Biomaterials

Biomaterials, Biomechanics, Biomimetics and more…
understanding “Bio”

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1920 Nieuport 17/23 Scout

Drugs in the 1920s, looked like this…

1960 Tupolev Tu-134

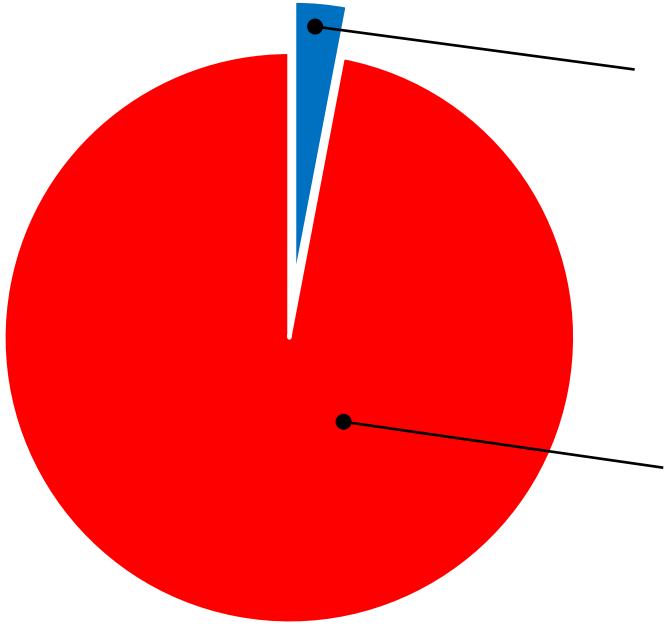
Drugs in the 1960s, looked like this…

Drugs today, looked like this…

So, what is wrong with medicine?

There are about 30.000 diseases known to humans… of those 75% have no treatment what so ever (!) and it gets worse…

