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Meeting of Modern Science and School Physics: College for School Teachers of Physics in ICTP

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How biology can help to teach physics

Konstantin Bogdanov
How biology can help to teach physics
Moscow
Russian Federation

Meeting of Modern Science and School Physics:
College for School Teachers of Physics in ICTP
the Abdus Salam International Centre for Theoretical Physics
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Dr. Konstantin Bogdanov, Ph.D.

How biology can help to teach physics

One-hour lecture

Slide 1.

Teachers tell us "If you want to know physics, you have to read textbook and solve problems". Our teachers are right. However, a lot of physical phenomena surround us – rain, thunderstorm, wind and so on. Our life also can be considered as a complex interaction of physical phenomena. Therefore we can study physics explaining life phenomena. Let's do it!

Everyone knows that we need oxygen to live. Oxygen is delivered into our body when we inhale. Oxygen is needed to support combustion in our body. Oxygen interacts with meal inside our body producing heat. As a result, our temperature is always higher than ambient one.

Slide 2.

The heat is continuously produced inside our body even when we are sleeping or sitting. When we sleep we emit 60 Watts of heat energy. This value is close to heat emitted by lamp used to illuminate a small room. Of course, during activity, for example, walking or running, we emit more heat.

And now surprise! We need a soap in our lungs to breathe. Why?
Before answering the question let's remember a structure of lungs.

Slide 3.

A lung consists of bronchial tubes (bronchi) and small balloons (alveolas) located at the end of each lung tube. During inhale a fresh air enters each alveola, where oxygen crosses very thin membrane of alveola and goes to blood. As a result, the blood flowing out lung contains more oxygen and has red color.

So, during every inhale (10 times per minute) we have to expand all our millions alveolas. Otherwise we have no oxygen to live. It's a very hard work. To make the work easier, soap molecules are produced in lungs.

Slide 4.

Everyone can produce soap bubbles. It's very easy to expand the soap balloons. This is because soap molecules decrease a work needed to expand the bubbles.
Presentation: If somebody never produced soap bubbles, come here and do it!

Slide 5.

To make breathing easier, molecules which are similar to soap molecules are produced inside our lungs. These molecules are named as **surfactants**.

Slide 6.

During some diseases a production of surfactants is decreased and this is very dangerous for patients. It's difficult for them to breathe and they can even die. One of treatments of the diseases – to inhale artificial surfactant. Firstly, an aerosol containing the surfactant is prepared and then it is inhaled.

O.K. Now we have lot of soap inside our lungs. Let's go to Olympic games for records!

Slide 7.

What does counteract us when we try to set up a new record?
Firstly, what does push us forward? Can we run without touching ground? No, we can't, of course. Can we run fast on ice? No, we can't. This means that a force of friction is a force pushing us forward!

Now, let's answer a main question – "What does counteract us when we run?". Answer is very simple – air resistance! Air molecules counteract us when we try to set up a new Olympic record. To run faster we have to decrease air density. For example, if air pressure decreases by 20%, we can run 100 m almost 0,2 sec faster than at normal air pressure. Keep in mind, during aircraft flights air pressure inside a cabin can decrease to almost 50% of normal. So, aircraft cabin is a best place to set up new records in running.

So, firstly we conclude that oxygen molecules give us heat, and then the same molecules counteract our running.

We have enough soap in lungs not only for running. Let's try to jump higher. Can we calculate a maximal height of jump? Firstly, let's answer question – where does energy needed for the jump come from? Let's jump!

Presentation: As you can see, nobody can lift mass center of own body even by half a meter.

Slide 8.

What is a cause of our inability to jump higher? How can a jumper lift own body on 5-meter height? To answer the question let's play back this pole vault.

Slide 9.

If you want to jump higher you have to take a run. Your kinetic energy (*KE*) is increasing with velocity V of running as $mV^2/2$, where m – mass of runner. When a runner puts its pole in ground whole kinetic energy goes into elastic potential energy of bended pole. When the pole is unbended, the jumper is lifted and elastic potential energy of the pole is transformed into gravitational potential energy (*PE*) of lifted jumper: $PE=mgh$, where g – free-fall acceleration, h – height of jump.

According to principle of conservation of energy, a kinetic energy of jumper after the run should equal to gravitational potential energy of lifted jumper. From this equation follows that a maximal height of jump corresponds to maximal speed of running. Assume that you Olympic winner in 100 m sprint and can run at speed of 10 m/sec. Then a maximal height of your jump with a pole will be about 5 m.

Slide 10.

Thus Olympic record in 100 m sprint is linked to record in pole vault. Russian Olympic winner Elena Isinbaeva set up a record in pole vault – 5.06 m which is linked to record by American Olympic winner Florence Griffith-Joyner in 100 m race – 10.5 sec. Almost all records are interlinked because they are set up on the Earth with its gravity and atmosphere.

Slide 11.

Most of us are considering Spiderman as a fantasy. It's impossible for man to climb such a slippery vertical surface. But, how about house fly?

Slide 12.

Now scientists think they have the answer — hairs. Using microscope, scientists discovered hundreds of thousands small hairs on the feet of fly. The researchers think the force that allows flies to climb glass and hang on ceilings is electric force. Other words, this is an attraction between opposite electric charges which appeared on glass and foot of fly after they touch each other. Estimations show that attraction force between fly and glass is 100 times larger than weight of the fly. So, Spiderman could be not so fantastic in future when nanotechnologies will be able to produce millions of special hairs on outer surface of our gloves.

Same attraction takes place between air balloon and glass if the balloon is rubbed against glass before.

Presentation: let's try to demonstrate how our balloon sticks to glass. Firstly, rub the balloon over glass and then touch glass with it.

Slide 13.

Everybody knows that time goes on and window glasses become dirty and this is time to tell you about "Lotus effect". The leaf of lotus is a symbol of purity in many cultures because of its ability to remain clean. Water does not wet a lotus leaf. Lotus leaf repels water and particles of dirt. When rain falls onto a lotus leaf, the drops of water that form on the surface roll off, taking any dirt with them. Lotus leaf repels even a glue. It's impossible to find a glue to stick two lotus leaves together. You see how the drop of glue rolls off.

Slide 14.

