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The importance of light in our life and from the technological point of view

The International Year of Light

and Light-based Technologies

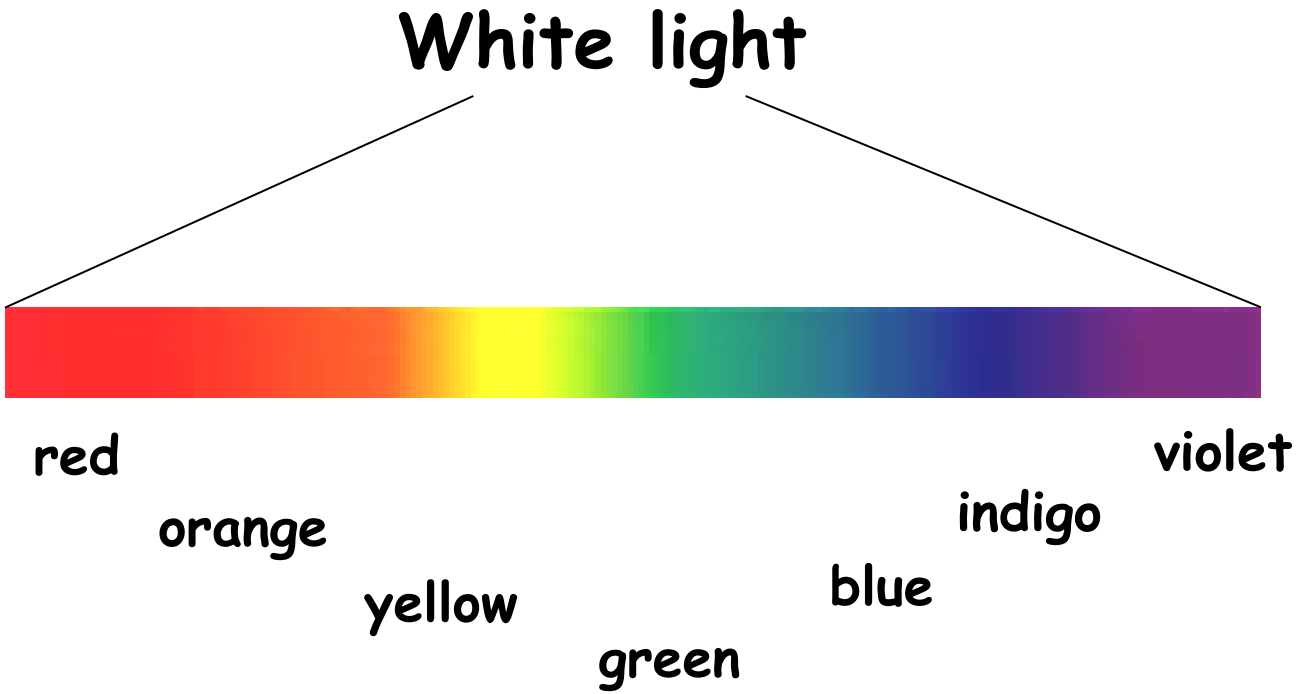
2015

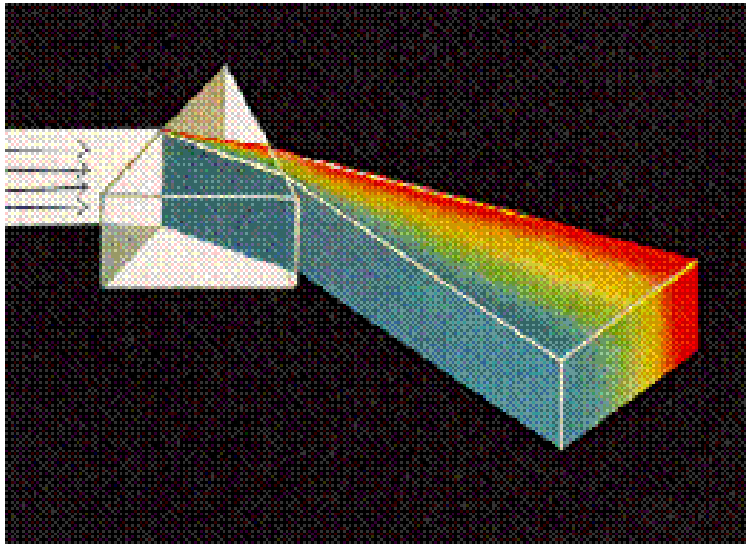
INTERNATIONAL
YEAR OF LIGHT
2015

Light radiations are responsible of the color of the things

The color origin

First, we have to consider that white light is actually formed by radiations of different colors





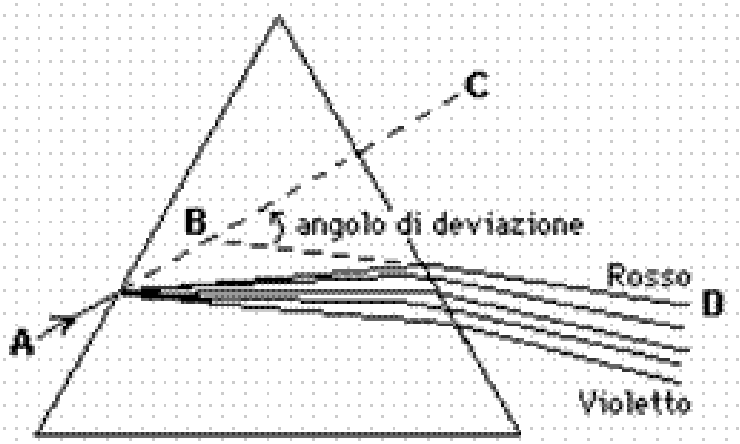


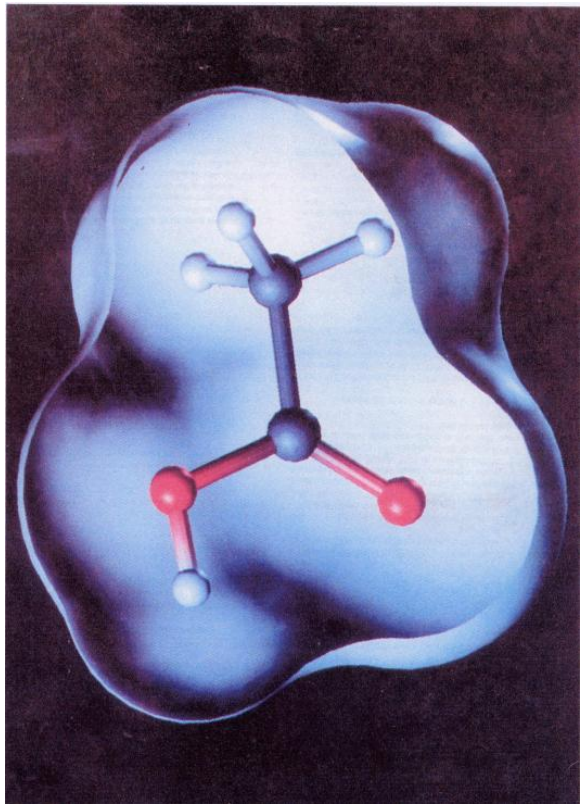
Figura 5

Rifrazione della luce attraverso un prisma

Isaac Newton
1642-1727

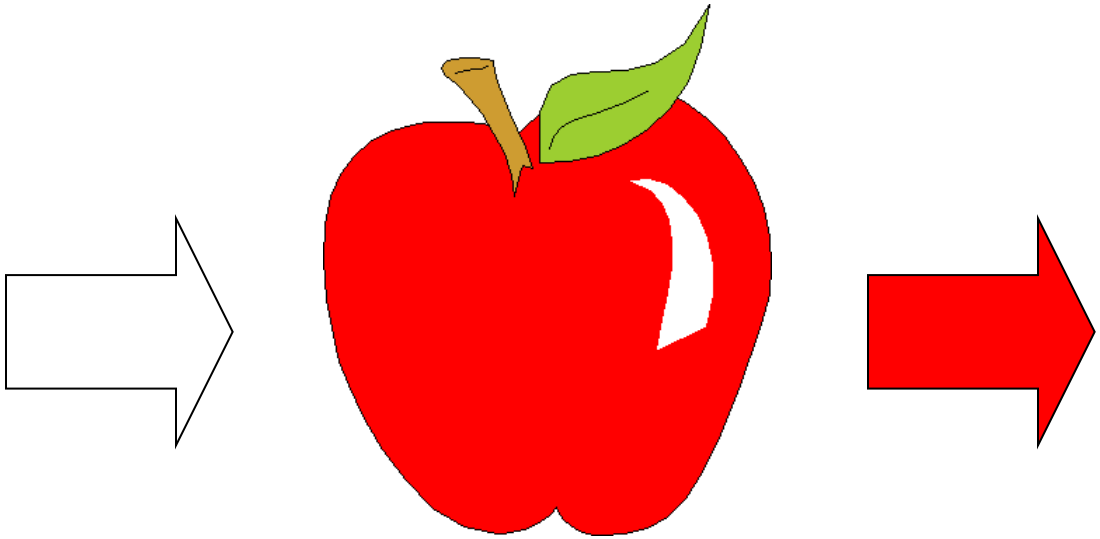
The color origin

Second, we have to remember that radiation-matter interaction occurs at the molecule level