If we look at all pharmaceutical inventions since 1945…

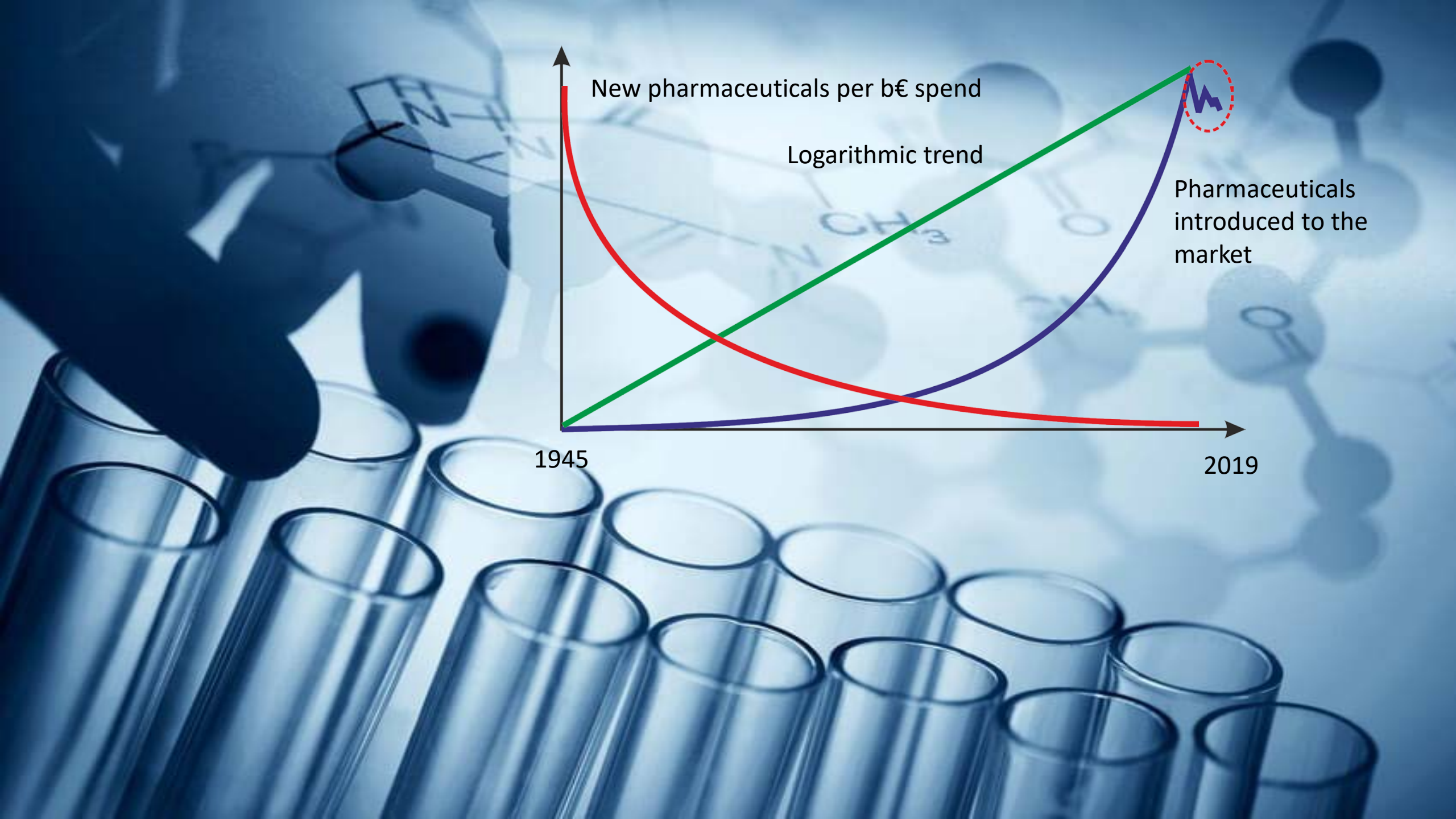


… only 3% are cures
(mostly antibiotics)

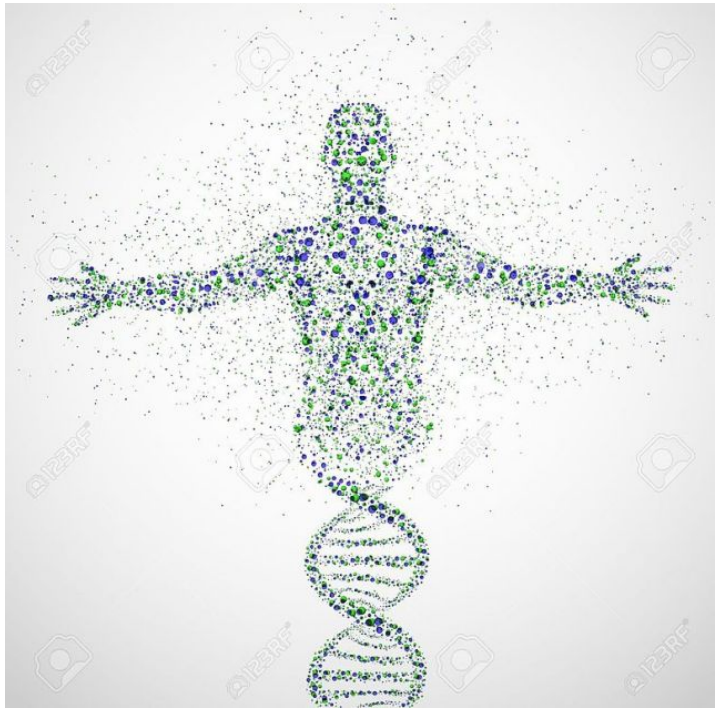
The remaining 97% just treat symptoms!
(duct-tape analogy)

And again, it gets worse…

The peak for pharmaceutical inventions to the market was in 2010… we are at the end of their s-curve!

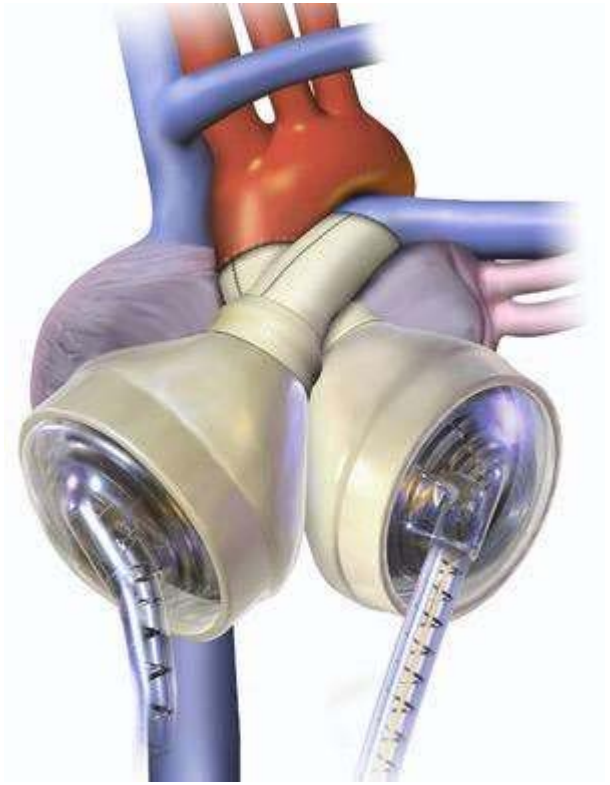

New pharmaceuticals per b€ spend
Logarithmic trend
Pharmaceuticals introduced to the market
1945
2019

Pharmaceuticals vs. Genetics vs. Duct-tape

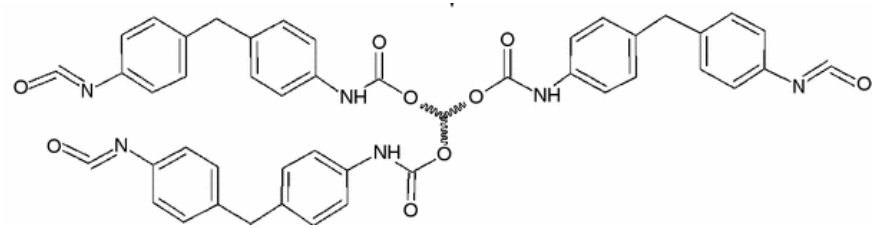


How do materials get into medicine?