Microscope observations reveal that the waxy surface of the lotus leaf is made of micron-sized bumps that, in turn, are covered with nanoscale hair-like tubes. This structure of the leaf traps air under any rain drops that fall on the leaf, creating a surface that efficiently repels water. This is because of the reduced contact area between water and the leaf. In the lotus leaf, the actual contact area is only 2-3% of the droplet-covered surface.

The lotus is of interest to the nanotechnologists. Scientists developed a spray-on coating that mimics the way lotus leaves repel water droplets and particles of dirt. This spray contain nanoparticles. As it dries, the surface becomes self-cleaning and hydrophobic. Look how water droplets do not wet wood surface coated with “Lotus spray”.

I’ve already two times pronounced very popular word “nanotechnologies” during my speech. It’s enough for today. Now let’s move to place where nobody knows what the word “nanotechnologies” means.

Slide 15.

Arctic ocean. White polar bear is sleeping on white snow. But his nose is black. Why?
It’s obviously, that white color of his fur makes him almost invisible on snow and help in hunting. Why does he have a black nose? The black nose may counteract successfull hunting!
To answer the question, let’s move back to people.

Slide 16.

How does the skin tan? Tanning begins the moment you step out into the sun. Most powerful rays of sunlight are called “ultraviolet (UV)”. Ultraviolet rays penetrate the skin and start to break down DNA in nuclei of our skin cells. The DNA is a main molecule of our body. It controls all processes inside us. Tanning is protection of our skin from sun damage.

UV rays penetrate to the lower layers of the skin, where they trigger cells called **melanocytes** (pronounced: mel-**an**-oh-sites) to produce **melanin**. Melanin is the brown pigment that causes tanning.

Slide 17.

Let’s go back to polar bear. Now we are learned that black color of skin is a protection from sun damage. Therefore a nose of polar bear is black. But for what reason a polar bear does not have white hairs on his nose? Who knows an answer? …. Of course, hairs on nose surface will counteracts sense of smell. Molecules signaling, for example, about a seal located somewhere around, will not penetrate into nose openings. The molecules will stick to hairs near the openings. So, polar bear with white hairs on nose is absolutely invisible but has no sense of smell.

Slide 18.

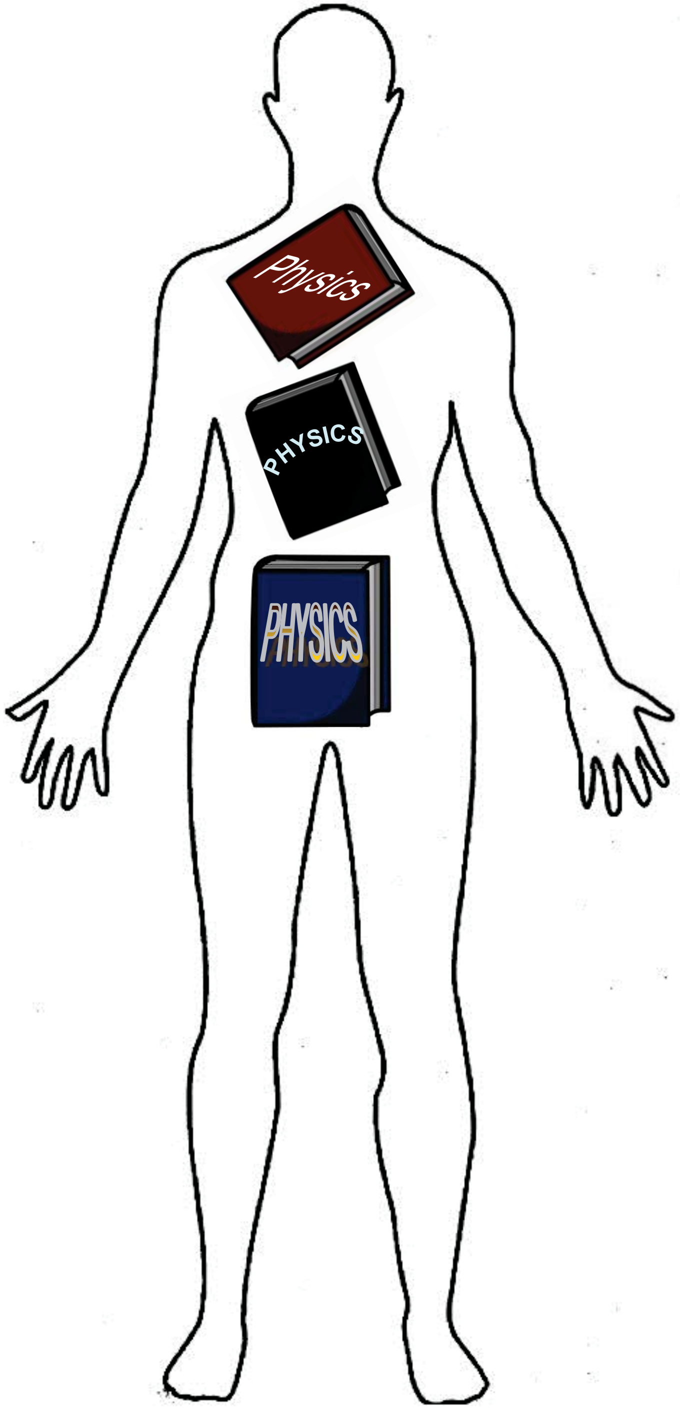
In conclusion, let’s go back to the first slide. Many people think there is not only physics inside us but computer, also. If you agree, please, check it!

Slide 19.

This is very old my photo with classmates made in 1955. Can you find me on the photo. Prize is waiting for you!

Slide 20.

Thank you for invitation to participate the meeting. Best wishes from me and Russia!