Molecules are capable of absorbing only radiations of specific colors

The color of an object illuminated by white light is due to the mixing of the colors of the non-absorbed radiations



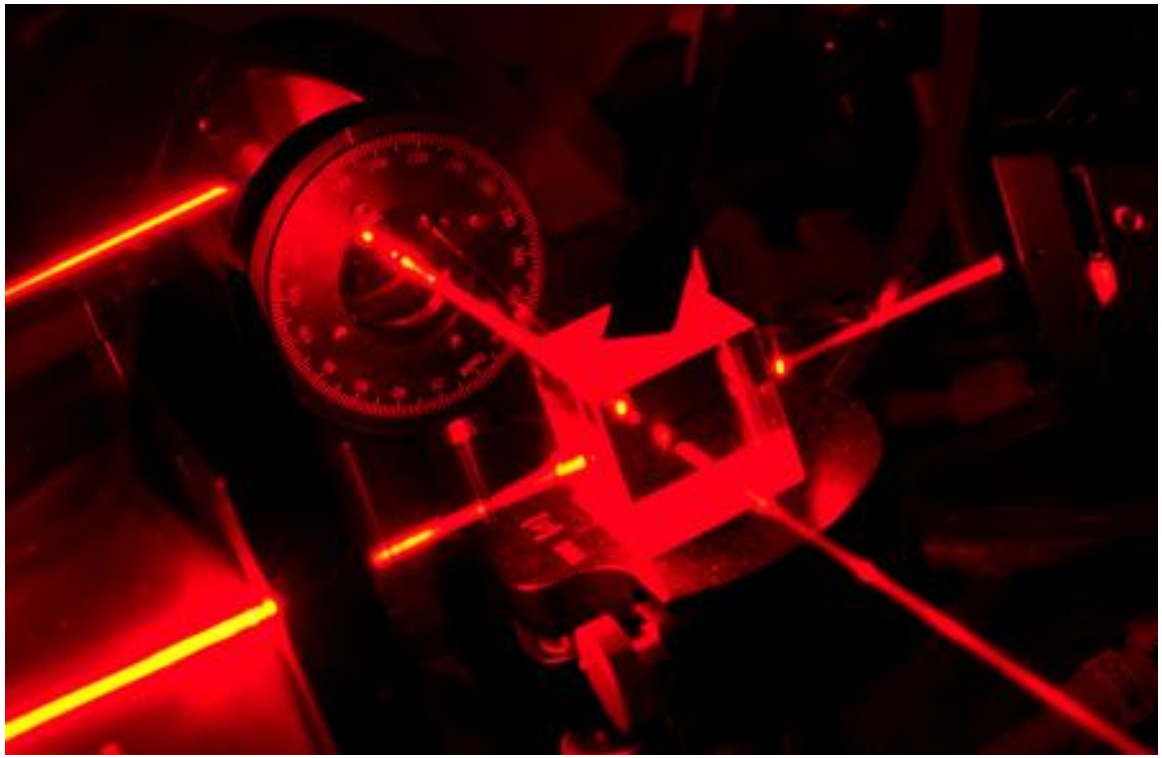
Color is not an intrinsic characteristic of an object because it depends on the color of the illumination source

Light Sources

Once the only source of light was the Sun, today we have various artificial sources of light created with the contribution of chemists: bulbs of all types

Laser

a very intense and focused source of radiation of only one color



Color is not the only result of the light/matter interaction

There are substances that, after having absorbed light, may in turn emit light, as the phosphorescent substances

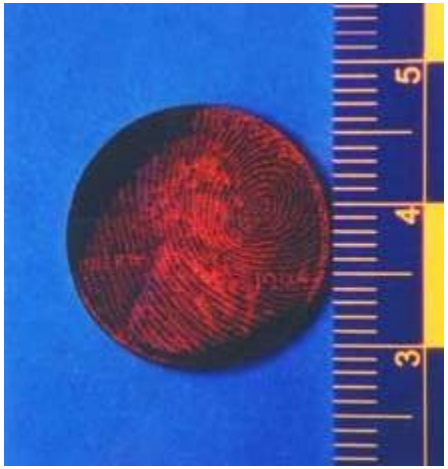
Chemists have created many other interesting examples

