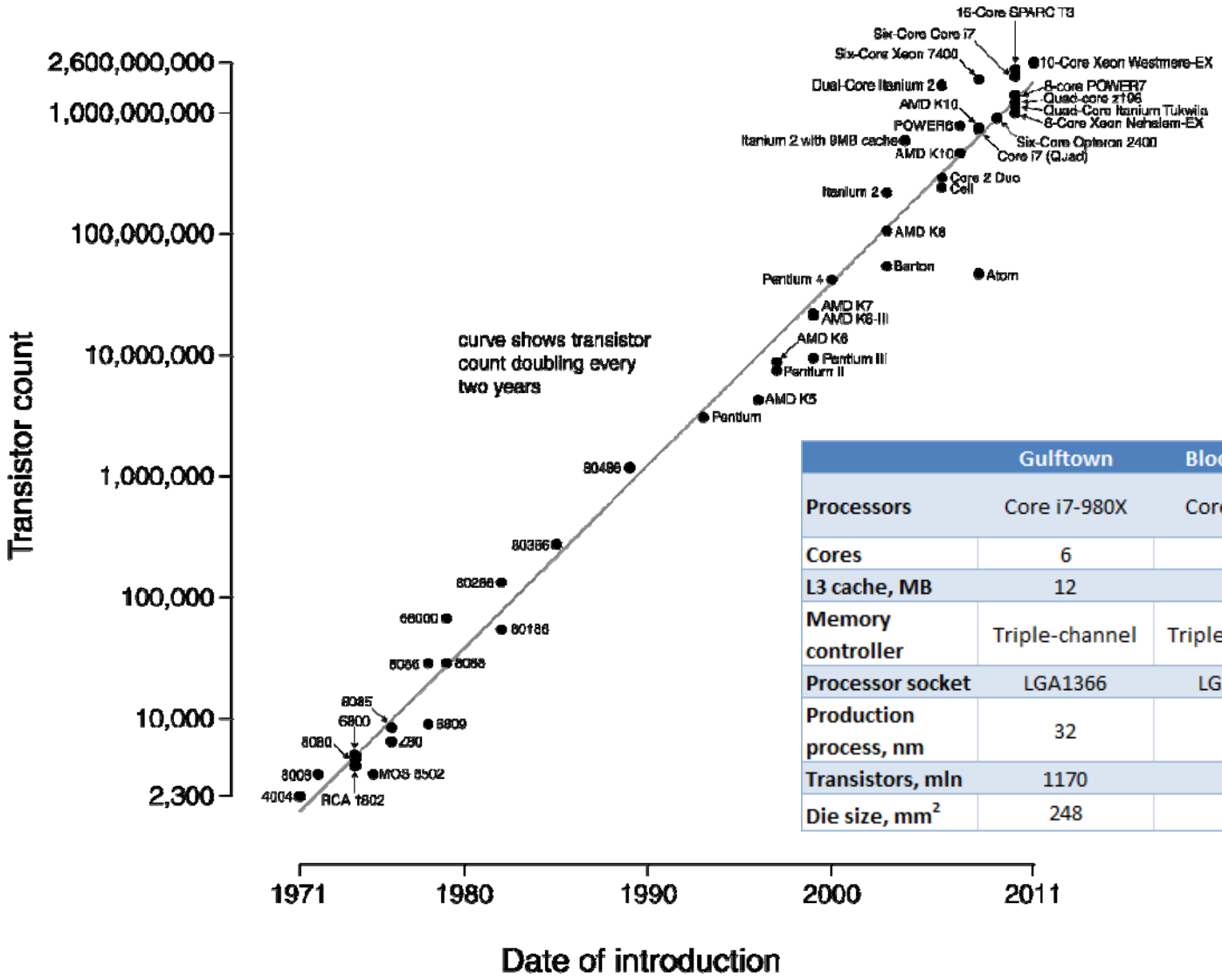
Schönenberger group www.nanoelectronics.ch



Modern processor chip

Schönenberger group www.nanoelectronics.ch

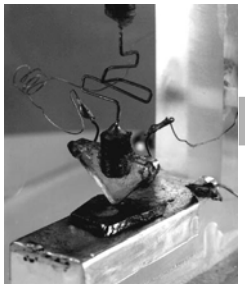
Microprocessor Transistor Counts 1971-2011 & Moore's Law

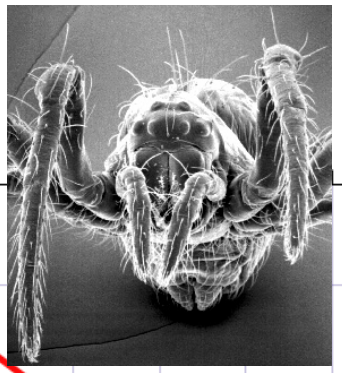


	Gulftown	Bloomfield	Lynnfield	Clarkdale
Processors	Core i7-980X	Core i7-900	Core i7-800 Core i5-700	Core i5-600 Core i3-500
Cores	6	4	4	2
L3 cache, MB	12	8	8	4
Memory controller	Triple-channel	Triple-channel	Dual-channel	Dual-channel
Processor socket	LGA1366	LGA1366	LGA1156	LGA1156
Production process, nm	32	45	45	32 + 45
Transistors, mln	1170	731	774	382 + 177
Die size, mm^2	248	263	296	81 + 114

Integrated circuits

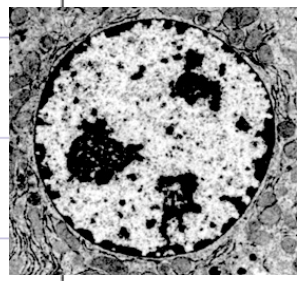
Schönenberger group www.nanoelectronics.ch