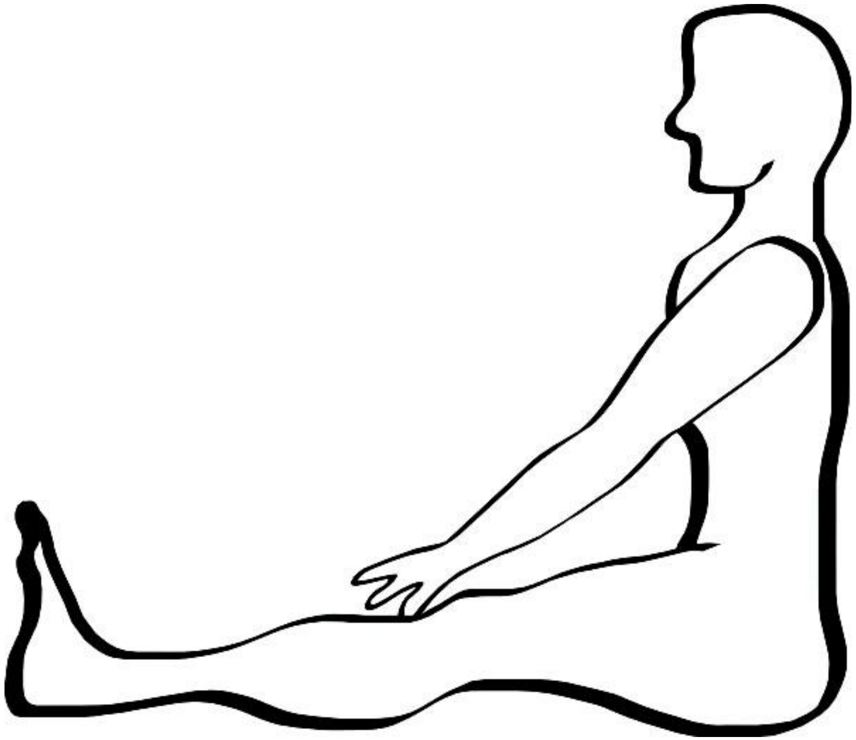
how biology can help to teach physics

Konstantin Bogdanov, Ph.D.,

Lyceum #1586

Moscow, Russia

Human body emits 60-Watt heat



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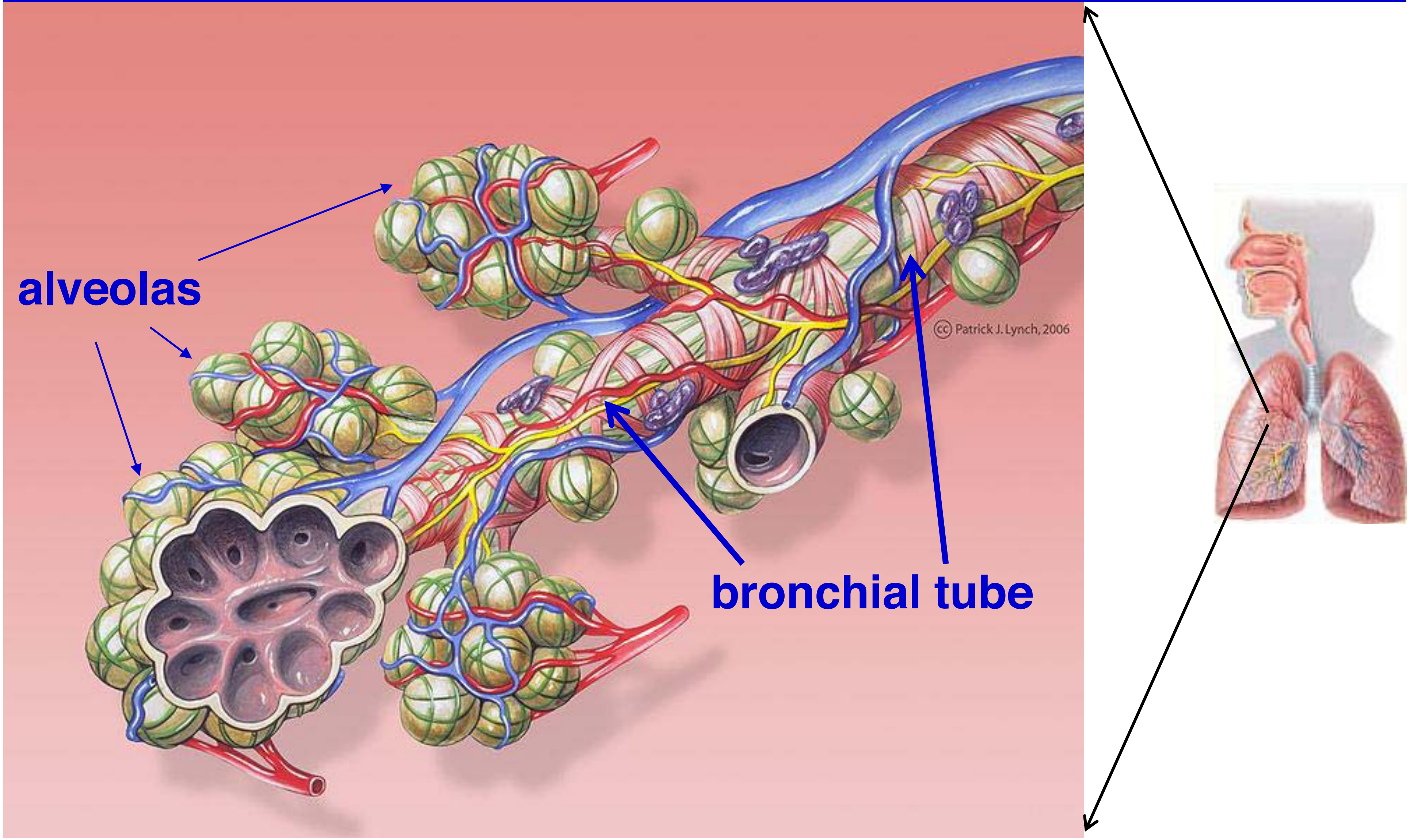
Why do we need a soap in our lungs?