250 мл
200
150
100
50

There are substances whose light emission can be switched on and off

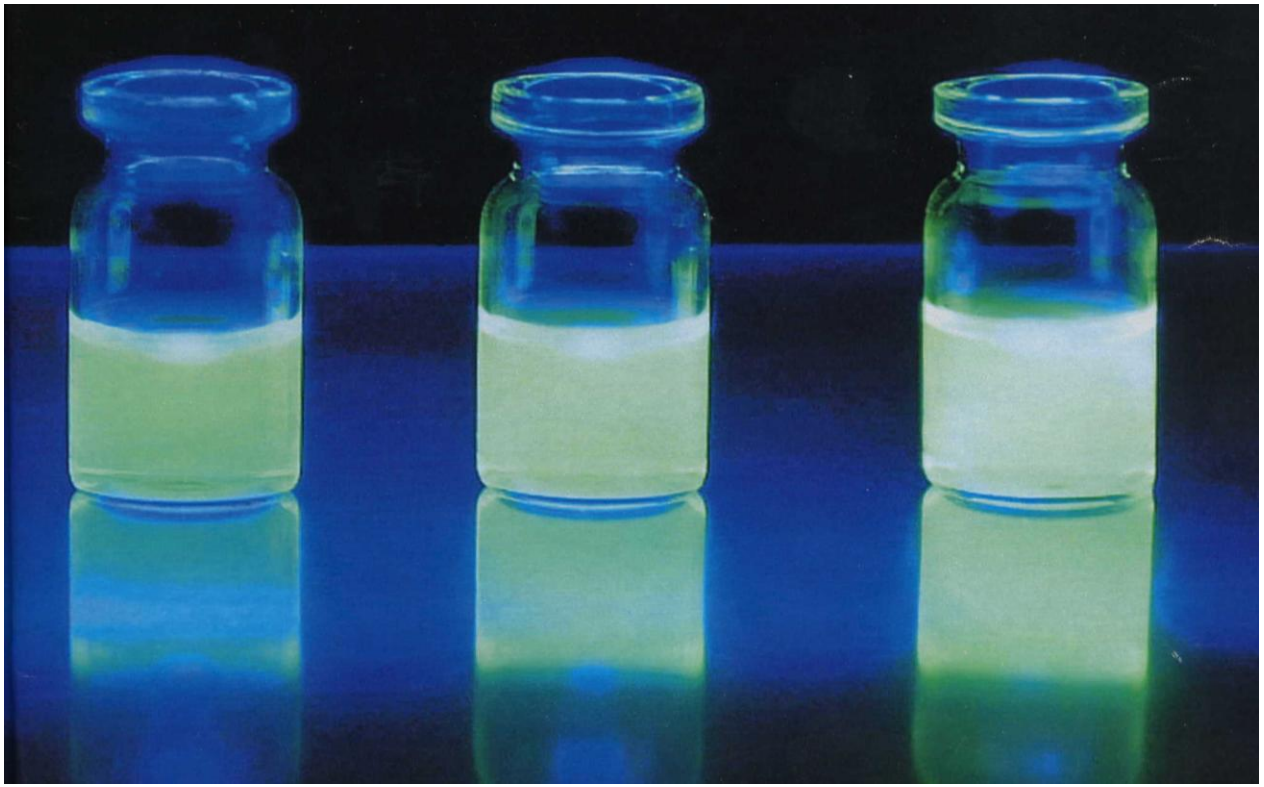
Luminescent nanosensors

They find applications in various fields

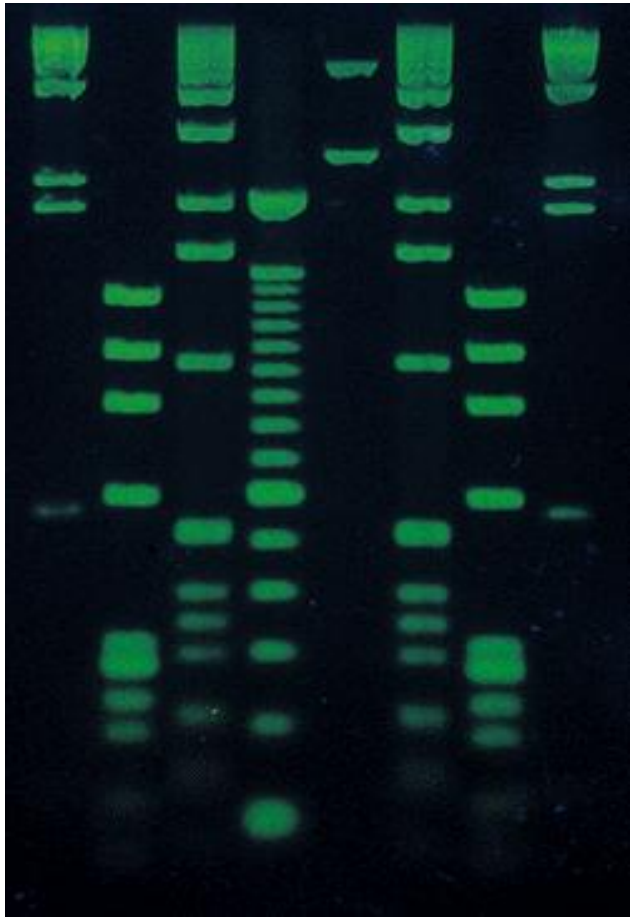


Forensic field

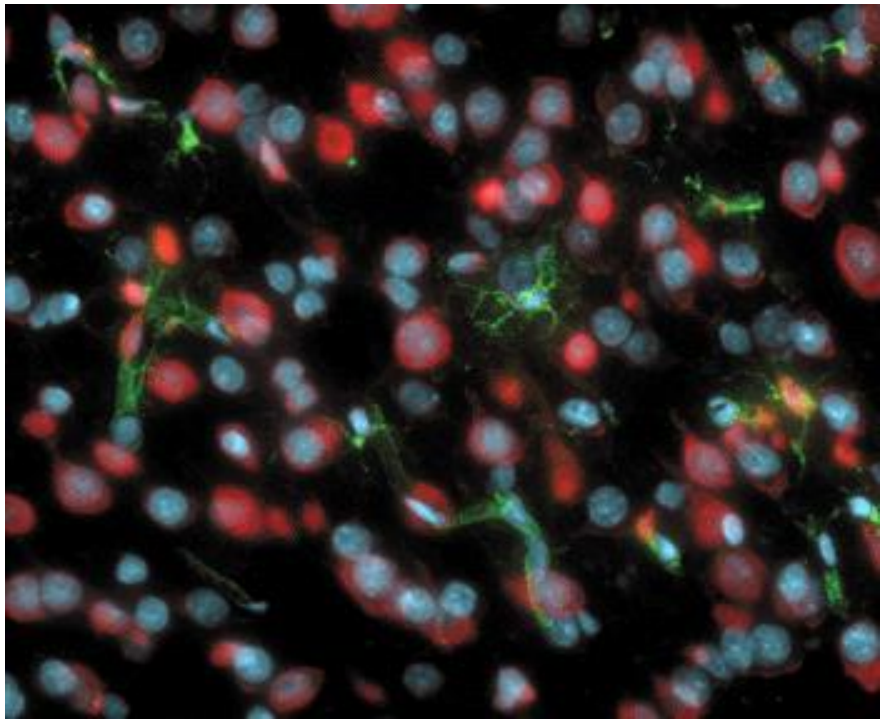
Luminescent nanosensors can be used for the qualitative and quantitative determination of pollutants, such as mercury in the water