spider

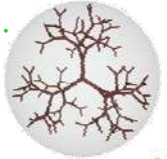
hair



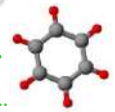
cell

virus

proteins

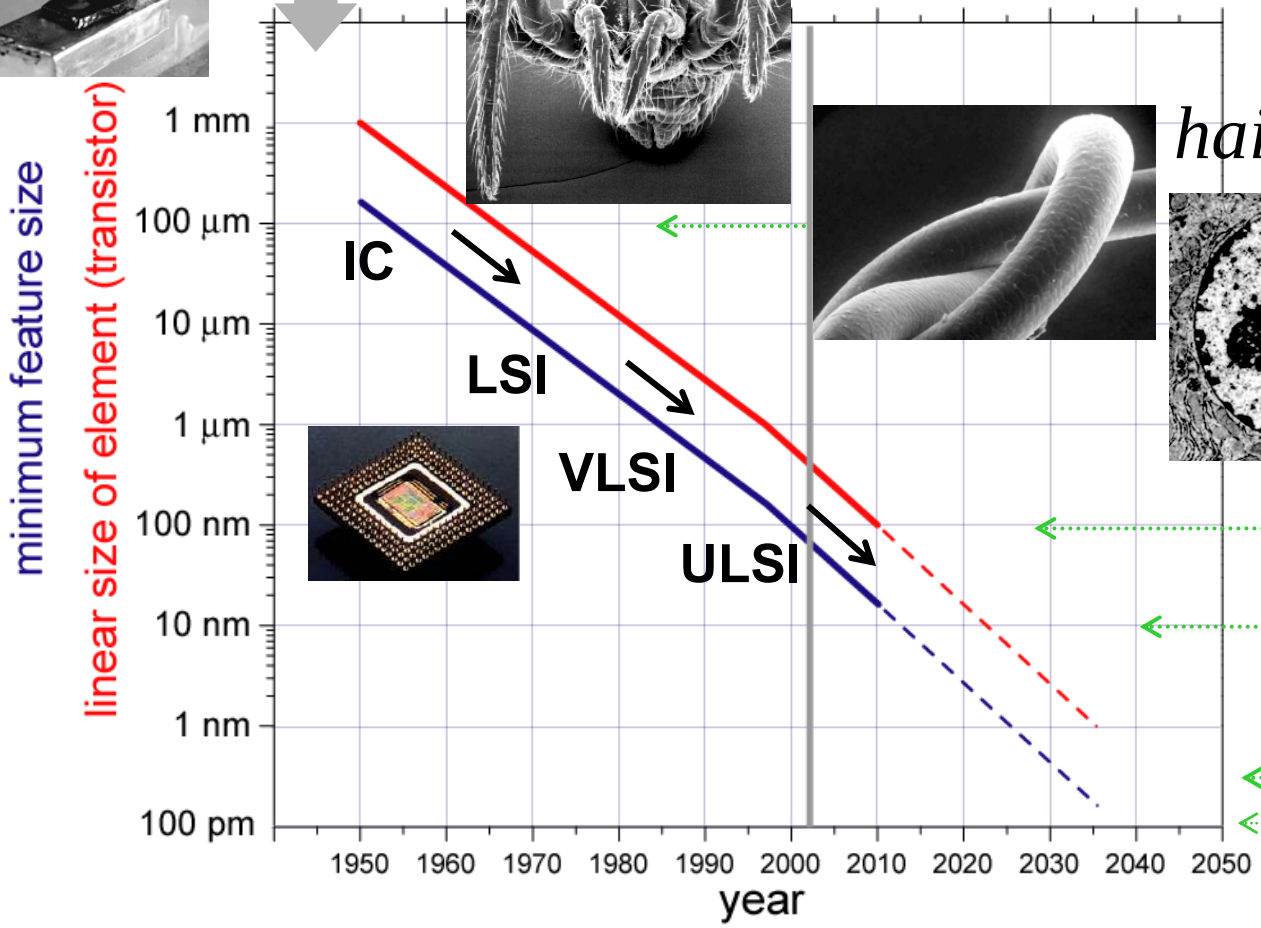


supramolecules



molecule

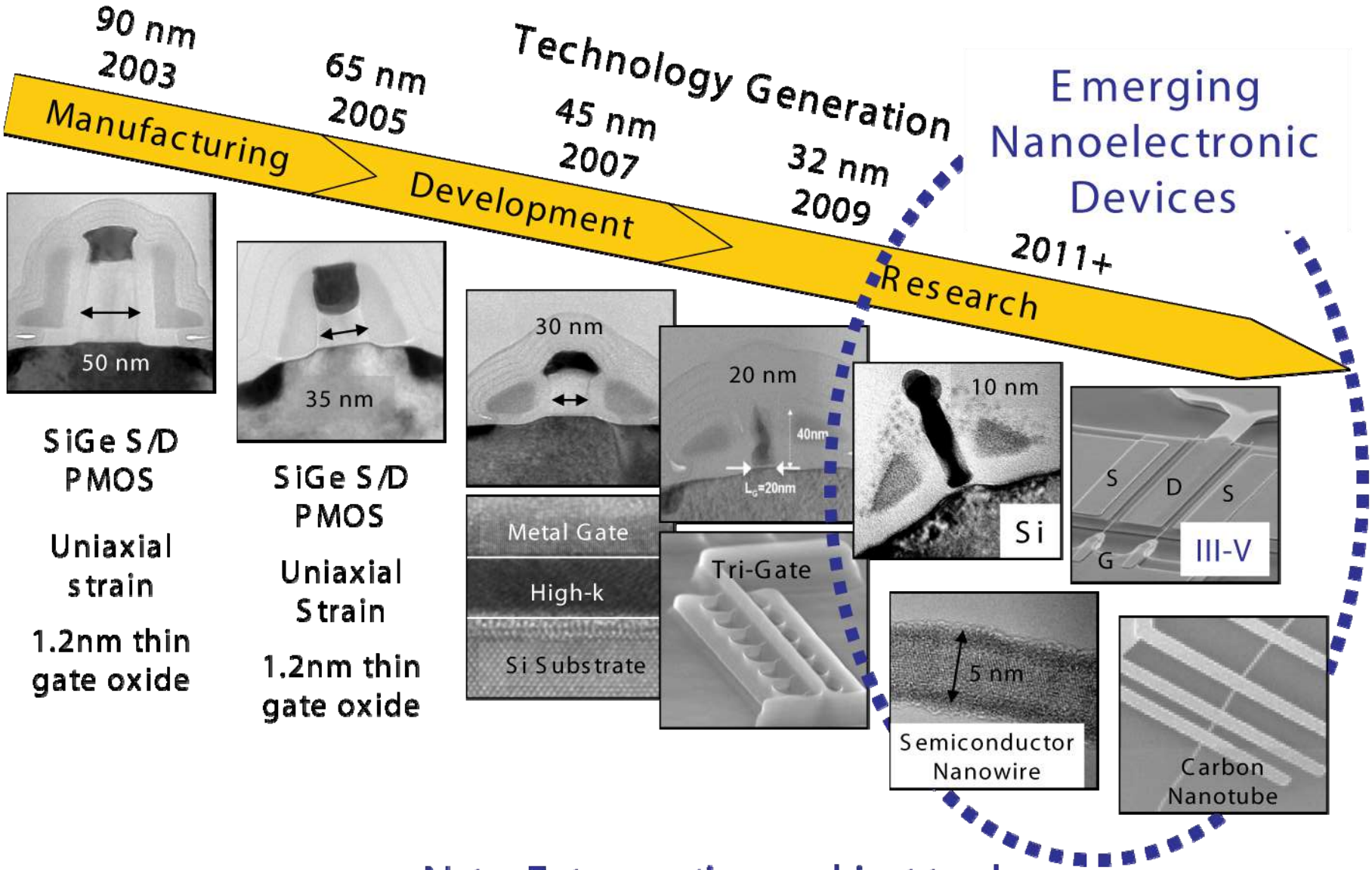
atom



Moore's law: doubling every 18 months

Integrated circuits: CMOS

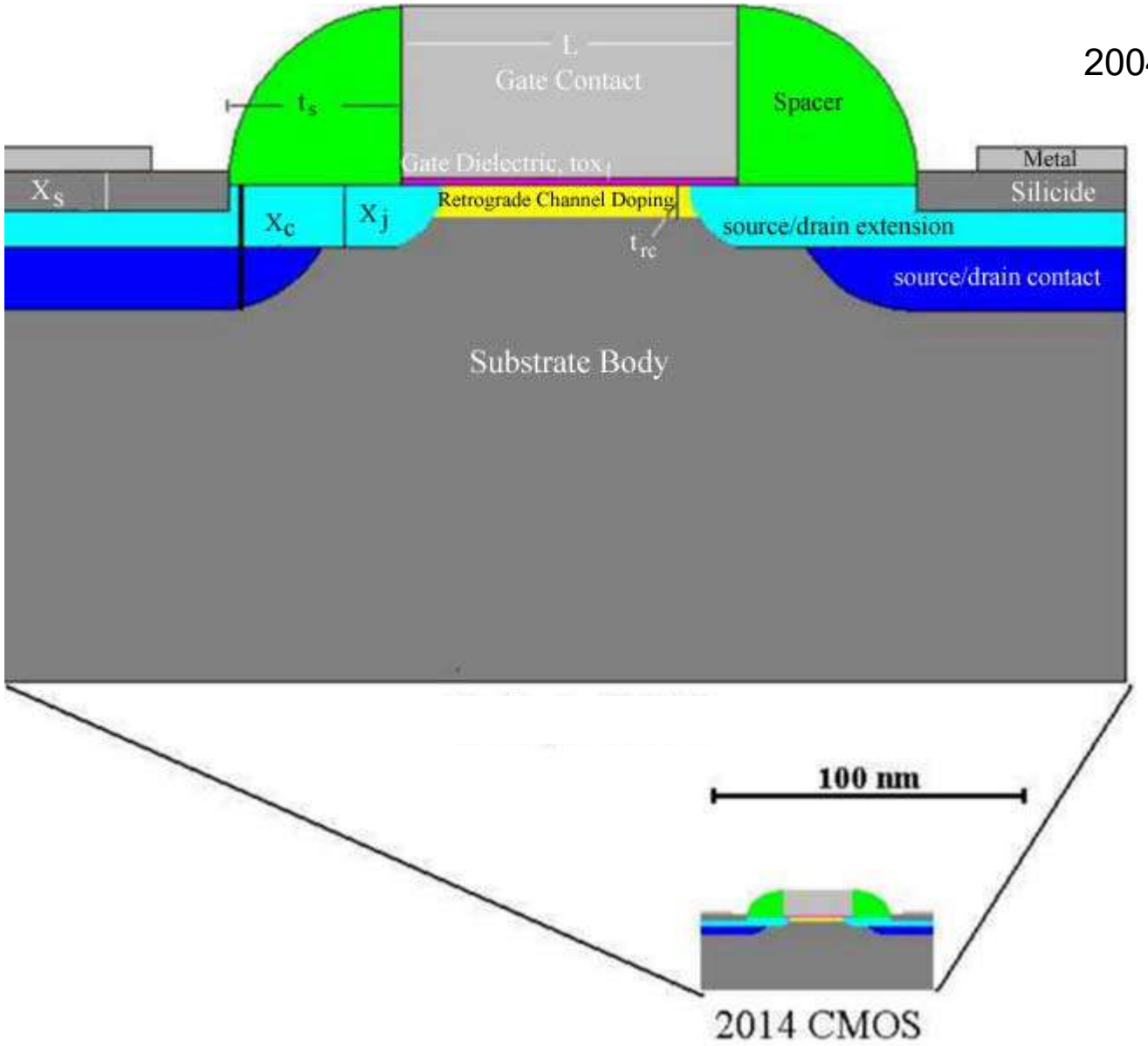