Artificial Heart



Polyether Urethane

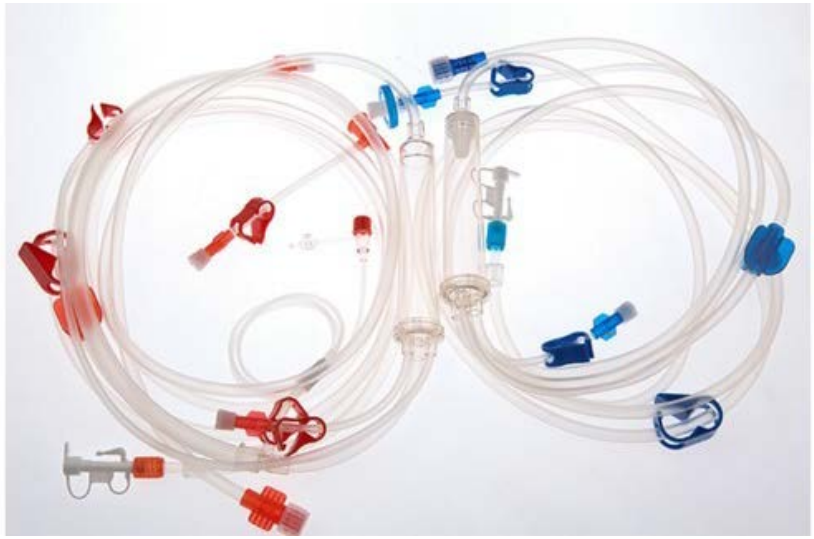


polytetra- fl uorethylene (ePTFE)
bovine pericardial tissue processed in glutaraldehyde

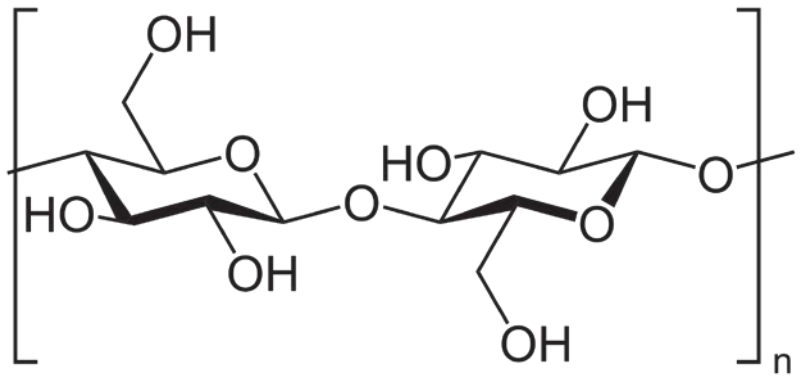
Ladies Gridles
(1967)

How do materials get into medicine?

Dialysis tubing



Cellulose



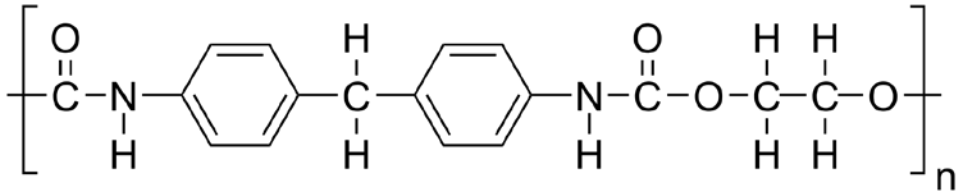
intestines!

NOW… artificial semi-permeable membrane
(molecular-weight cutoffs)

How do materials get into medicine?

Breast implants

Polyurethane



Mattress stuffing

NOW… crazy sophisticated silicones

Today we work the other way around:

- What concepts should the material fulfill from an
  - ✓ an engineering standpoint
  - ✓ a biological standpoint &
  - ✓ a chemistry standpoint
- If we can't find these properties in existing materials, can we synthesize them?

Creative vs. Mental capacity
on a scale of 1-10

Biomaterials

Robert Langer
(1 of 10 Institute Professors at MIT)

Biomechanics

Walter Herzog
(University of Calgary)


Death Valley (CA, USA)


2005 Super Bloom

Citius, Altius, Fortius

(Faster, Higher, Stronger)

Athletes are doing so very effectively, records are broken constantly and Humans are evolving at an unprecedented pace…

Armin Hary (1960)

We are still (without a doubt) the same species…
So what changed?