Environmental field



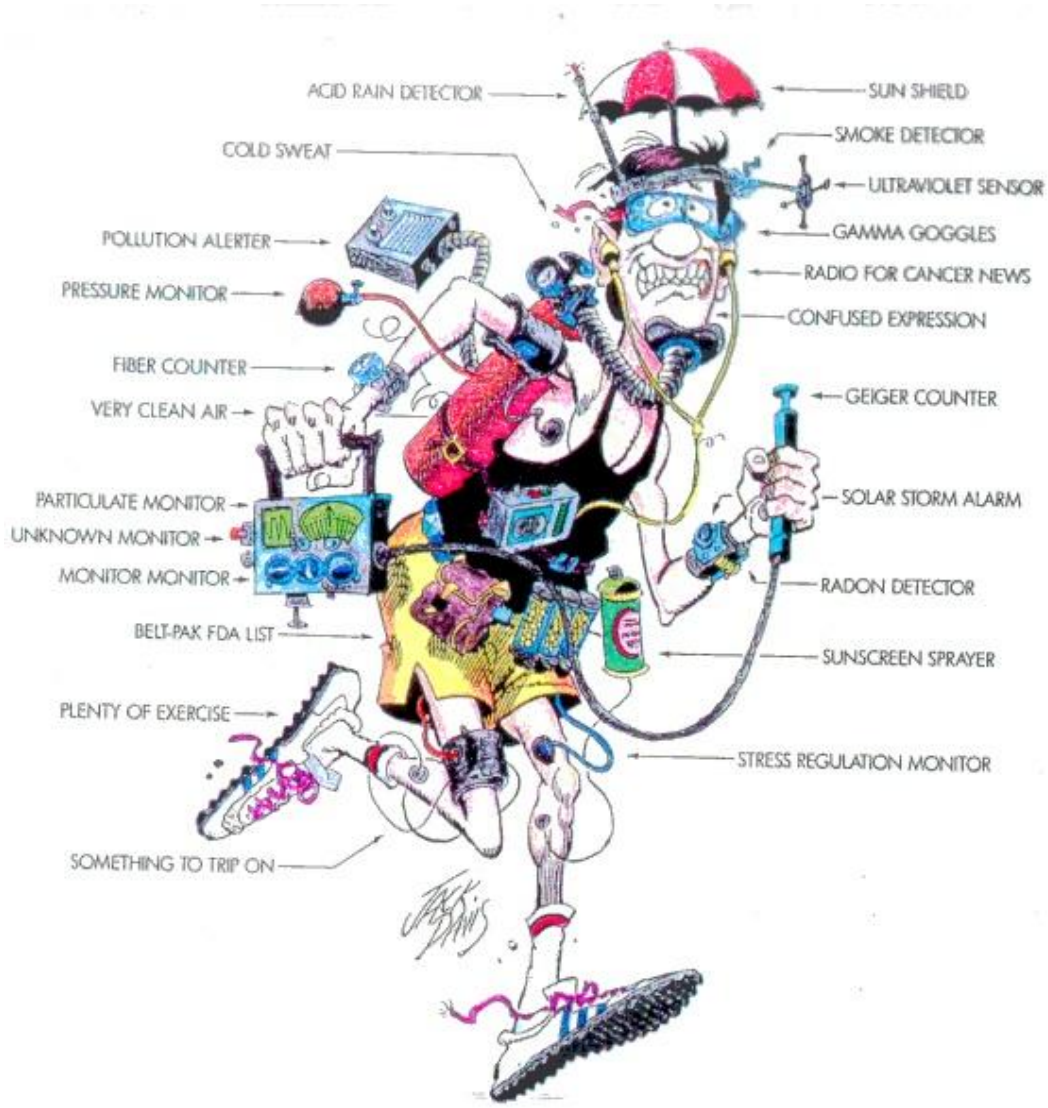
Recognize specific DNA sequences



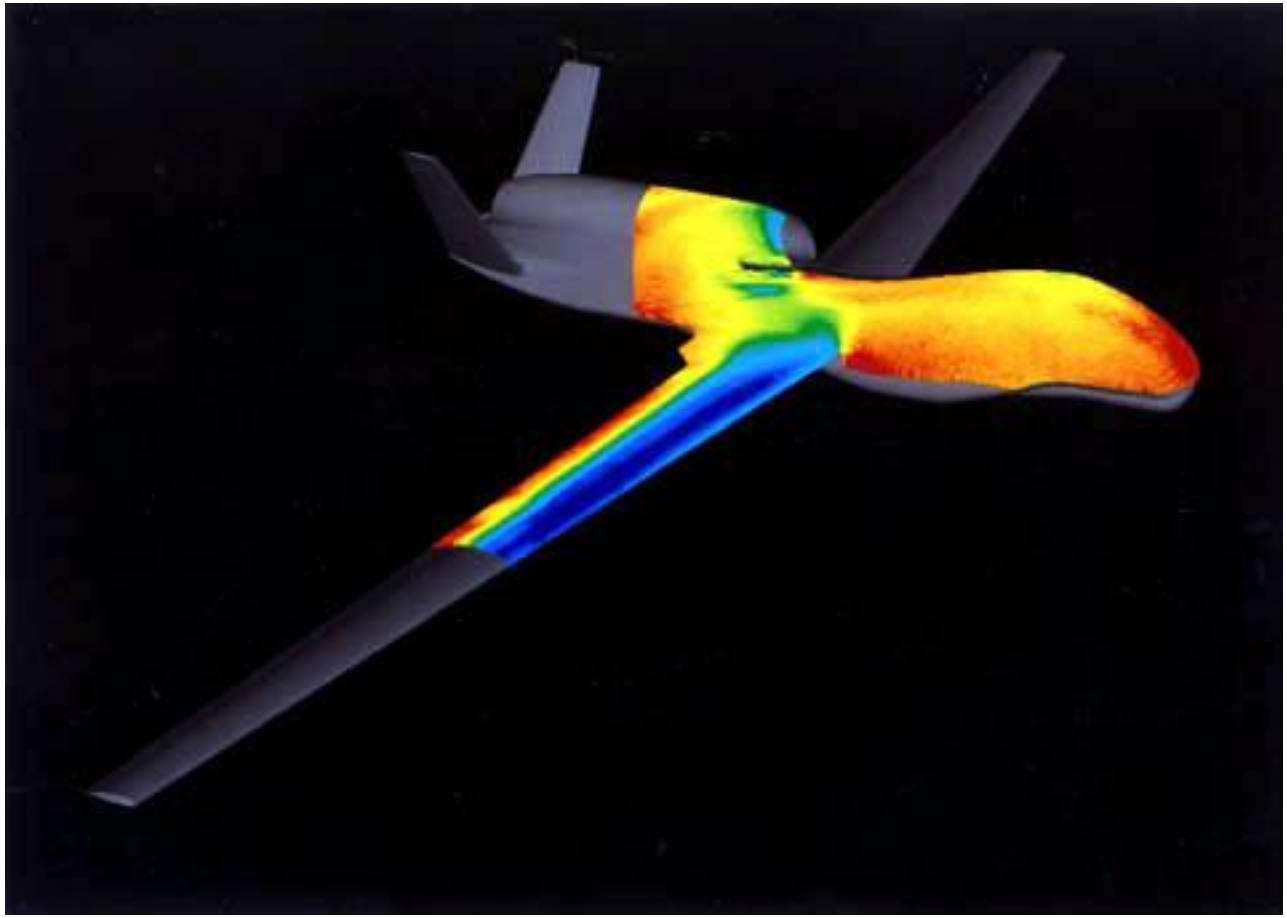
See cells

Medicine

Medical diagnostics in real time

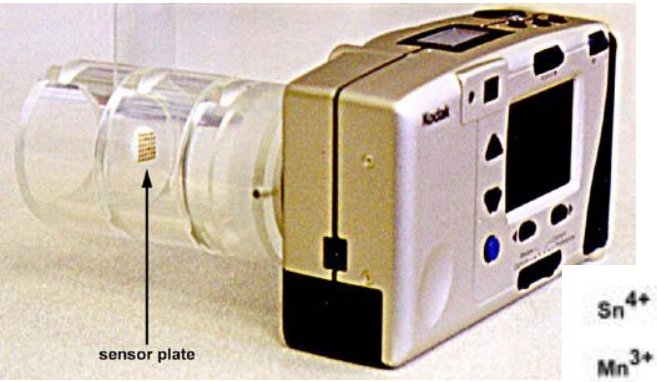


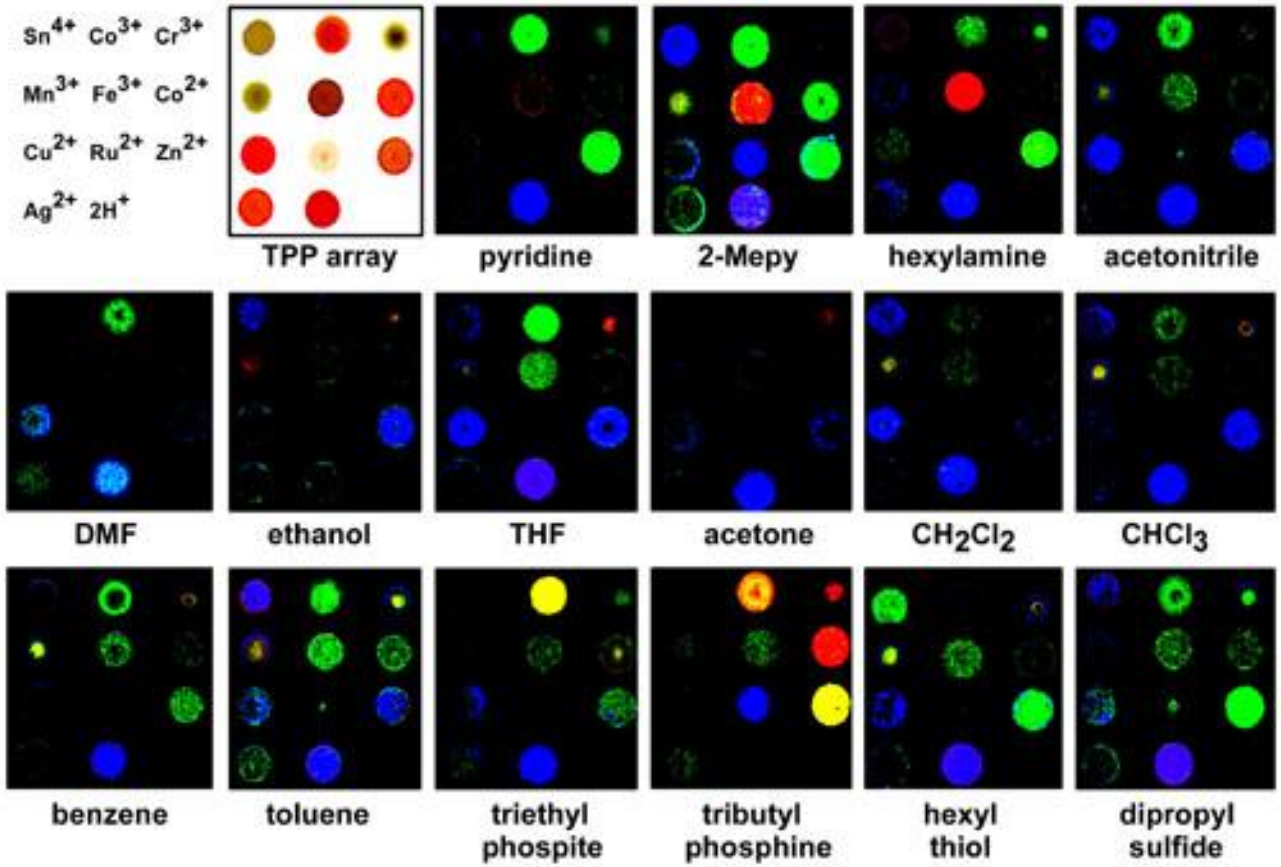
Pressure sensors



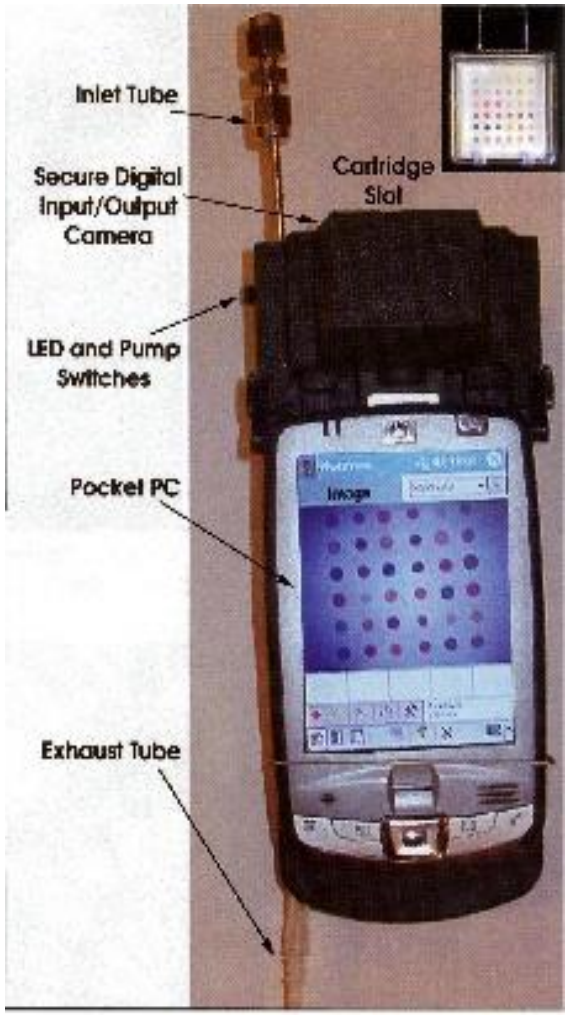
Technological field

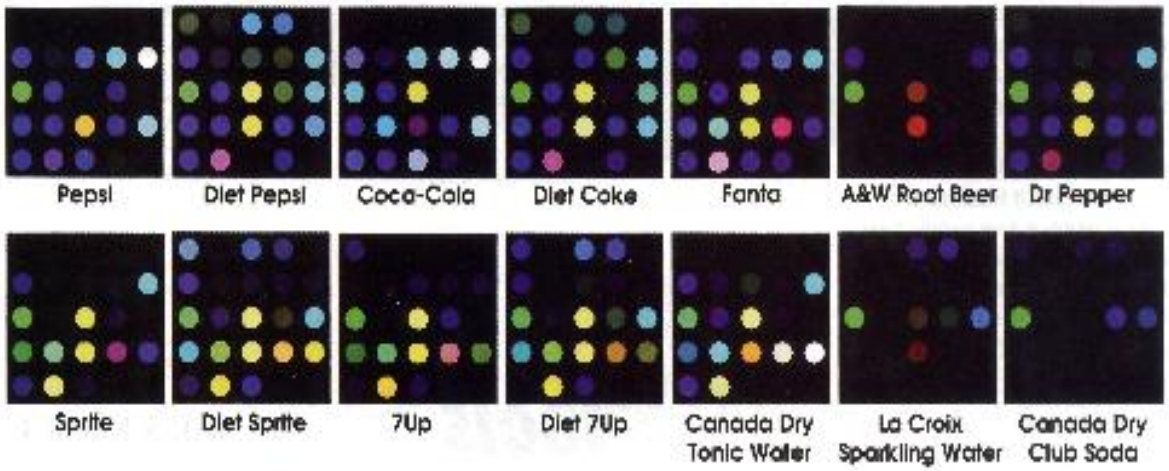
Luminescent nanosensors to capture odors





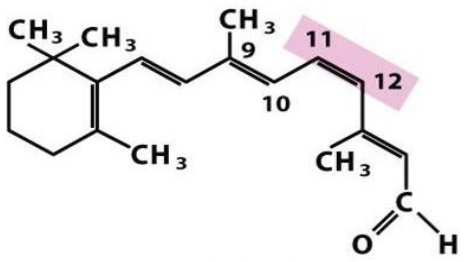
...and also flavors



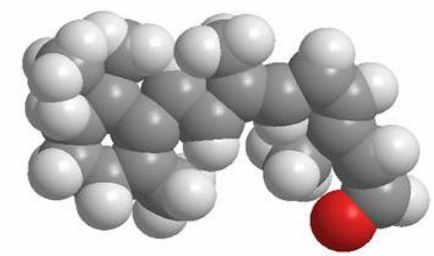


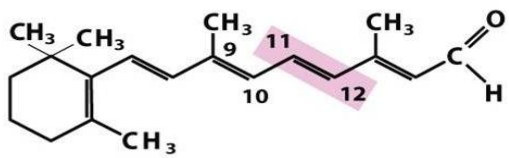
Other results of the light/matter interaction

Light can make change the shape of appropriate molecules