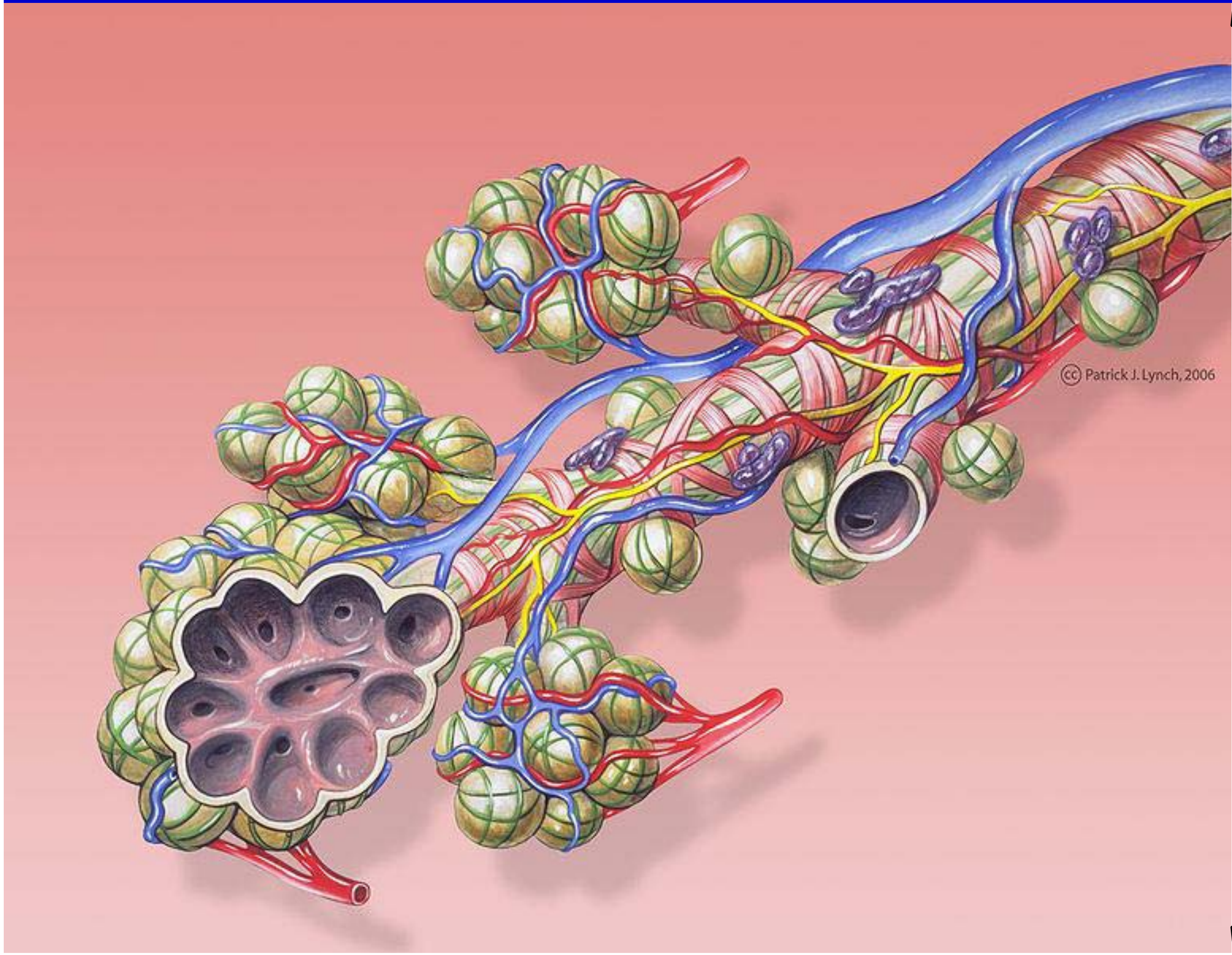
Structure of lung where oxygen goes from air to blood