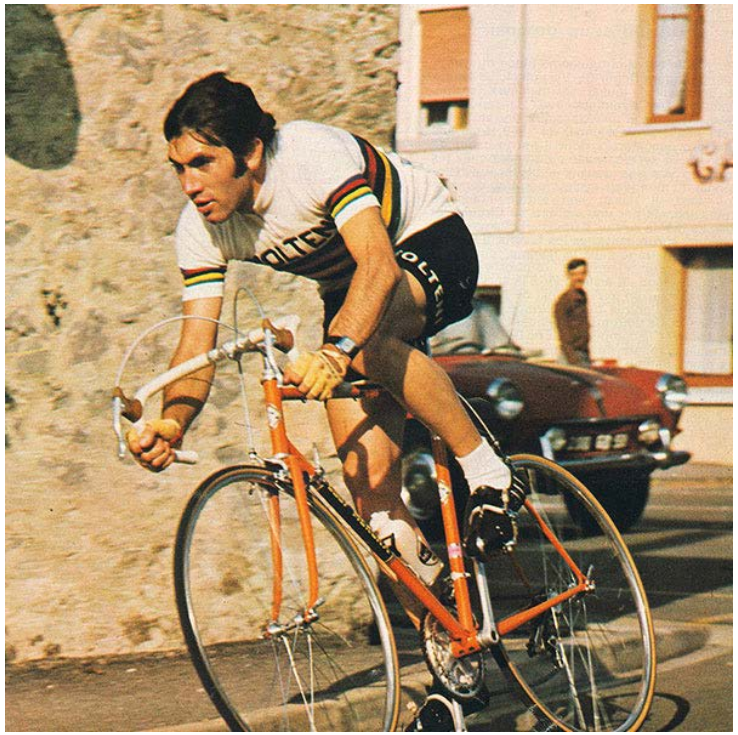
Some new guys joined the game:

- Bio-mechanists
- Bio-engineers
- Bio-chemists

Let's look at some examples of why we need an different point of view in Biomechanics let's see what you can spot…

Usain Bolt (2016)

1972



Eddy Merckx set a 49.43 km record (longest distance cycled in 1 hour)

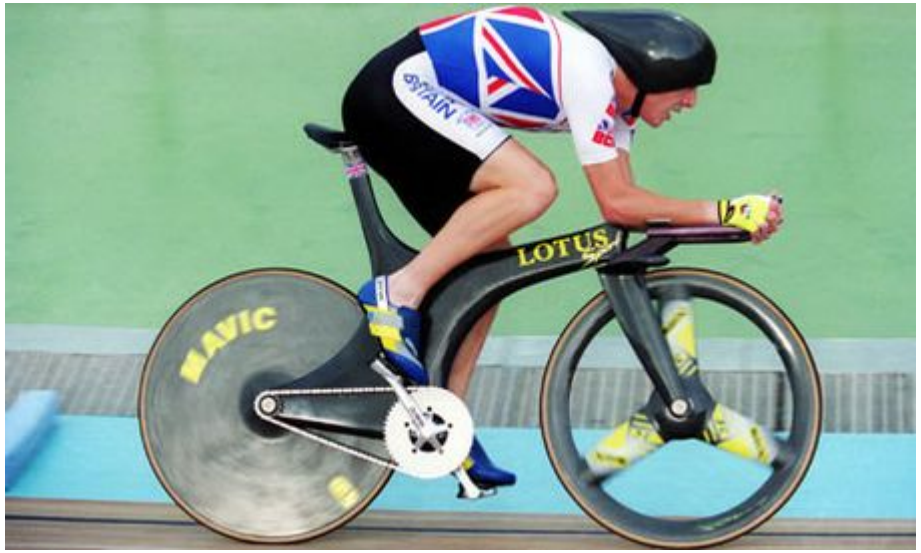
In 1997 the Union Cycliste Internationale (UCI) restricted competitors of the "**UCI Hour Record**" to roughly the same equipment as Merckx, banning time trial helmets, disc or tri-spoke wheels, aerodynamic bars and monocoque frames. Standing records which modern equipment were classified under "**Best Human Effo**rt"

How do you think this affected the UCI Hour Record?

In 2000, Boardman attempted the UCI record on a traditional bike, and rode 49.44 km…