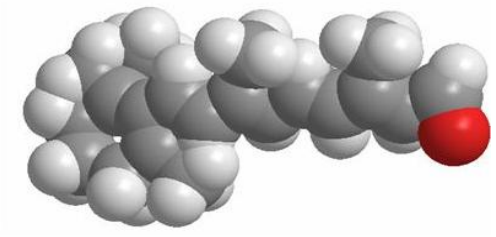


cis-Retinal





trans-Retinal



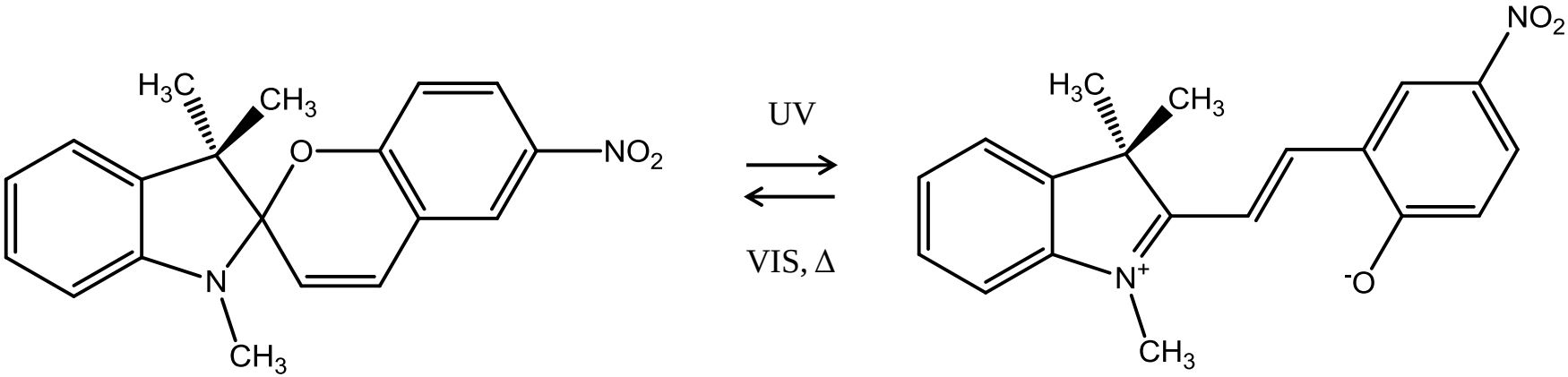
Vision is based on the light-induced shape change of Retinal molecule

There are also substances that upon light absorption change shape and concomitantly change color

Photochromic substances

A common use: photochromic lenses

Another example of photochromic substances



spiropyran
colorless

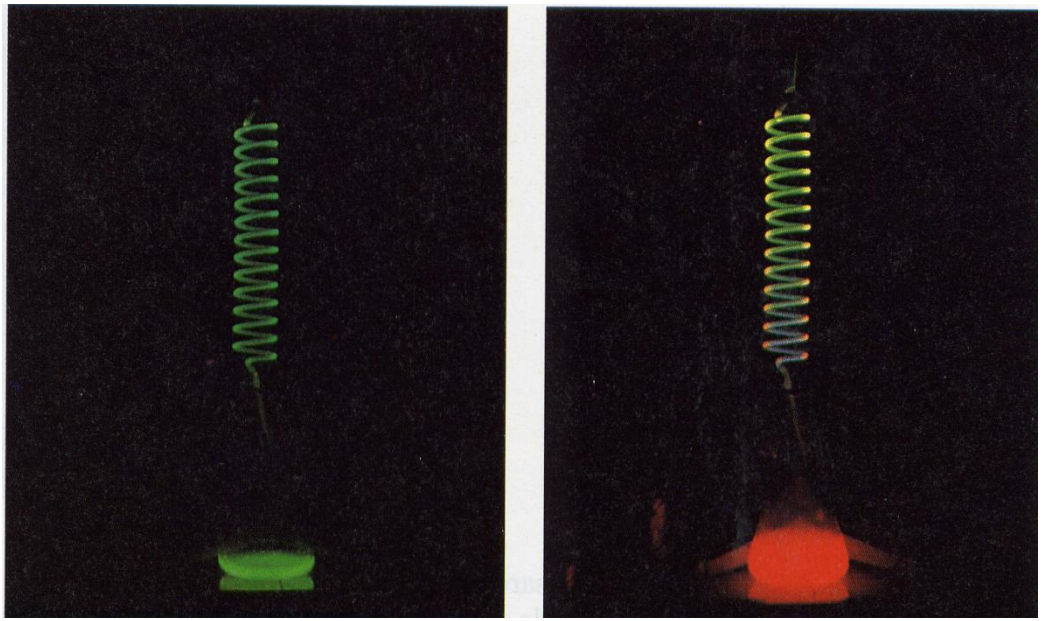
merocyanine
blue

Light sensor because with its color gives information on the type of the absorbed light

… but that's not all

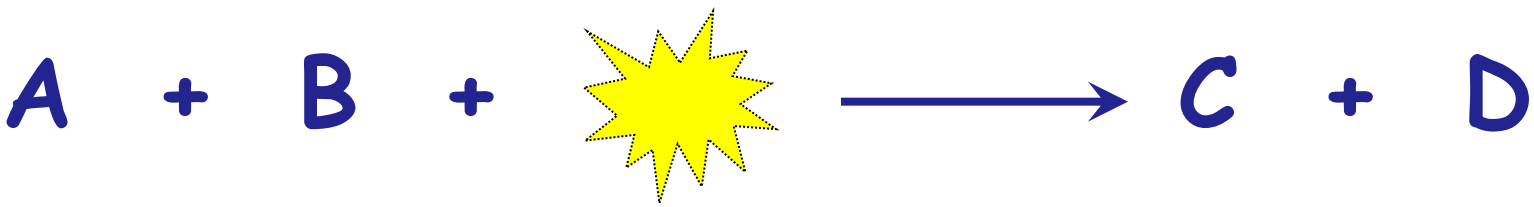
Light emission can accompany product formation in a reaction