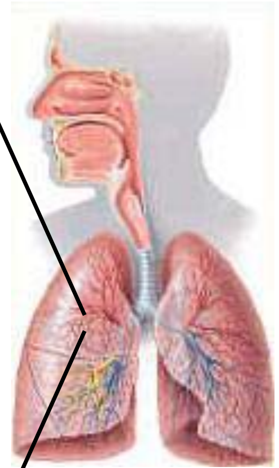


Soap molecules make breathing easier

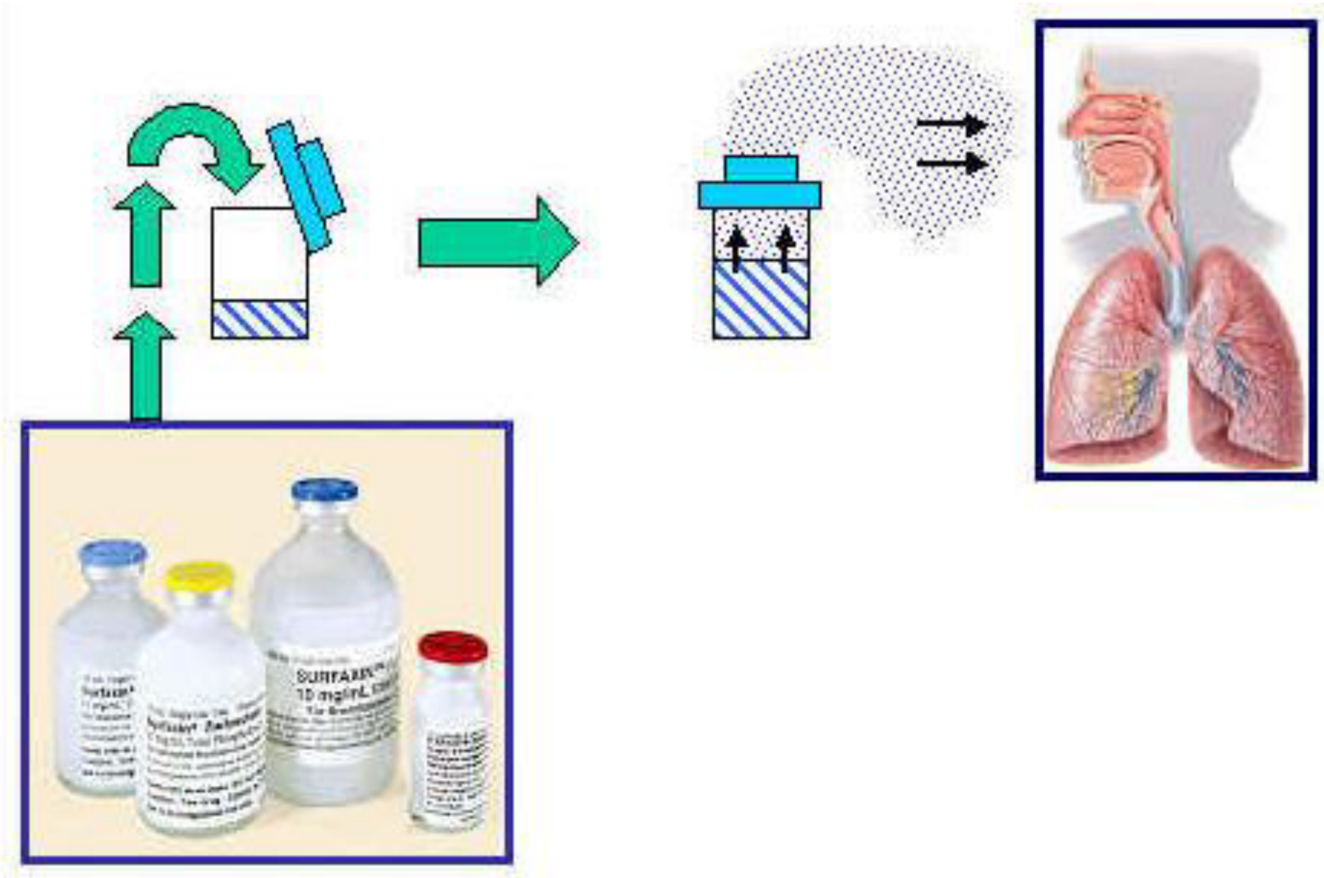
Soap molecules make expanding easier

Surfactants – molecules acting as soap in our lungs

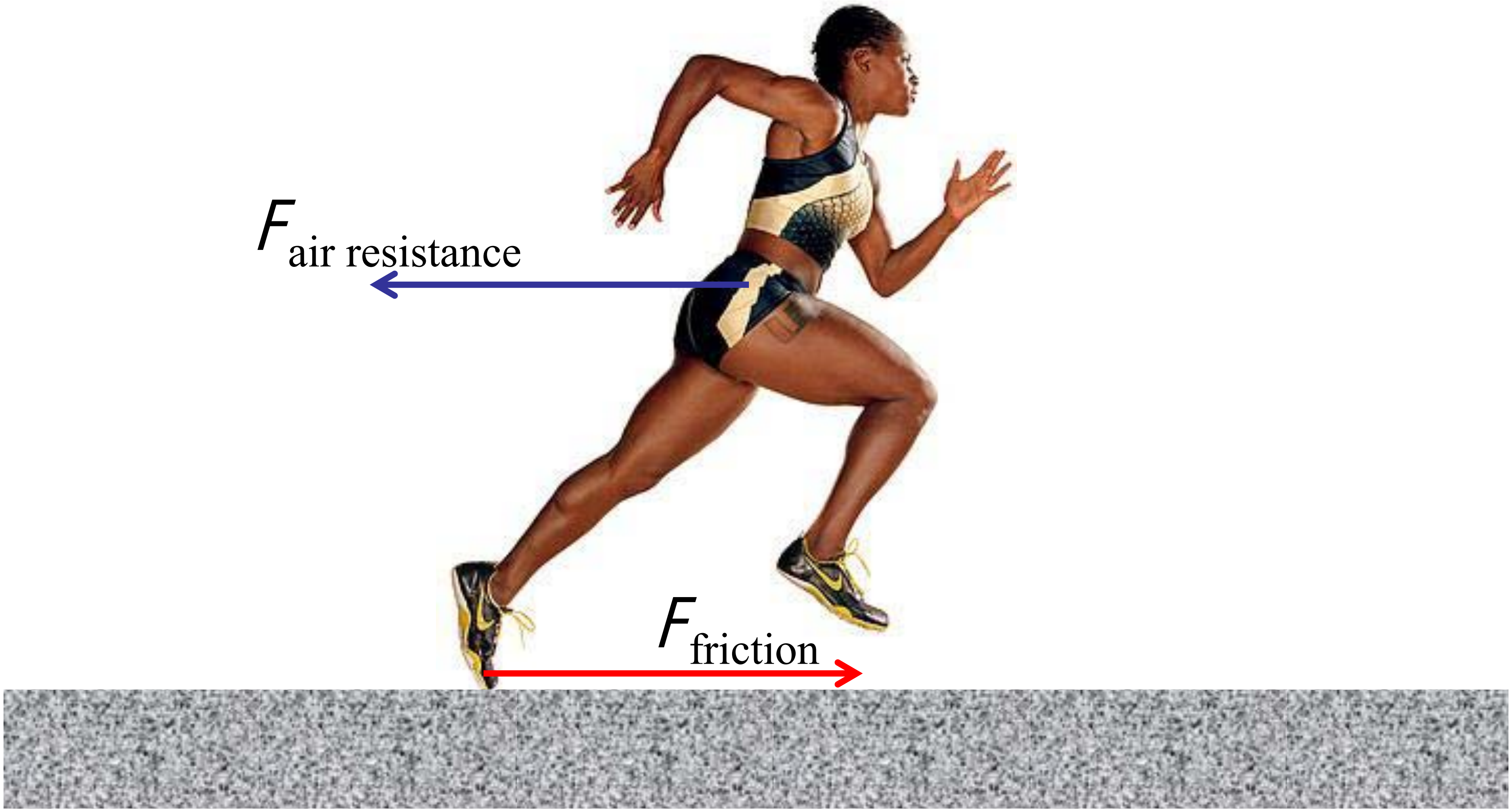




Inhaled surfactant helps treat some lung diseases