1984
Francesco Moser
51.15 km

1996

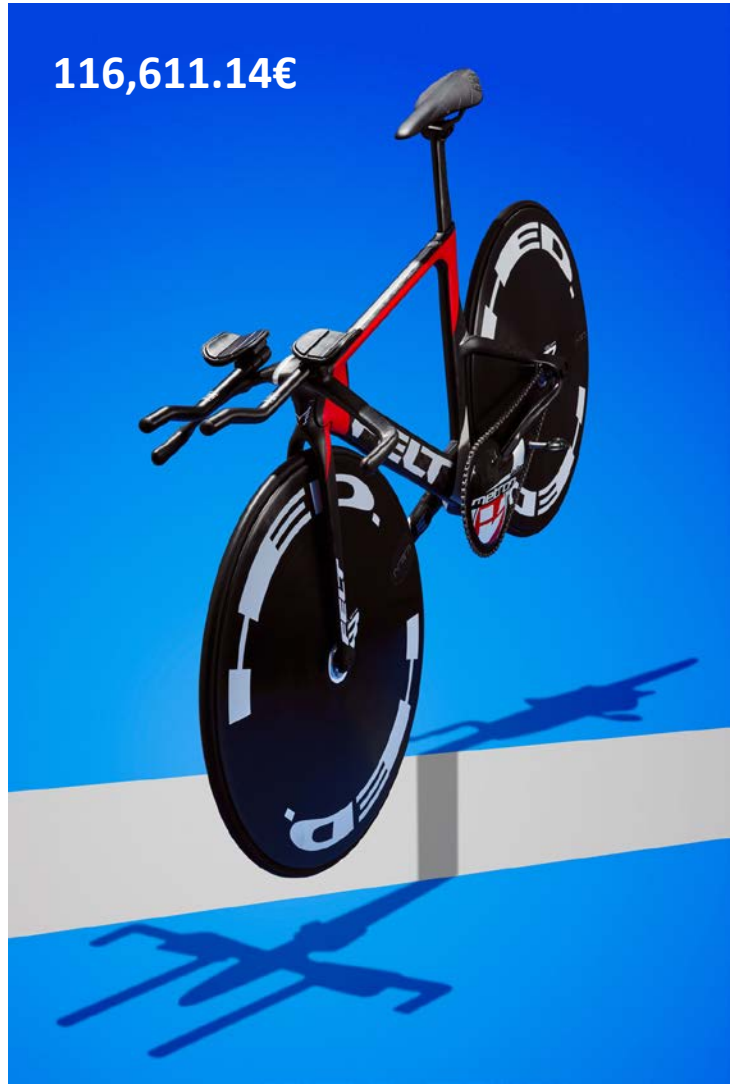


Chris Boardman challenged the record with 56.37km

His record was never broken!

But the "superman" position was banned.

- Merckx became a legend to live by, his record was only topped by a max. of 270m in 2015 (Ondřej Sosenka).
- However, Sosenka failed a doping control (2001 & 2008) and used a 54×13 gear on his bike!
- The UCI however realized that maintaining records for decades is bad for the sport, which became unpopular!
- So, in 2014 the UCI unified the two classifications into a single one, allowing track pursuit bikes…



<u>Are track pursuit bikes considered Biomaterials?</u>

<u>NO,</u> but they involve a lot of biomechanics and engineering!

- The frame is also asymmetrical (left-leaning)
- The bike's drivetrain on the left side (to reduce drag)

Just these 2, result in 125 fewer grams of drag, which roughly translates to 4' on the Track!

What about aero helmets that are 3D laser scanned to bicyclist's head! Skin suites, shoes….

It's all about money!

Talent

IT

Biomechanics

In 1954, Sir Roger Bannister became the first man to run 1 mile below 4minutes

Today

- Runners propel themselves out of blocks
- We have engineered track surfaces (not cinder ash)
- etc.

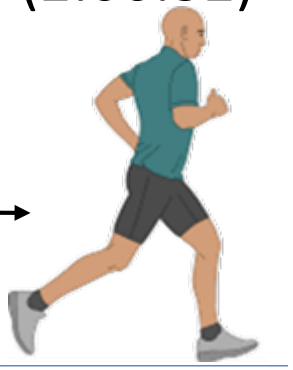
As a result, most athletic college scholarships in the US, have a sub-4 mile as a perquisite!

1904 winner of the Olympic Marathon (3:28:53)

He drunk rat poison and brandy as a performance enhancing drug!

Care to guess what such caliber athletes use?

2008 winner of the Olympic Marathon (2:06:32)