Schönenberger group www.nanoelectronics.ch



Note: Future options subject to change

Rob Chau, Intel

Scaling electronics



2004 CMOS

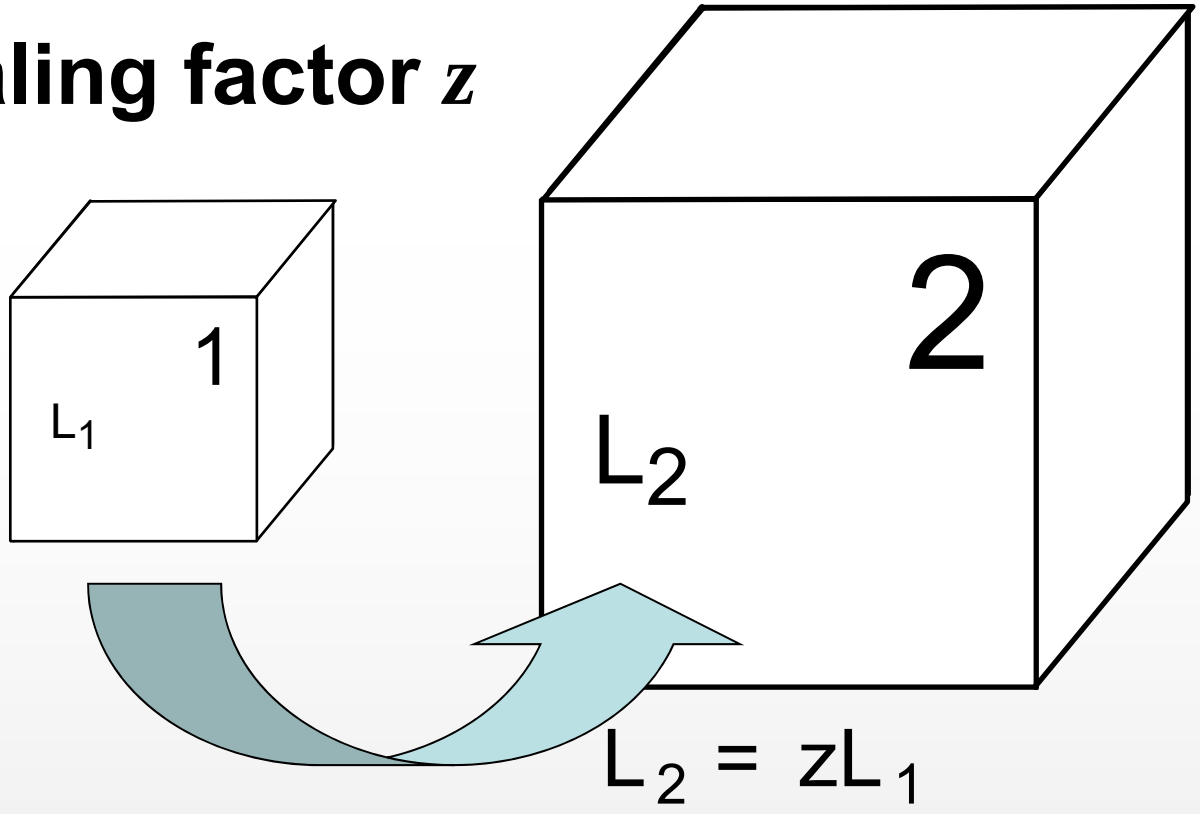
Scaling

www.nanoelectronics.ch

Christian Schönenberger
Department of Physics & Swiss Nanoscience Instiute
The University of Basel, Switzerland