$$A + B \longrightarrow C + D + \text{light}$$



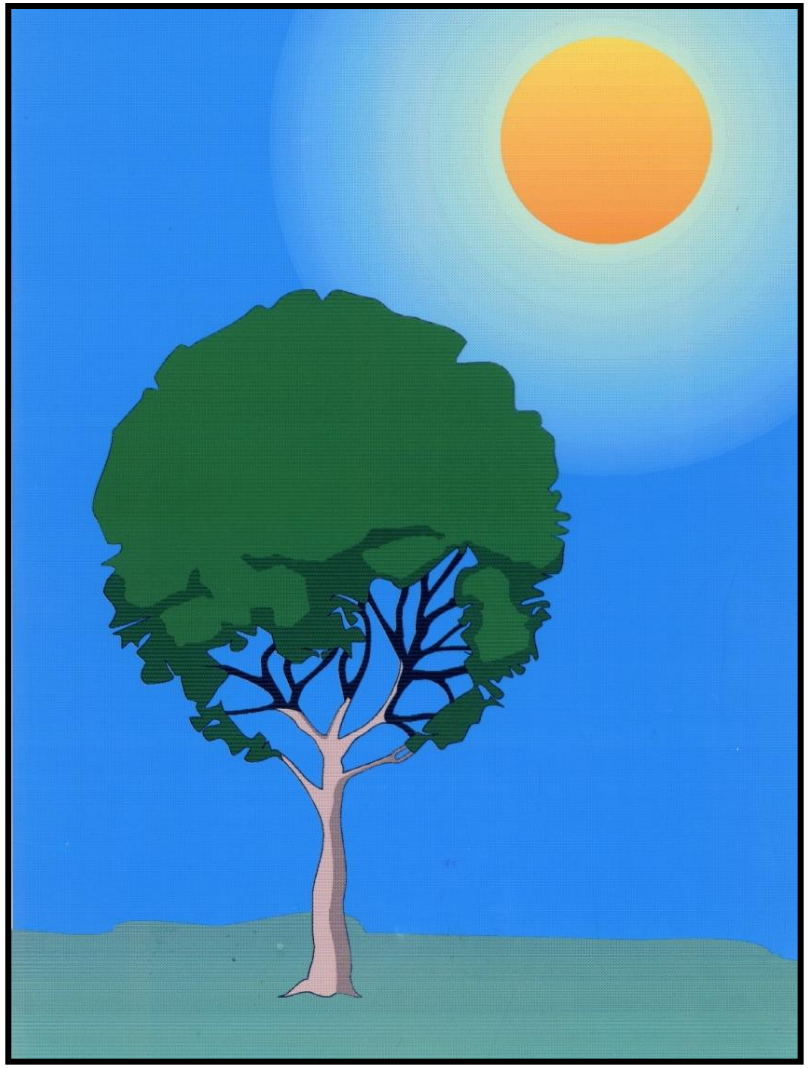
Chemiluminescent reactions

Light can allow the occurrence of a reaction



Photochemical reactions

Photochemical reactions



Photography

Photosynthesis

Natural photosynthesis is the most important process that occurs on Earth

It indeed converts sunlight into fuels, producing all our food

Furthermore it allowed the formation of oxygen in our atmosphere and, over geological time, fossil fuels

Fossil fuels (oil, gas, coal)

They provide about 80% of the global energy consumption

Using fossil fuels was and still is easy and very convenient, but, as everybody knows, there are problems

Problems with fossil fuels

1) They are a gift of nature, that is going to be exhausted

2) The use of fossil fuels causes green house effect and pollution

3) There are strong disparities concerning energy consumption

Therefore we need to save energy and to develop the use of renewable energy sources

Hydroelectric energy

Wind energy

Geothermal energy

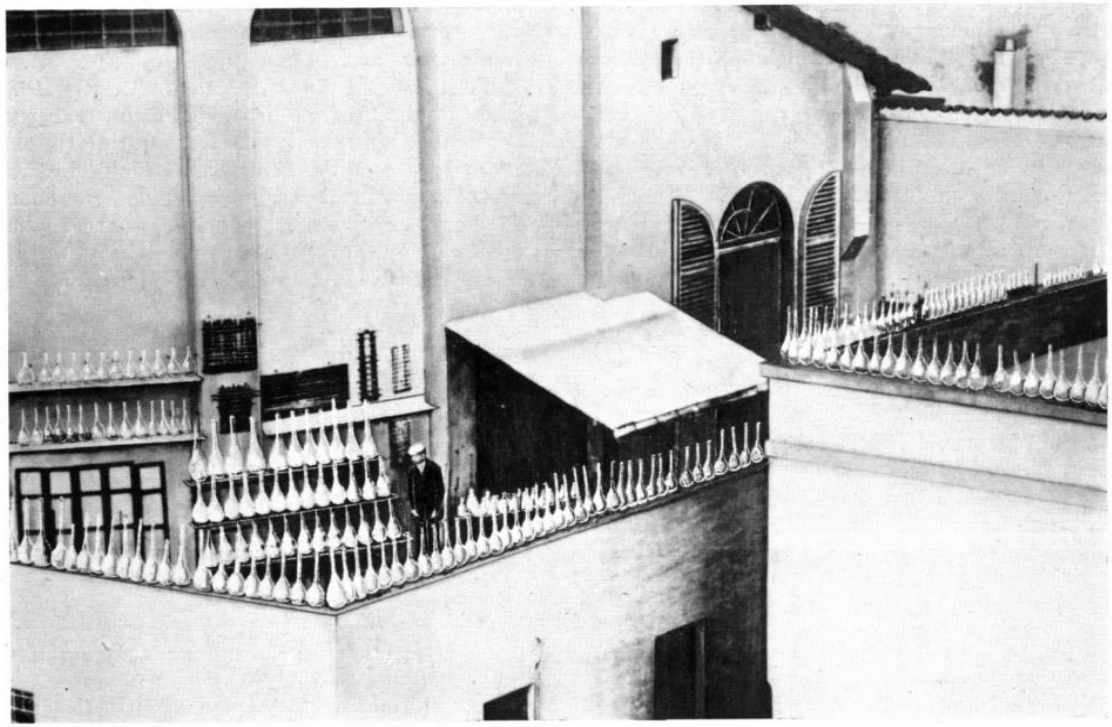
The best renewable energy: solar energy

Solar energy is indeed

- an inhexaustible, abundant, clean, safe and flexible energy source

- being diffuse all over the world, it will reduce disparities among the world's nations and will lead us toward a more stable and peaceful society

Giacomo Ciamician (1857-1922) the prophet of solar energy



Ciamician *passant eu revue les centaines de flacons exposés au soleil sur le toit de son laboratoire.*

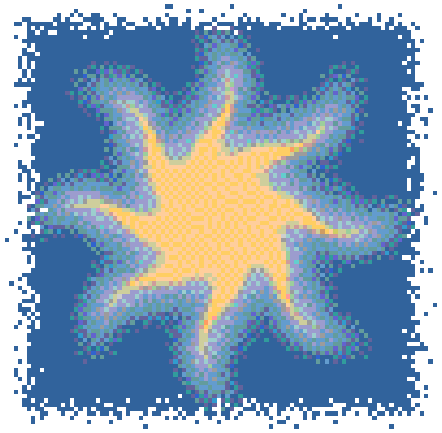
"... If our black and nervous civilization, based on coal, shall be followed by a quieter civilization based on the utilization of solar energy, that will not be harmful to the progress and to human happiness"