more than 1 hour 20 min

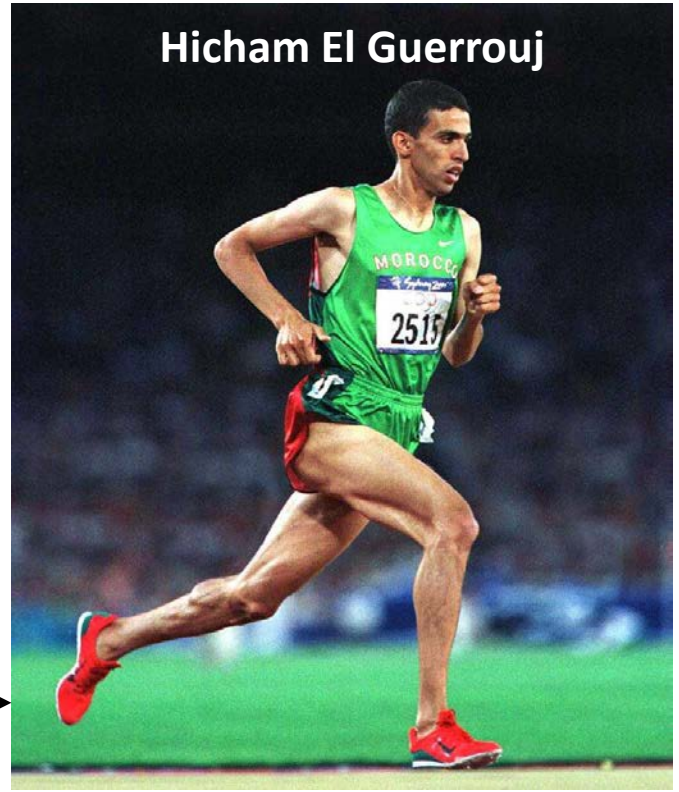
Sure, performance enhancing drugs have had an influence on records in some sports… engineering has had an impact on all of them! And so has our gene pool…

- The average female gymnast shrunk from 163cm to 144cm!
- The average NBA player got over 213cm
- The swimming world is dominated by athletes with large torsos whereas
- The running world by those with thin and large legs!

← 193cm

…yet they wear the same size of pants!

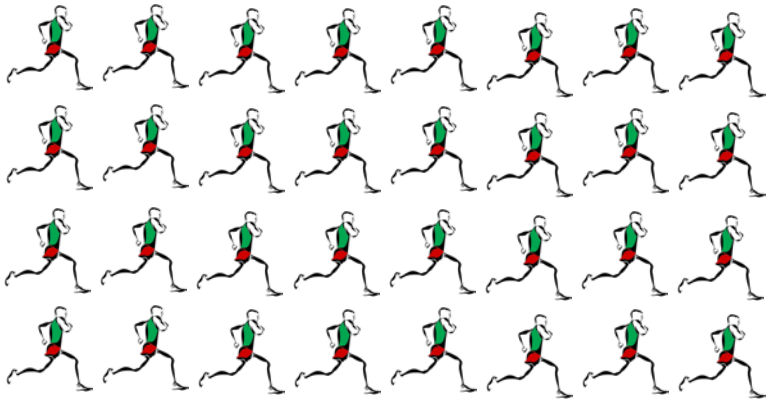
176cm →



2:10 time barrier

The quest for body types introduced new populations to sports e.g. Kalenjins

17 Americans in history



32 Kalenjin did the same during…

marathon

Out of the 10’ crunched-off the WR over the course of 50 years… 5’ are due to 3 events!

Can anyone guess what these were?

1956

Before that:

- Goggles revolutionized swimming
- Shaving body hair did too!
- etc.

1976

2008

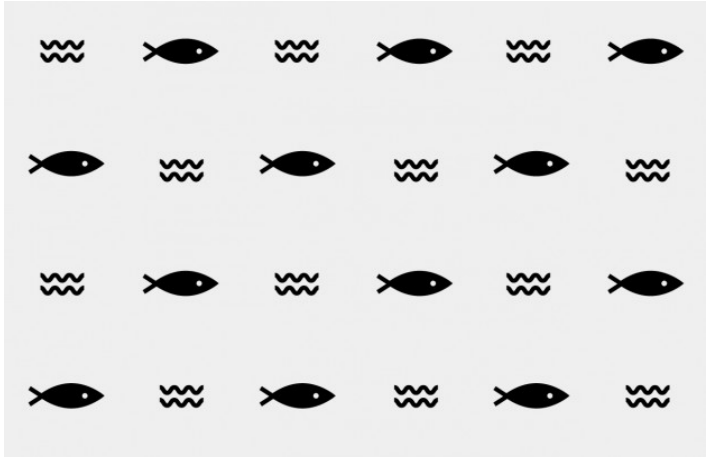
Are “shark-suites” biomaterials?
No, but they are bio-mimetic structures and fall by extension into *your field of expertise*!