Length-Scaling

1) Scaling factor z



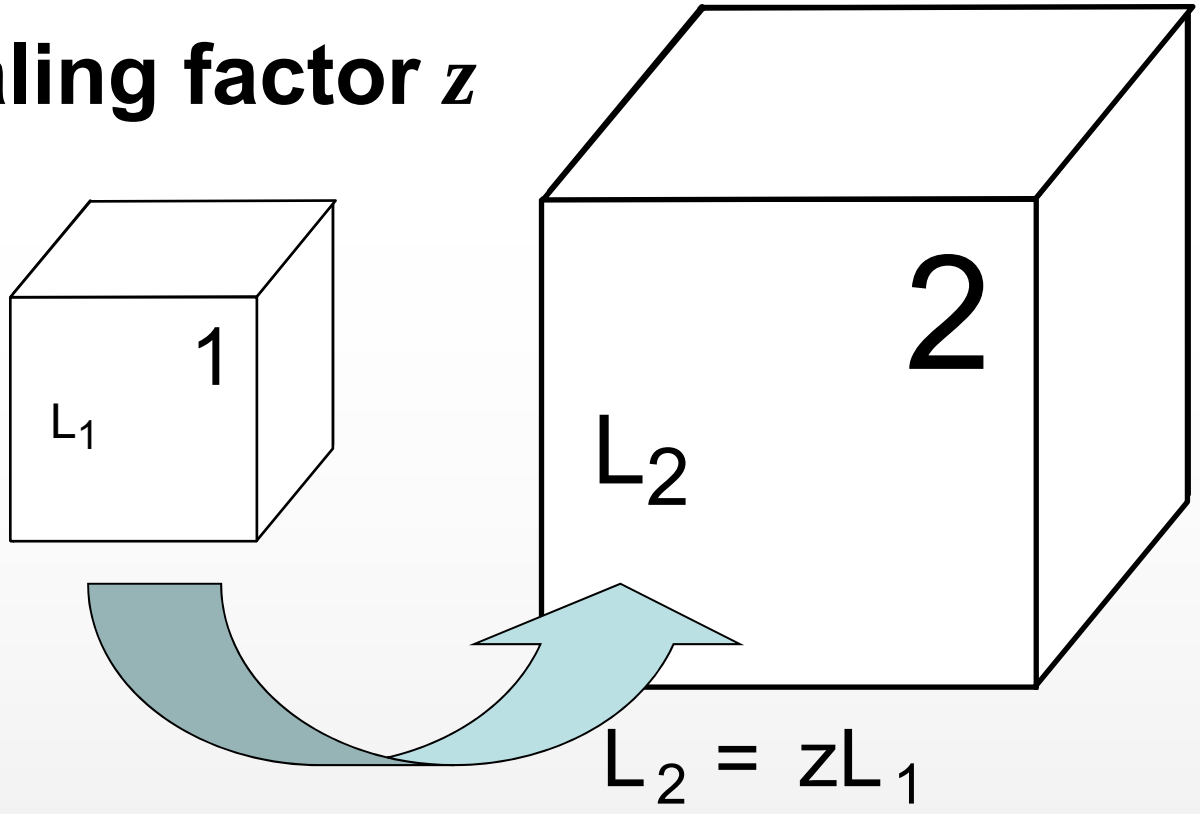
Assumption: all lenghth in 3d (3 dimensions)
scale with the same parameter z

e.g. the volume then scales as: $V_2 = z^3 V_1$

and we say that the volume scale in the third power of L

abbreviation $V \sim L^3$

1) Scaling factor *z*



e.g. the **area** then scales as: $A_2 = z^2 A_1$

i.e. the area scales in the 2nd power of L

abbreviation: $A \sim L^2$

1) Example to get a feel of the idea

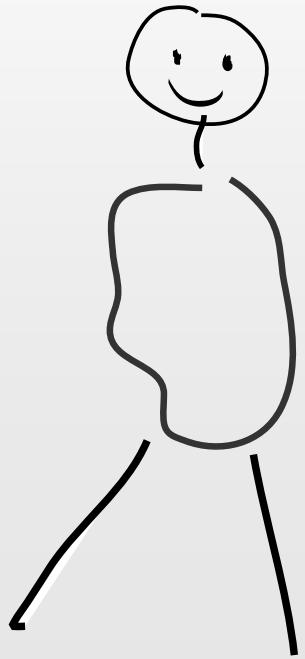
how does the time of free fall T_{fall} of an object scales? $T_{Fall} \sim L^0$

how does the breaking distance d_{break} of a car scales?

all kind of physics, the laws of Newton … ?