"The Photochemistry of the Future" *Science*, 1912, *36*, 385

Solar energy is however diluted and intermittent

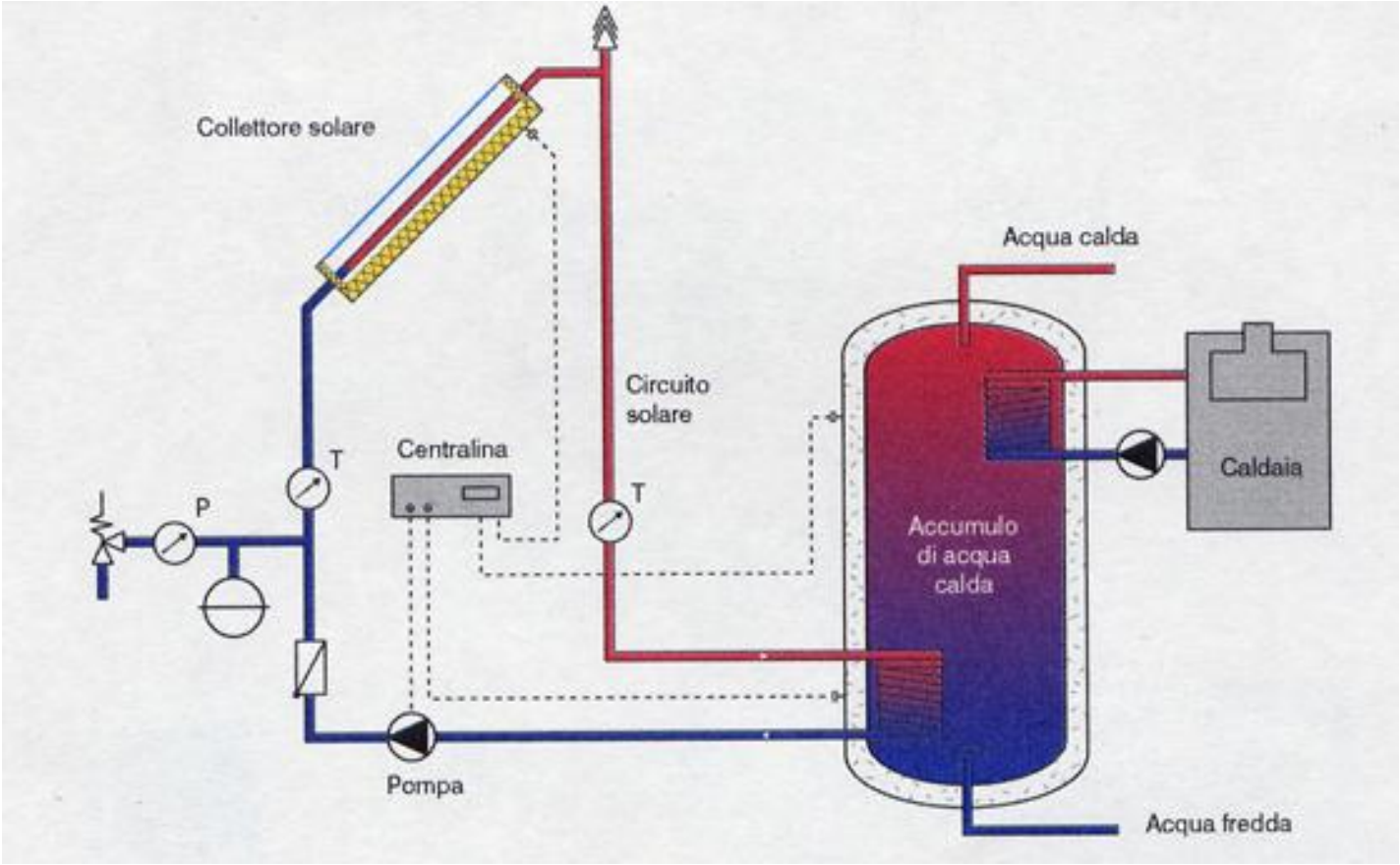
To be exploited, it must be converted into useful energies, i.e. heat, electricity, and fuels

Solar energy conversion



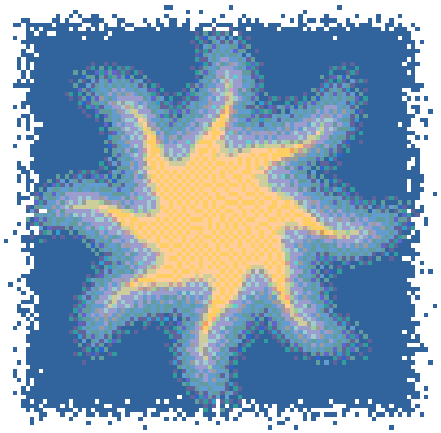
Heat
(thermal collectors)

Thermal collectors



The estimated total capacity of solar thermal collectors in operation worldwide by the end of 2013 is 330 Gw_{th} (471 million square meters of collector area) which is equivalent to savings of 30.1 million tons of oil and 97.4 million tons of CO_2

Solar energy conversion

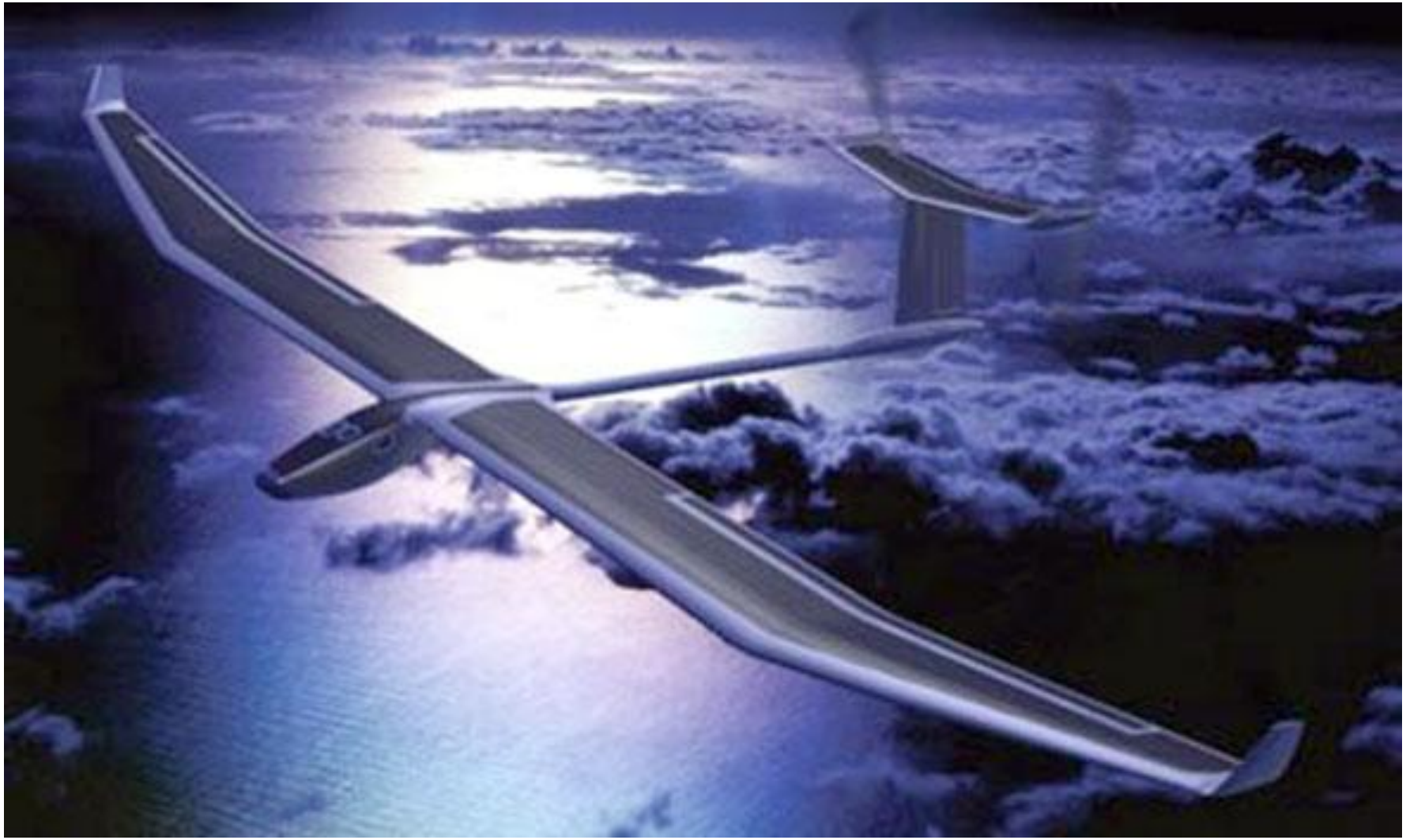


Electricity
(photovoltaic cells)

In solar cells, light absorption by a semiconductor material originates an electrical current; many cells are connected to form photovoltaic panels

SANYO solar ark, Gifu (Japan), 315 m

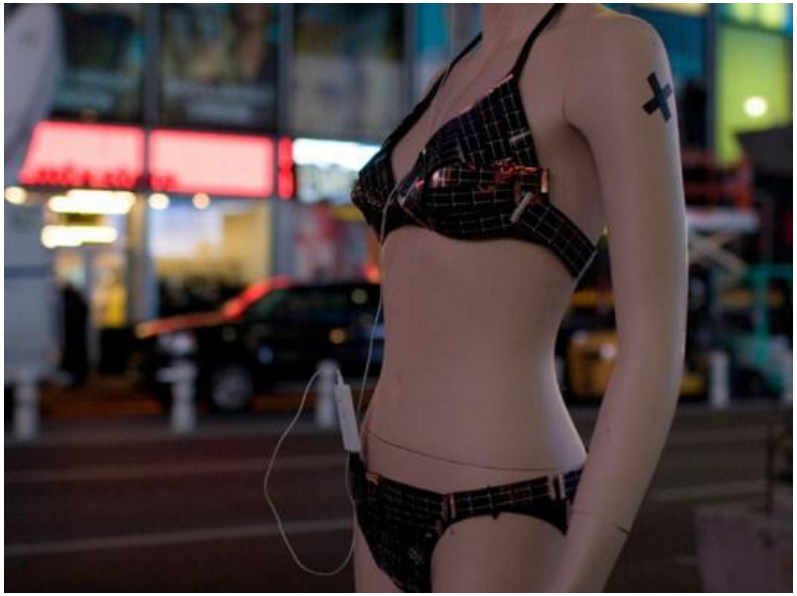
In developing countries, were power from the grid is unavailable, photovoltaic cells can be connected to batteries and supply fair amount of power for essential needs