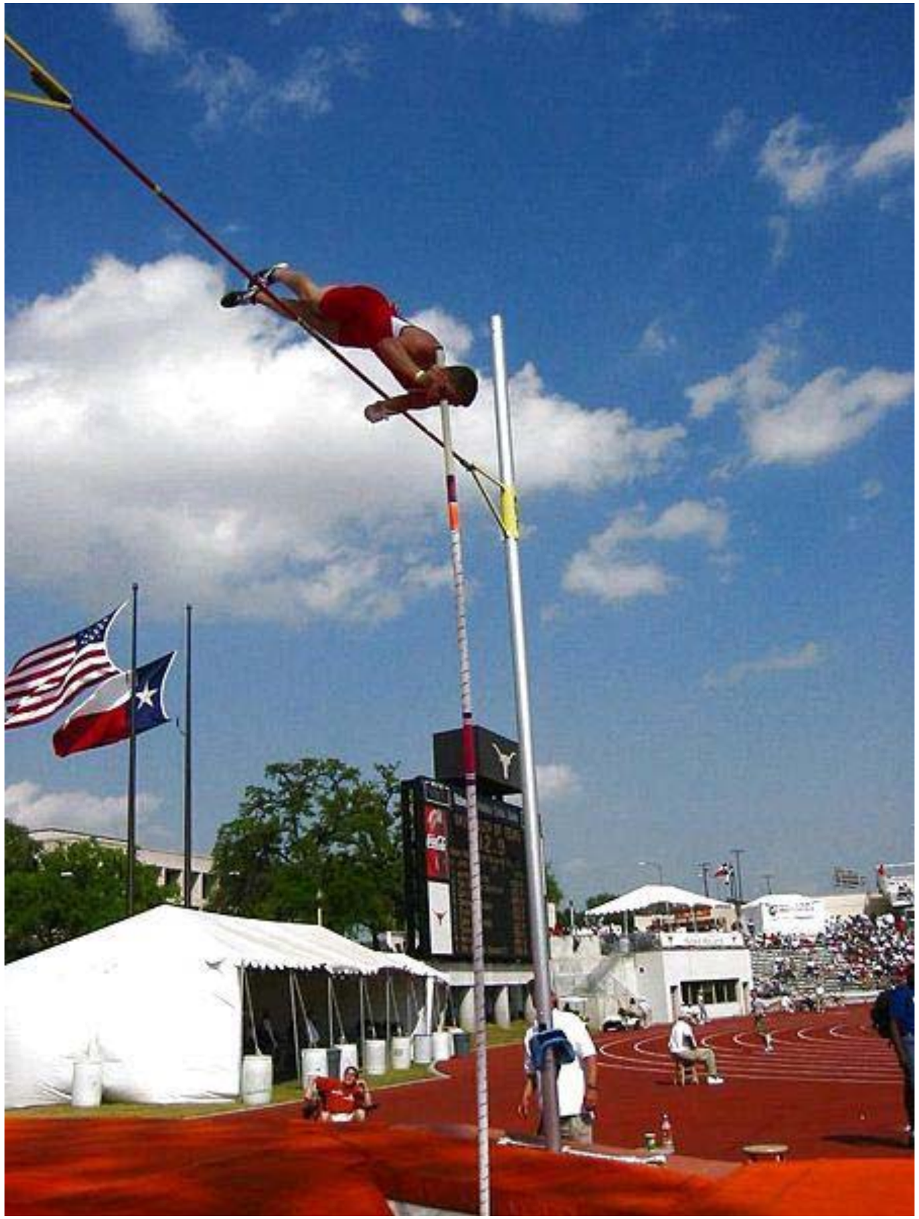


What does counteract us in 100 m sprint?

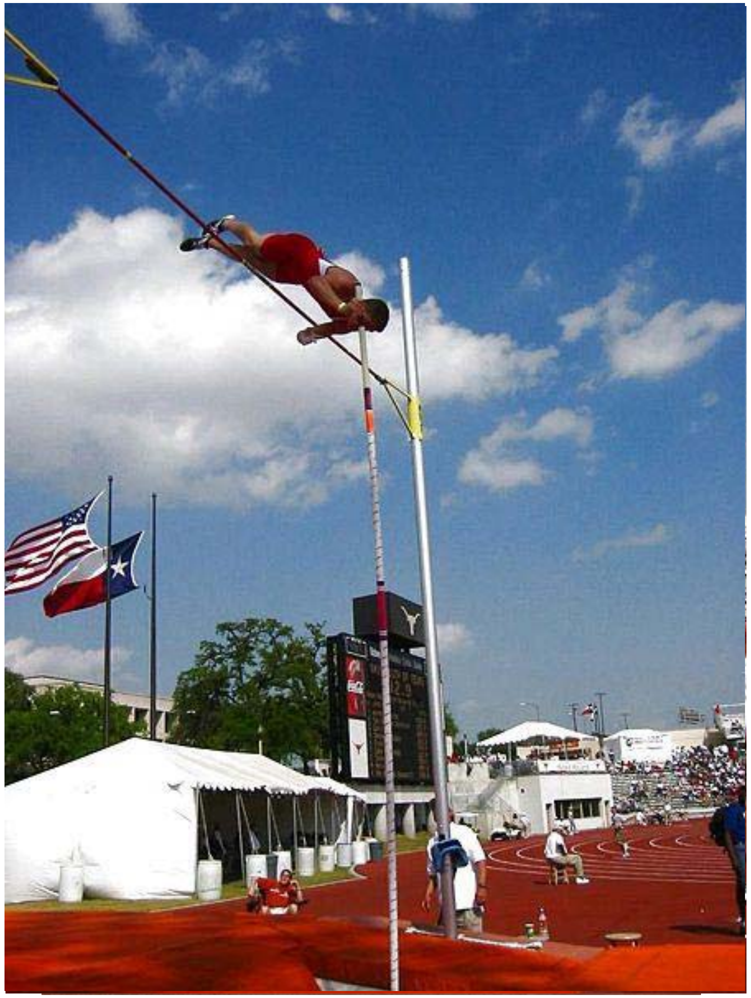


Air molecules give us heat and …
counteract our running

How can a jumper lift own body on a 5-meter height?



How can a jumper lift own body on a 6-meter height?