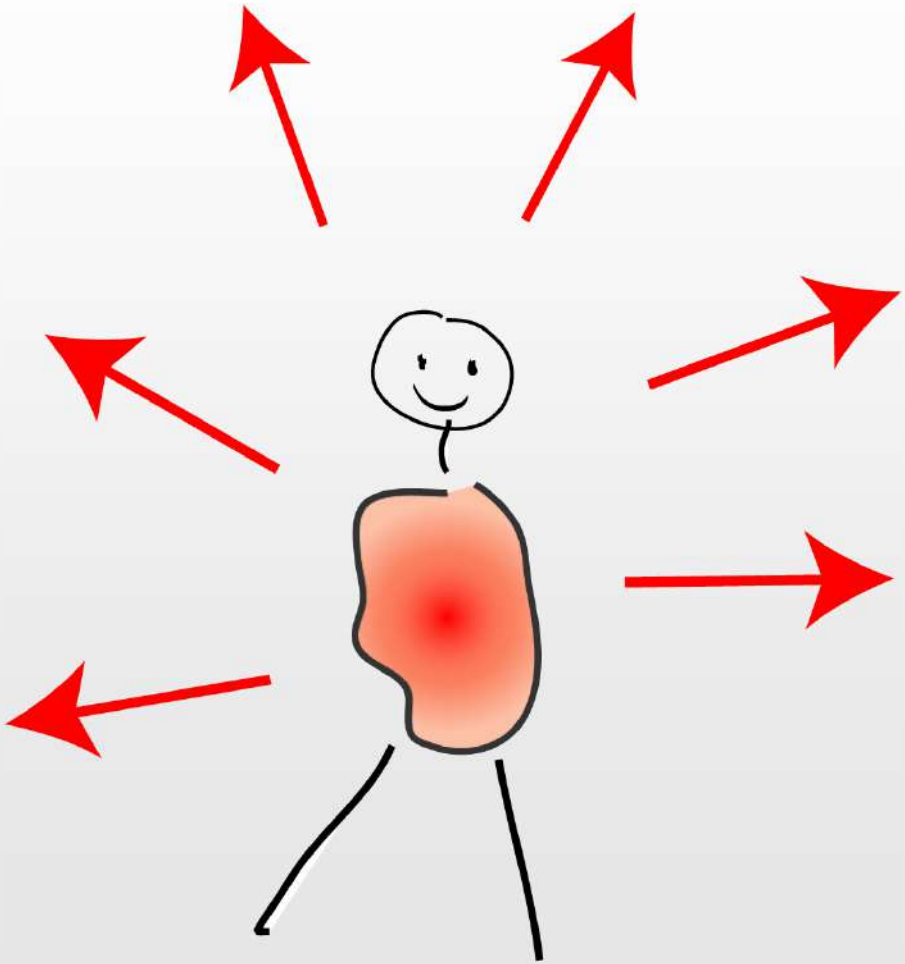
2) Power of a human (or animal) ?

The power P ... $P \sim L^3$? yes, but not for long…



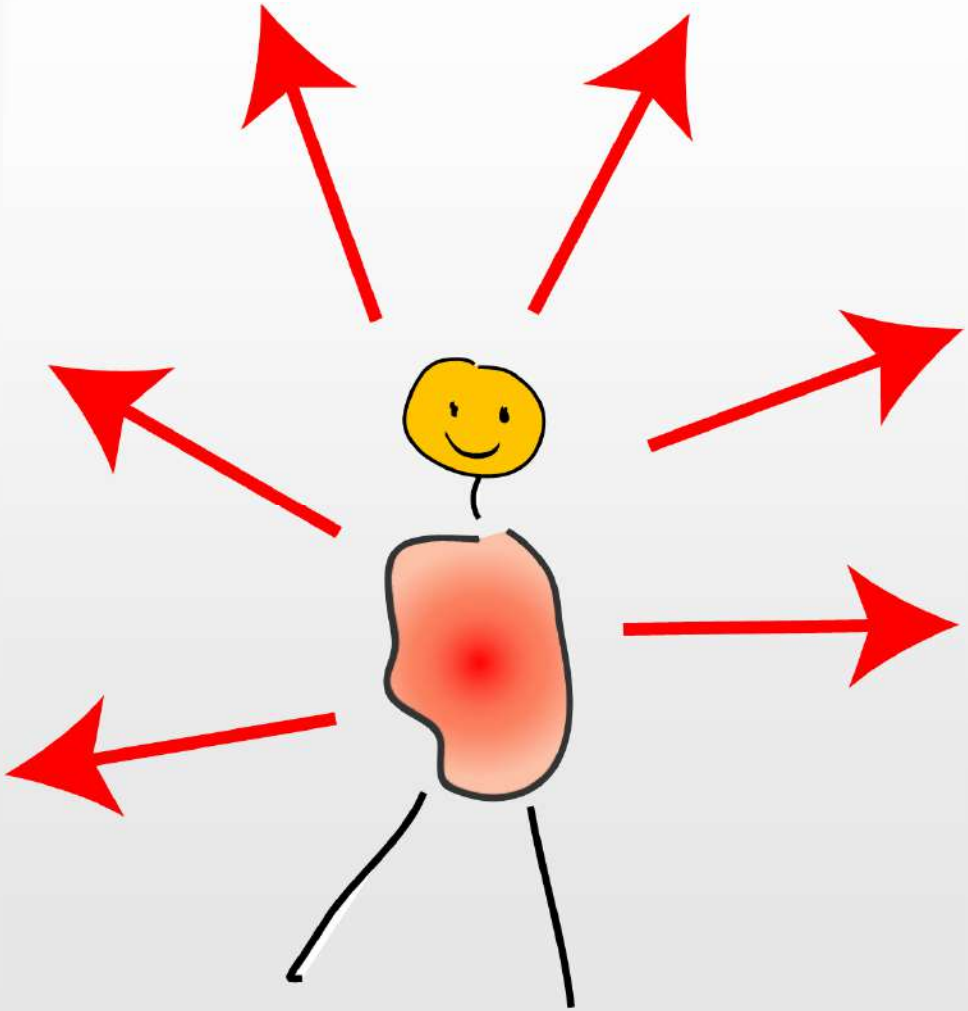
2) Power of a human (or animal) ?

The power P ... $P \sim L^3$? yes, but not for long…



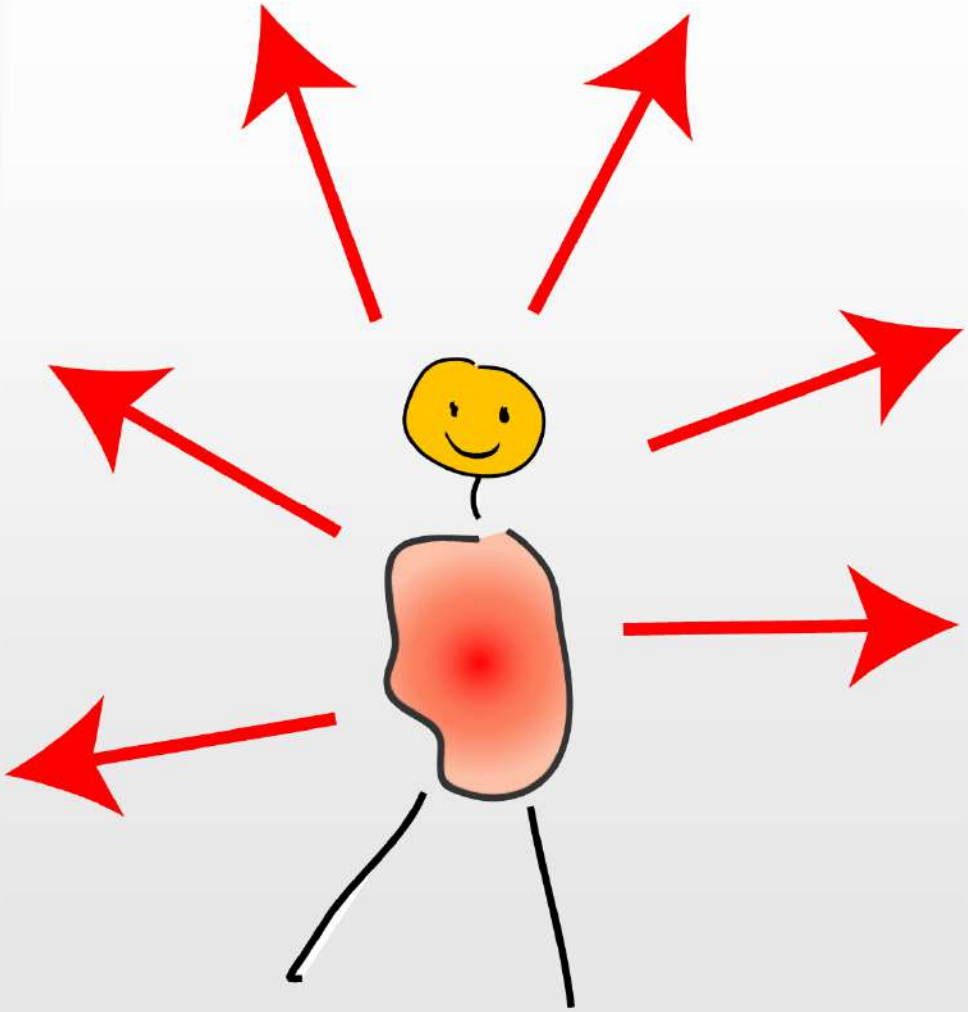
2) Power of a human (or animal) ?