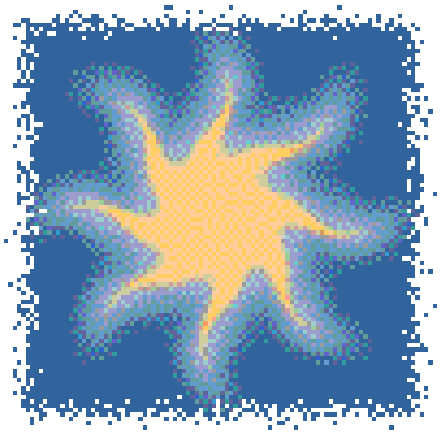
Solar Impulse is an ultralight aircraft powered by solar energy

- New materials
- New methods of manufacture
- New arrays

New photovoltaic technologies



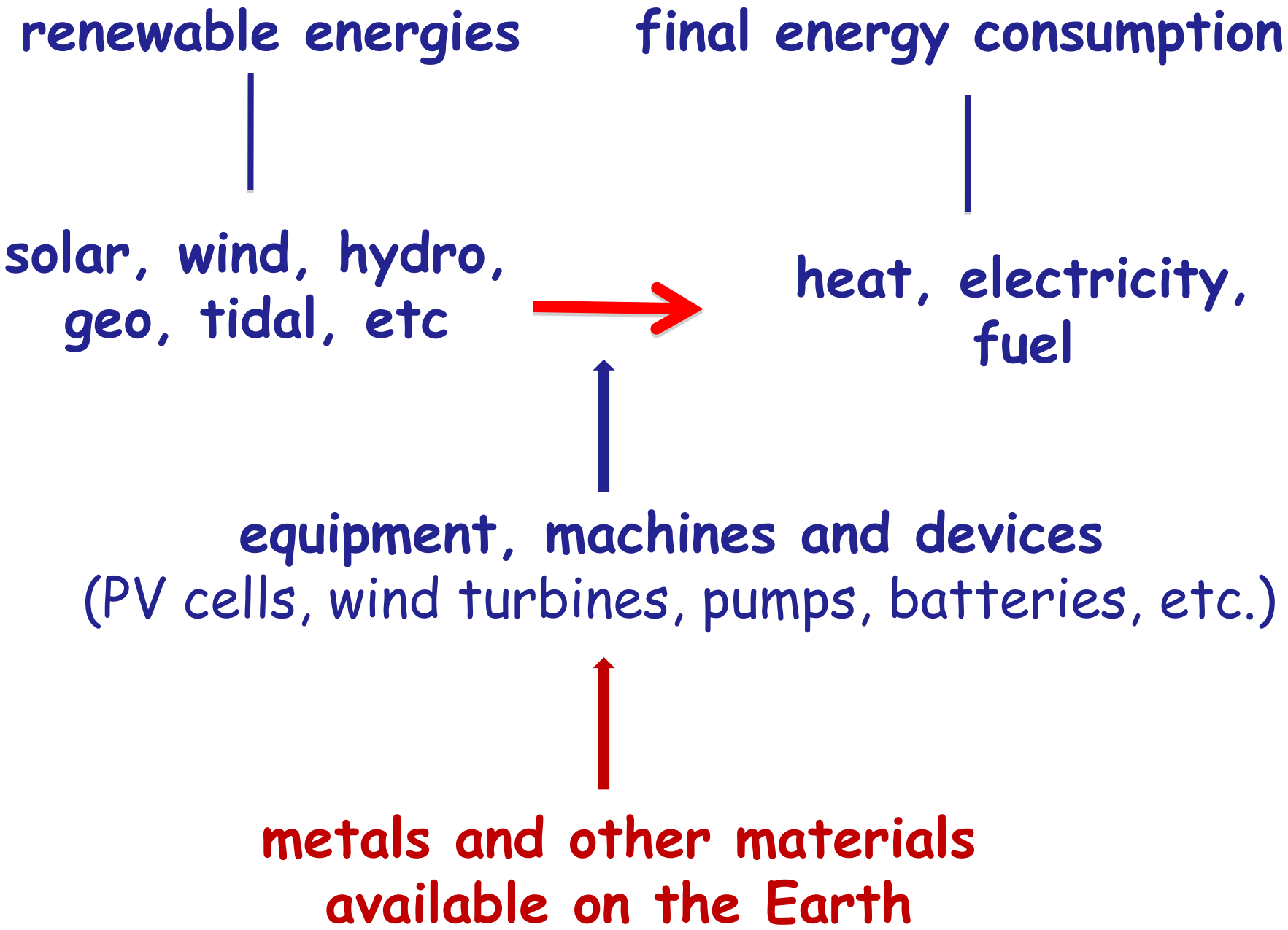
Solar energy conversion



Fuels
(biomass,
artificial photosynthesis)

Therefore solar energy, but also each type of renewable energies, must be converted into useful energy forms we need

To do that, we must use equipment, machines and devices (e.g., photovoltaic cells, thermal collectors, wind turbines, pumps, batteries, etc.) and to make them we must start from metals and materials available on the Earth


renewable energies
final energy consumption
solar, wind, hydro, geo, tidal, etc
heat, electricity, fuel
equipment, machines and devices
(PV cells, wind turbines, pumps, batteries, etc.)
metals and other materials available on the Earth

The only possibility we have is to use the chemical elements of the periodic Table and we know that some elements are abundant, but others are scarce

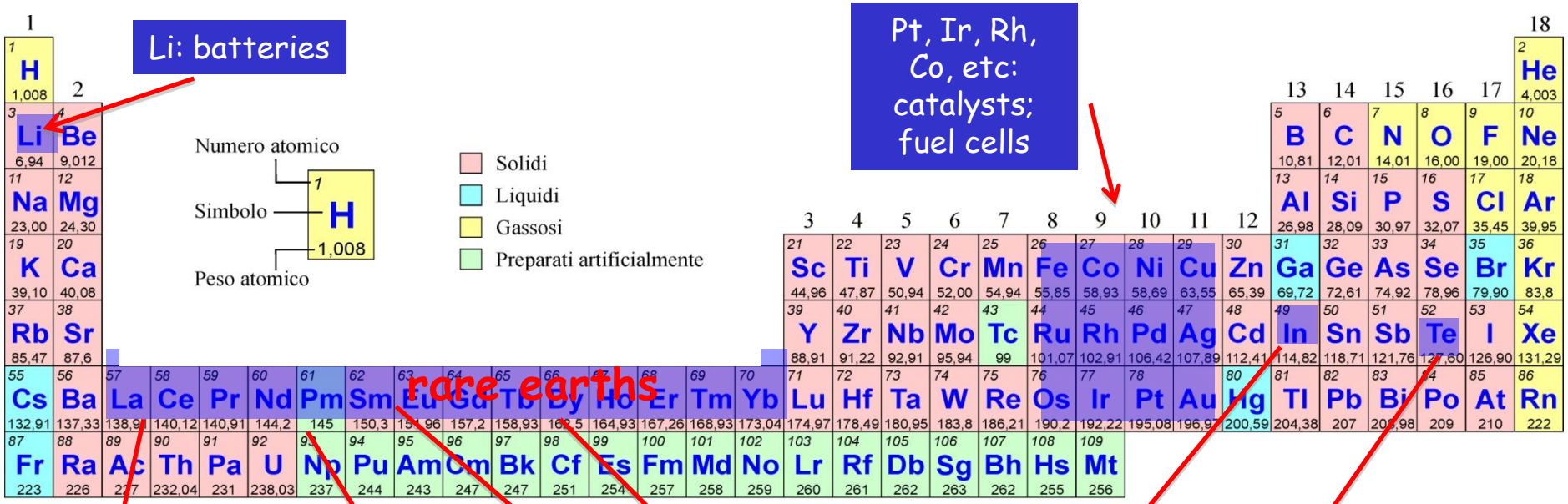
Relatively scarce are Li, In, Te, transition metals like Pt, Ir, Rh, Co, and rare earths

Periodic Table of the Elements

Critical elements

Li: batteries

Pt, Ir, Rh, Co, etc: catalysts; fuel cells



La: batteries

Nd: permanent magnets

Dy: hybrid engines

Eu, In, Te: photovoltaic devices

- Each megawat power of wind turbine needs one tonne of rare earths
- A Toyota Prius has 1 kg di Nd in the engine and 10 kg di La in the batteries

So, at the end of the day we will have plenty of renewable energies, but limited availability of materials to convert them into useful energy

Therefore RECYCLING is a MUST for our generation

CHEMISTRY
provides
SOLUTIONS