1. During a run a kinetic energy (KE) is increased as:

$$KE = \frac{mV^2}{2}$$

2. Then a whole kinetic energy goes to elastic potential energy of bended pole

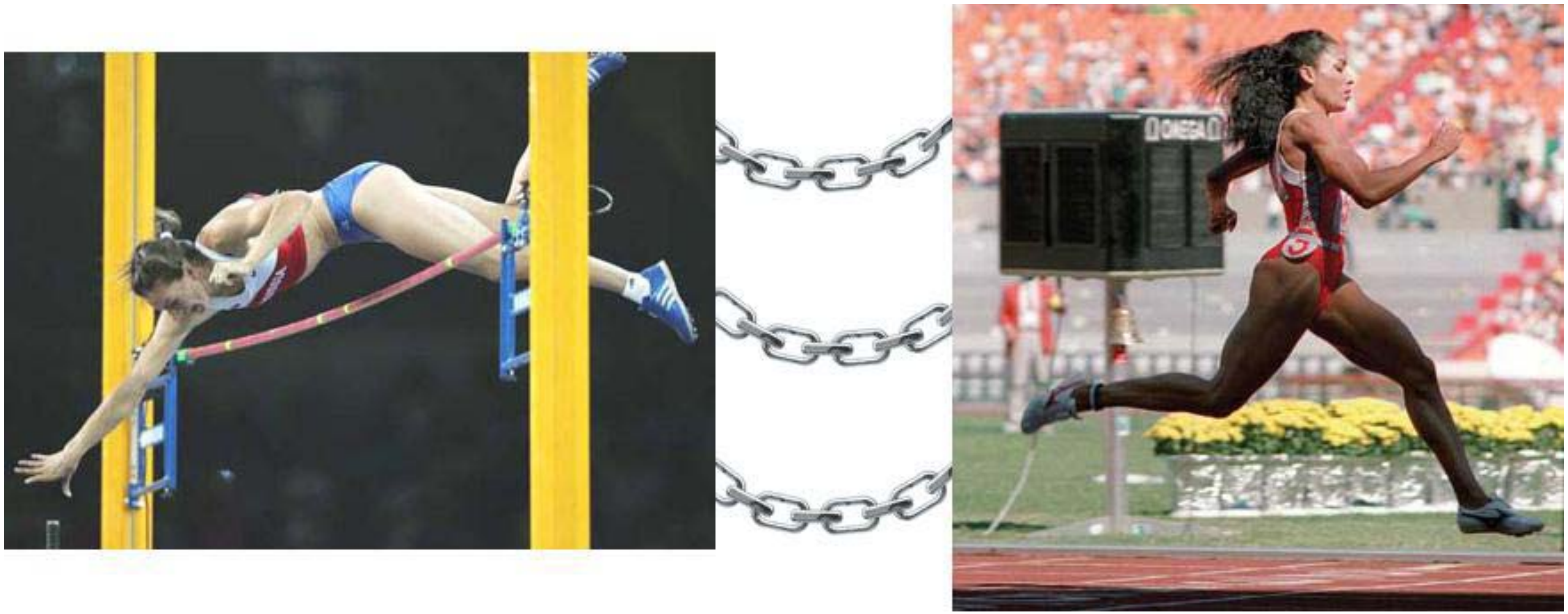
3. Elastic potential energy of bended pole transforms into gravitational potential energy (PE) of lifted jumper equaled to:

$$PE = mgh$$

4. From principle of conservation of energy follows that:

$$\frac{mV^2}{2} = mgh \Rightarrow h_{\max} = \frac{V_{\max}^2}{2g} = \frac{\left(10\, m \cdot s^{-1}\right)^2}{2 \cdot 9.8\, m \cdot s^{-2}} \approx 5\, m$$

Olympic records are linked to each other



Elena Isinbaeva (Russia)

5.06 m

Florence Griffith-Joyner (USA)

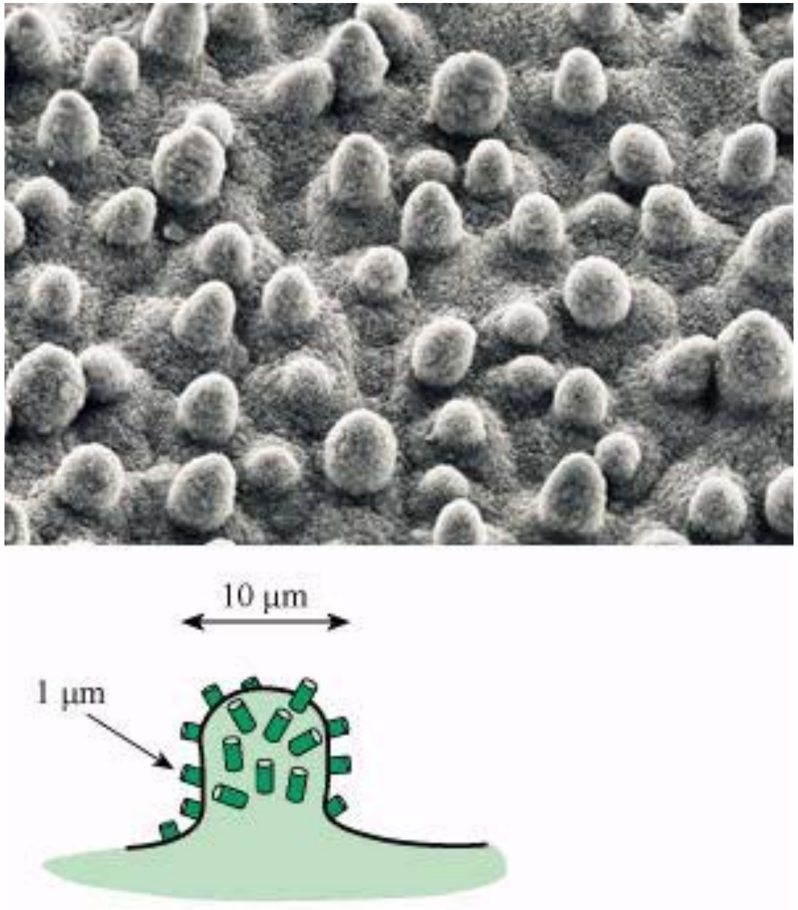
100 m – 10.5 sec

Is Spiderman real?

Is a spiderman real?