The power P ... $P \sim L^3$? yes, but not for long…



2) Power of a human (or animal) ?

The power P ... $P \sim L^3$? yes, but not for long…



Physics: there is no machine with the sole effect of converting energy in work (taken in the "thermodynamic" limit)

➔ heat appears

... the "system" adjust to an evaluated equilibrium temperature, determined by the **surface**

$P \sim L^2$

2.1) Application: „Rate of Eating“

How long can we be without food? T_{digest}

(added energy in food) E_{food} ... $\sim L^3$ (volume of stomache)

$E_{food} = P\, T_{digest}$ ➔

$T_{digest} \sim L$

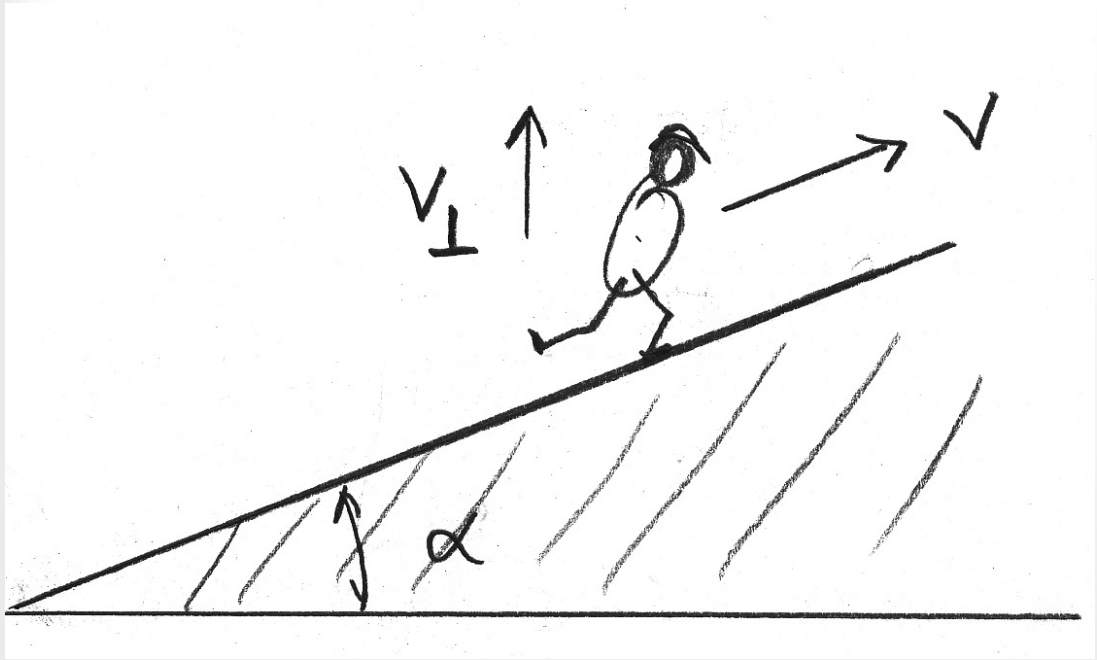
eat frequency = rate of eating $\sim \mathbf{L^{-1}}$

Apply it to:

a) camel
b) baby
c) fly
d) molekular biology (very tiny machines)