Design a Bio-application vs. Design any application “inspired” by Bio

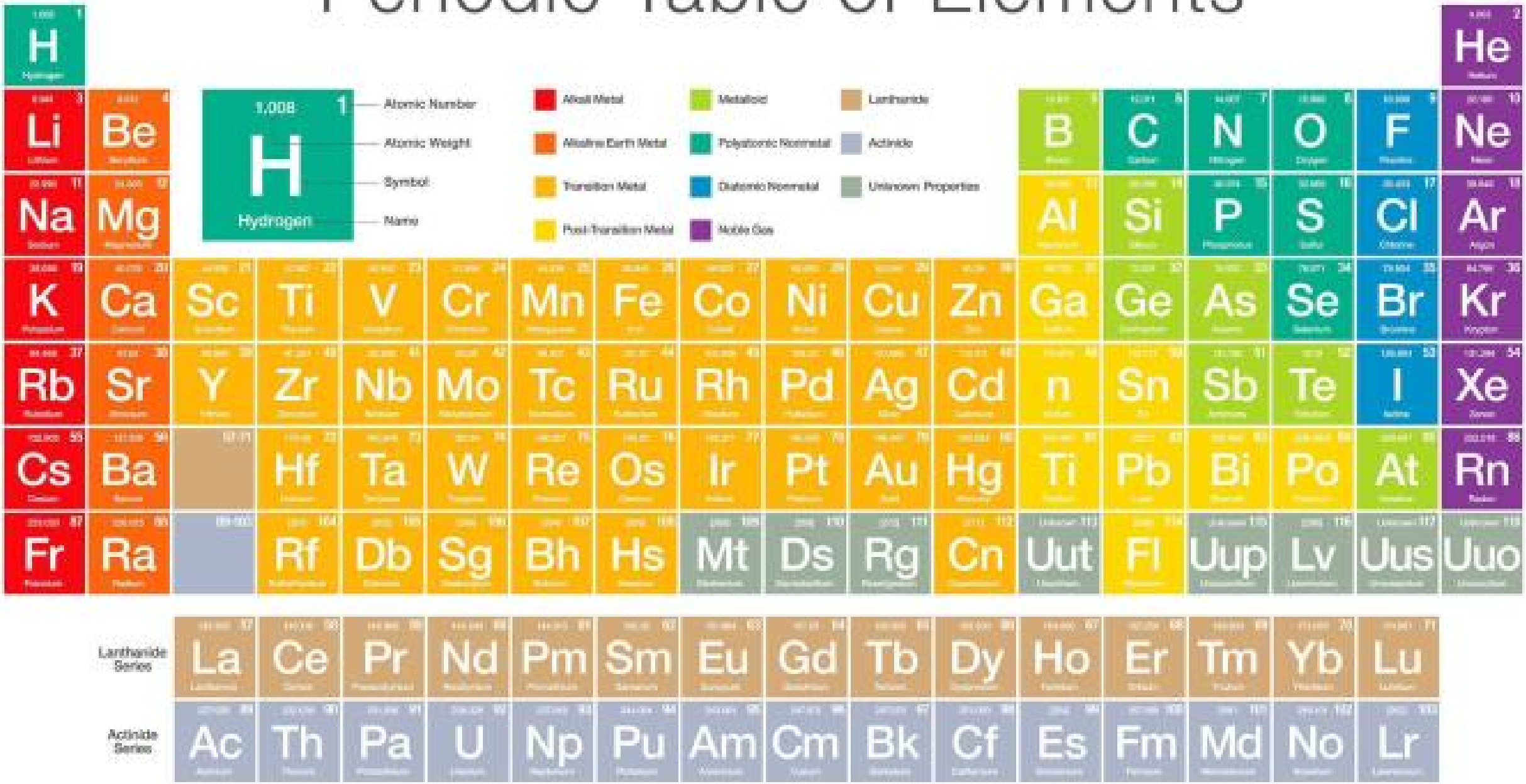
“99.7% of design engineers have never taken a Biology class… so the people who design our world are novices… in how it works!”

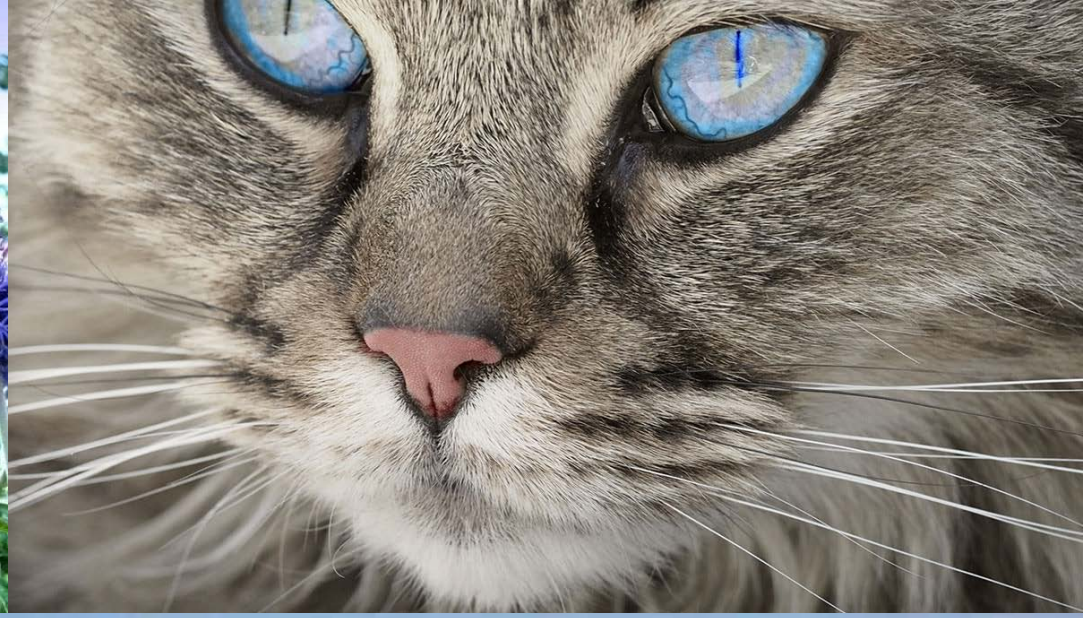
Copy Shark-skin topography to create antibacterial surfaces of optimize flow patterns

Use fish swim patterns to optimize wind energy placement in windmill parks!