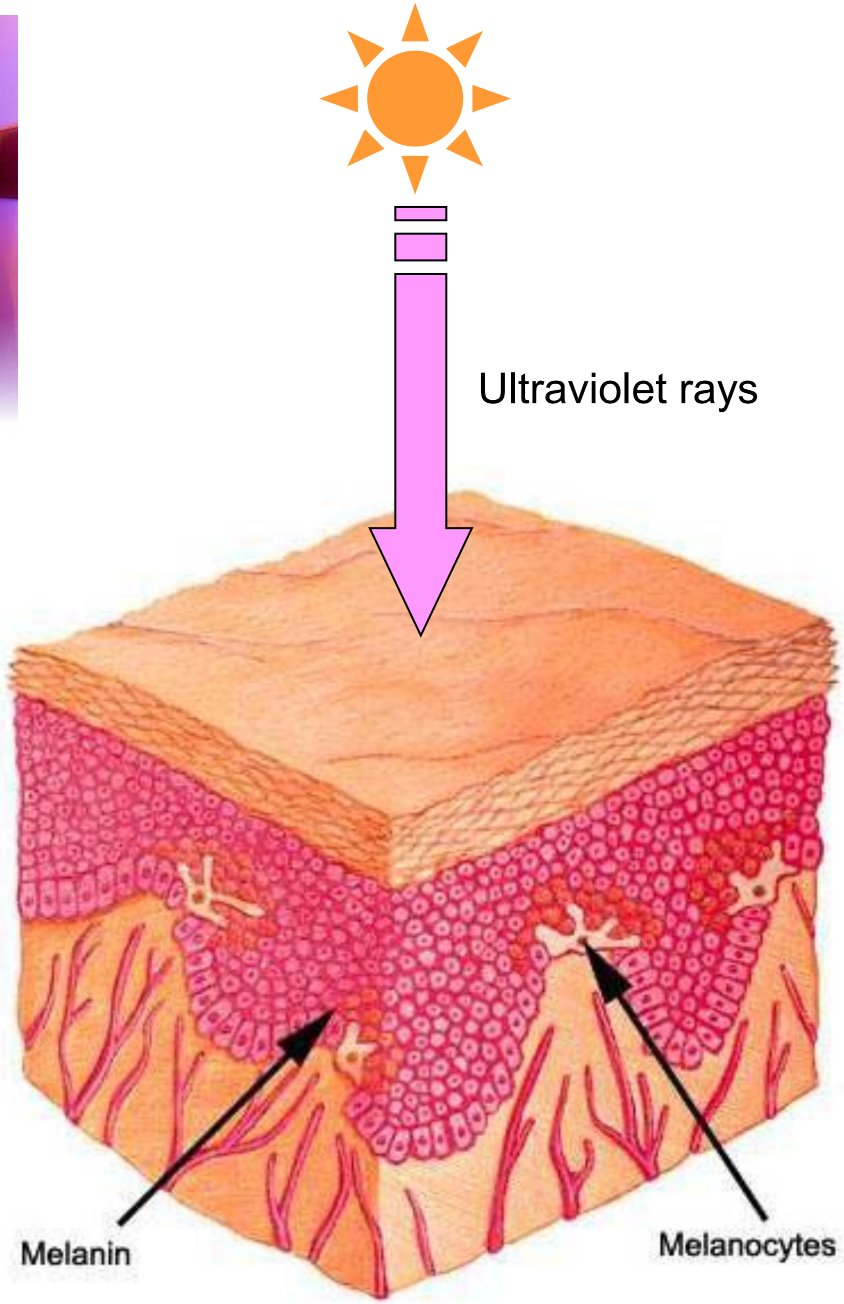
Self-cleaning properties of lotus leaf

Self-cleaning properties of lotus leaf



Why does polar bear have a black nose?

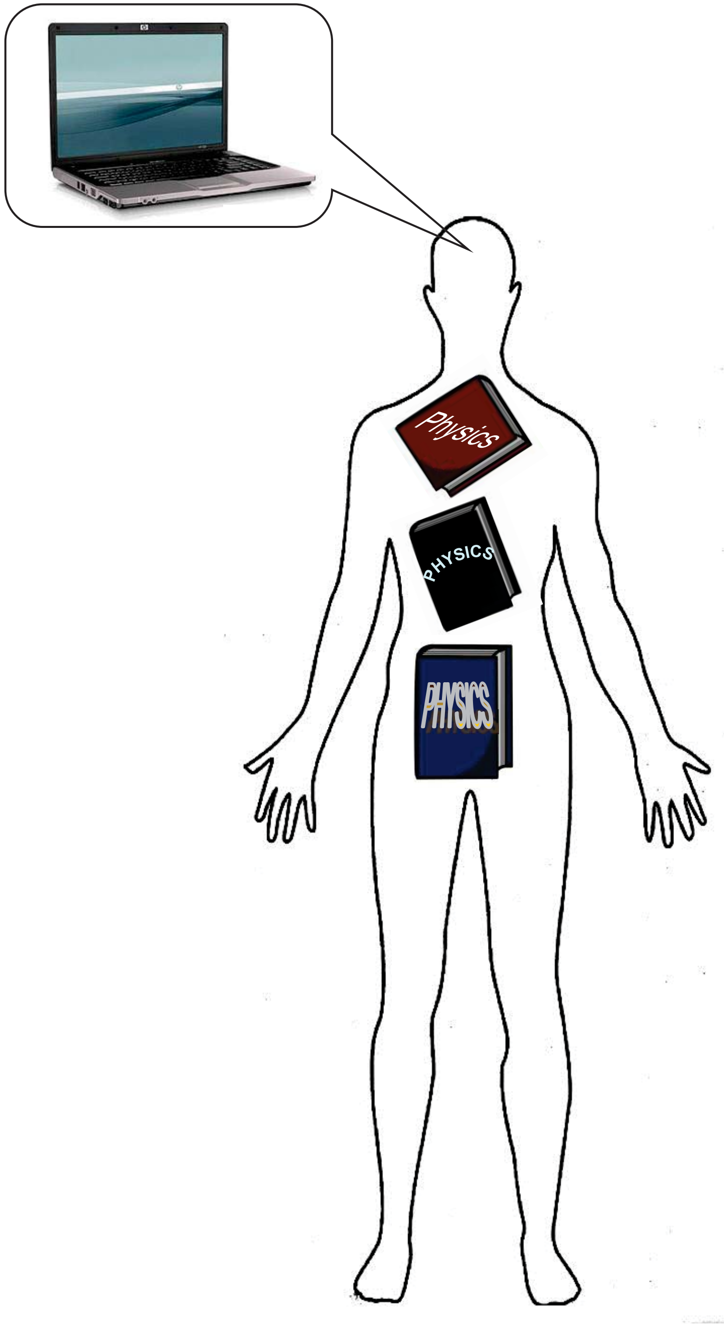
How does the skin tan?



Brown melanin –
protection from sun damage

Why does polar bear have a black nose?

Computer inside us



Computer inside us

Thank you and best wishes from Moscow !!!