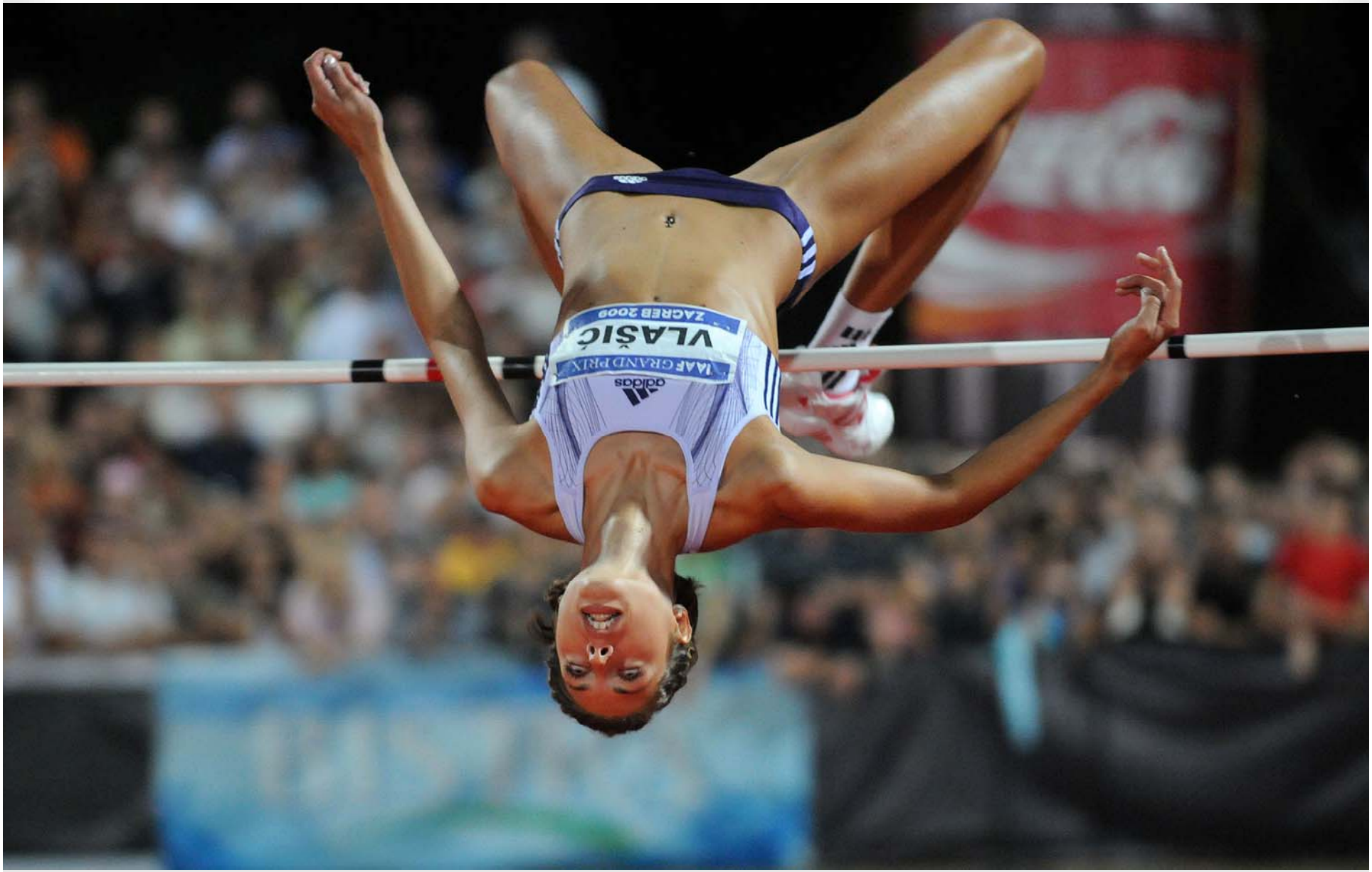
2.2) jogging uphill

Who runs faster uphill; a smaller or a bigger person?

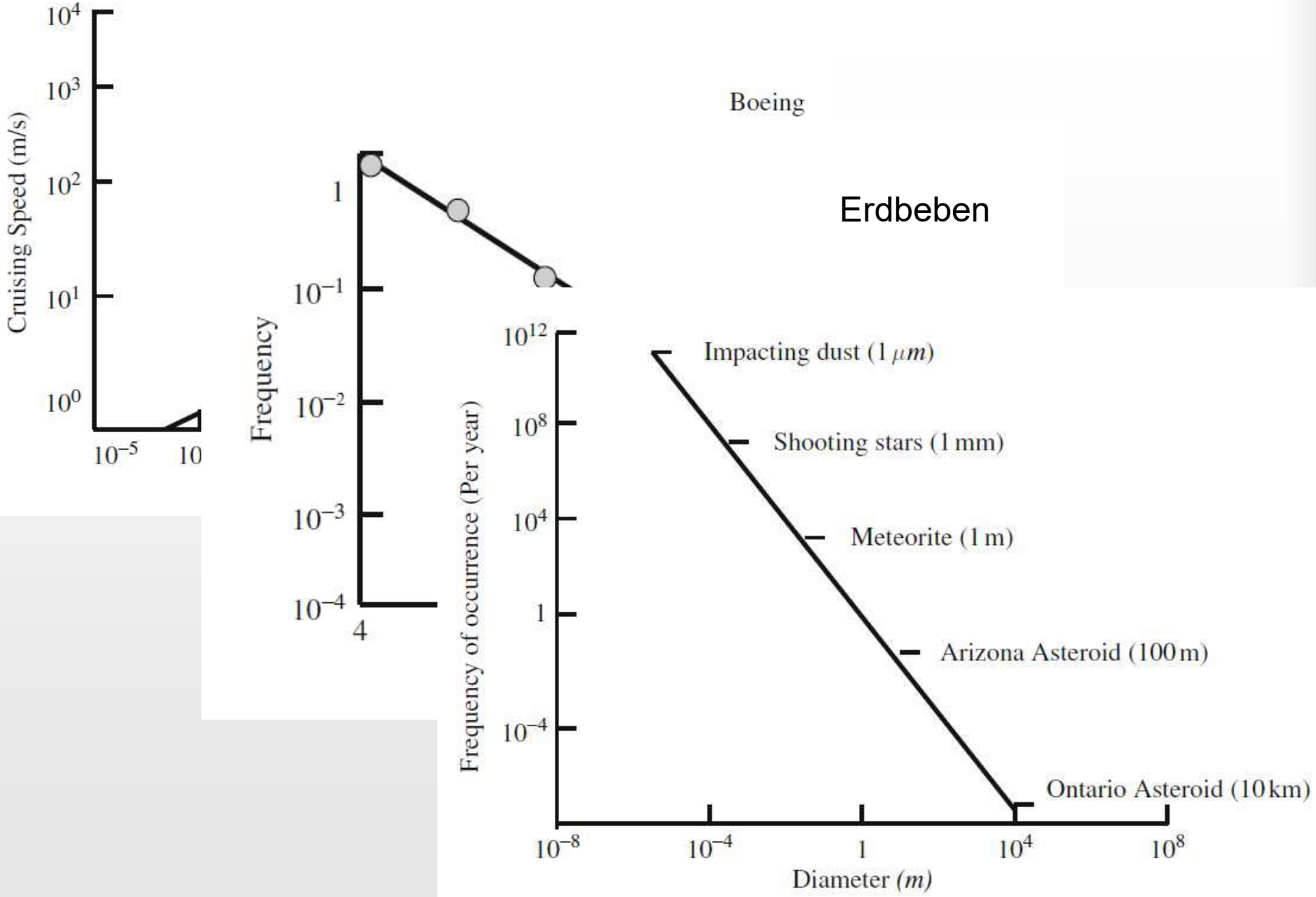


- you have to think how much work needs to be done to increase the height by e.g. Δh
- take the work per unit time yields the power, which $\sim L^2$