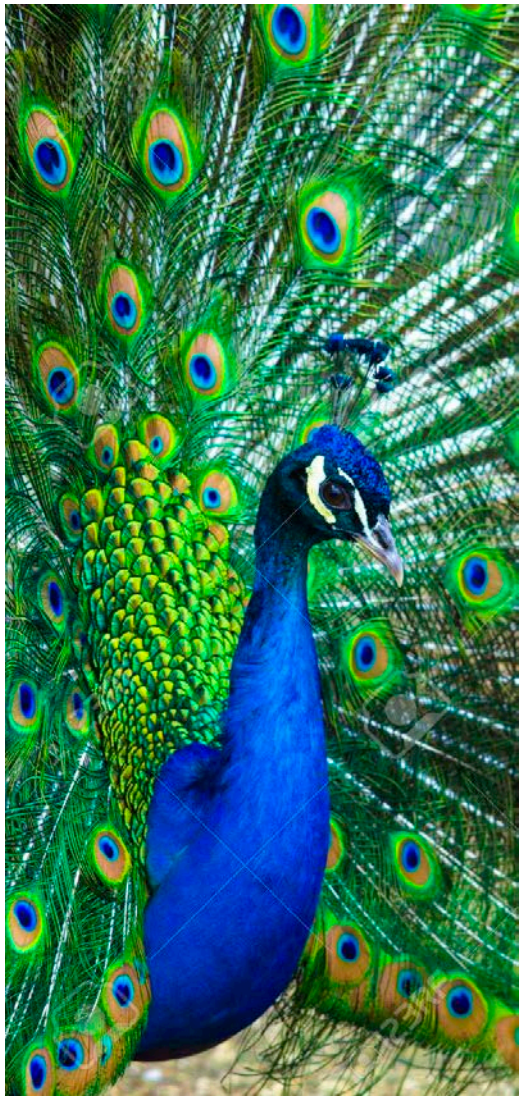


Periodic Table of Elements



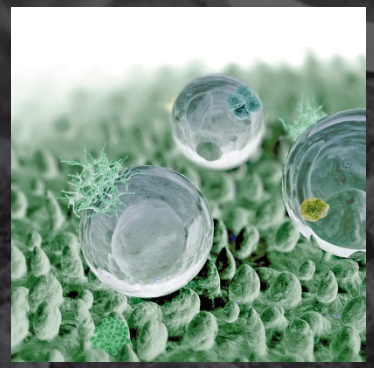


Material vs. Structure



Lotus effect:
Nanoscopic hair traps
a thin film of air that liquids
cannot penetrate.

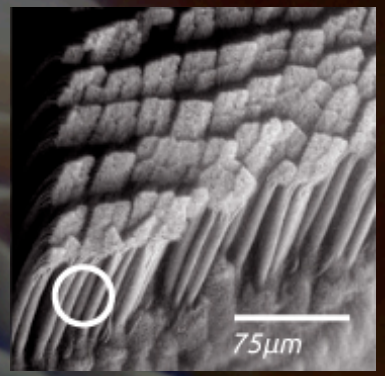
Hydrophobic
and self-cleaning!



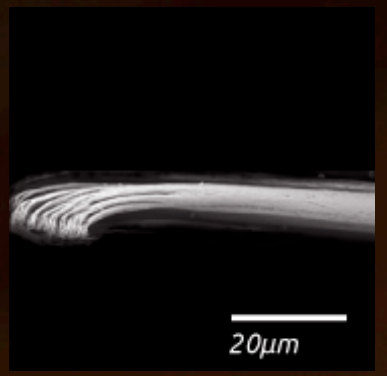
Adhesive Lamellae

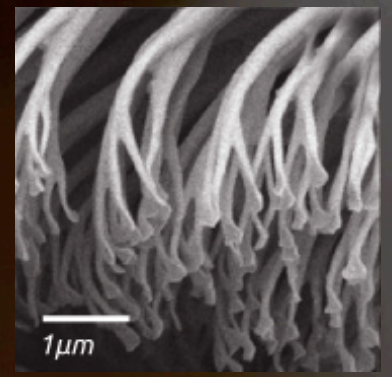
macro-

meso-



micro-





nano-

1989

Shinkansen train 100 series (≈270km/h)

1997

Shinkansen train 500 series (≈300km/h)