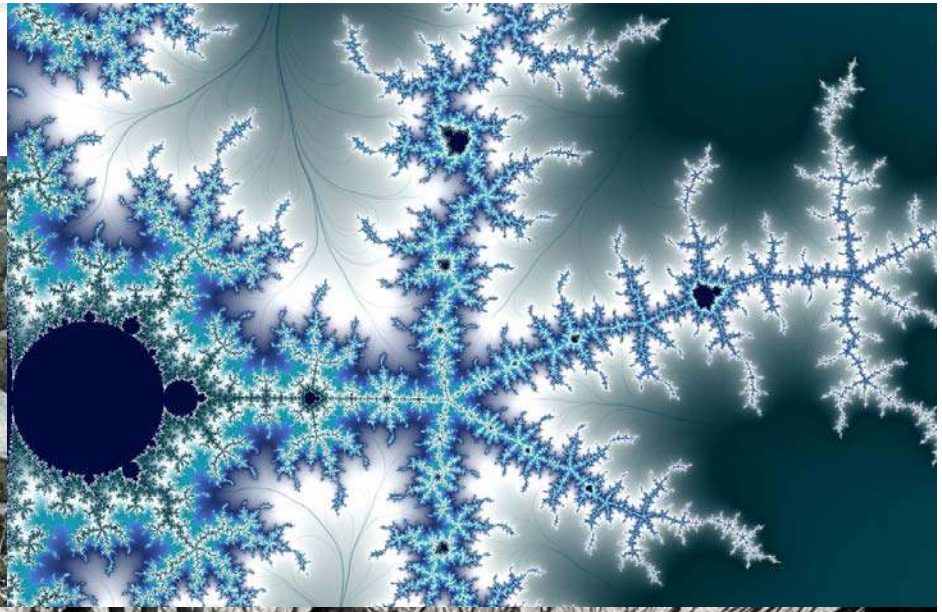
2.3) jump height: how does it scale?

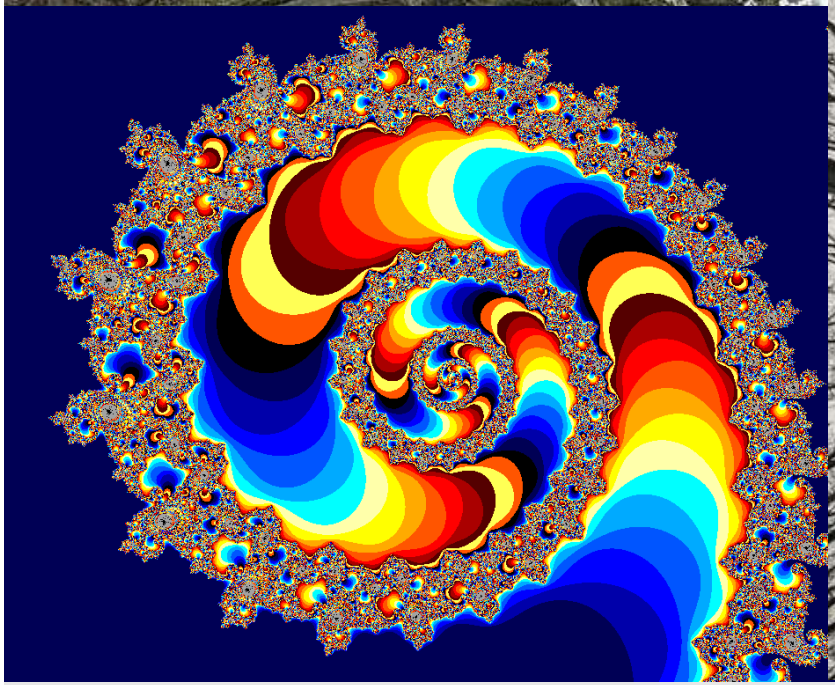


Many more scaling laws in nature



Fractals

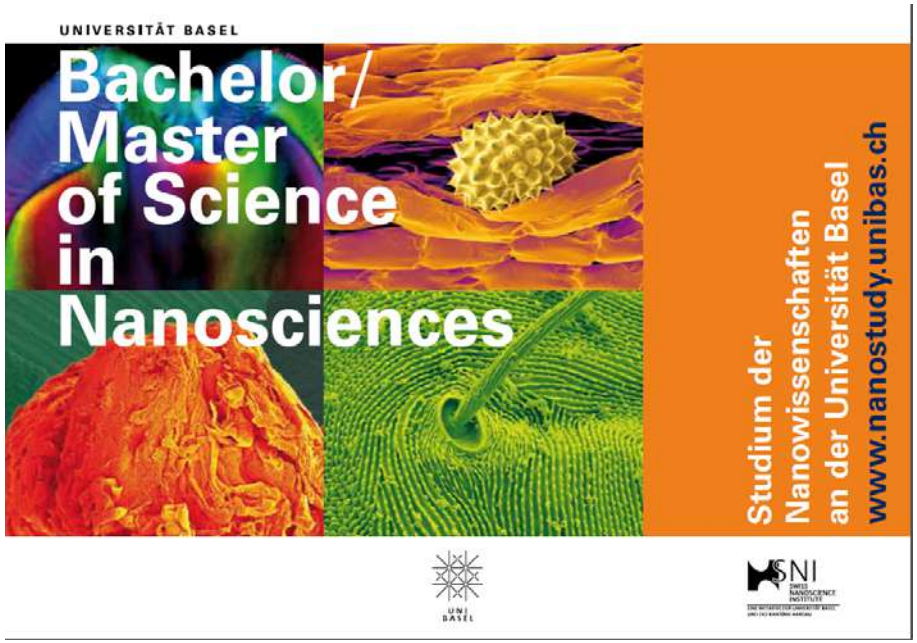




https://nanoelectronics.unibas.ch/wordpress/wp-content/uploads/teaching/What-can-we-learn-from-scaling.pdf

Swiss Nanoscience Institute SNI

Bachelor- & Masterstudies



For us (young people) Nano is attracting, because

- it is dynamic
- many new things are still to be discovered
- its vital for our future (potential and impact)
- it is highly interlinked (interdisciplinary)
- there are opportunities

Nanomaterialien
Farbiges Gol
Verschiedene Form
Woher kommt
Antike Kirchenfenster
Anwendung in der Medizin
Wie funktioniert Medizin heute?
Nanomedizin heute: Trojanische Zwerge
Wie merkt das Medikament, welches die bösen und welches die guten Zellen sind?
Das Medikament wird in einen ganz ganz kleinen Nanocontainer mit „Eisenhaken" verpackt. Die Krebszellen sind im Gegensatz zu gesunden Zellen sehr hungrig auf Eisen und schnappen sich die Eisen-Nanoteilchen und damit die eingepackten Medikamente. Das Medikament sammelt sich also in den Krebszellen und bekämpft diese, sodass nur sehr wenige gesunde Zellen zu Schaden kommen. Zudem kann man mit Hilfe eines MRI genau sehen, wo sich die vielen Eisen-Nanoteilchen befinden und kann den Krebs gezielt z.B. mit Strahlung bekämpfen.
Im Kampf um Troja versteckten sich griechische Krieger in einem Holzpferd. Die Bewohner von Troja zogen das Pferd in ihre Stadt und in der Nacht konnten die versteckten Krieger von innen angreifen und den Krieg gewinnen.
2'000'000 x vergrössert
2'000'000 x vergrössert
2'000'000 x vergrössert

Swiss Nanoscience Institute
(look for it on youtube)
ELISE AEBY
Studentin der Nanowissenschaften
Universität Basel