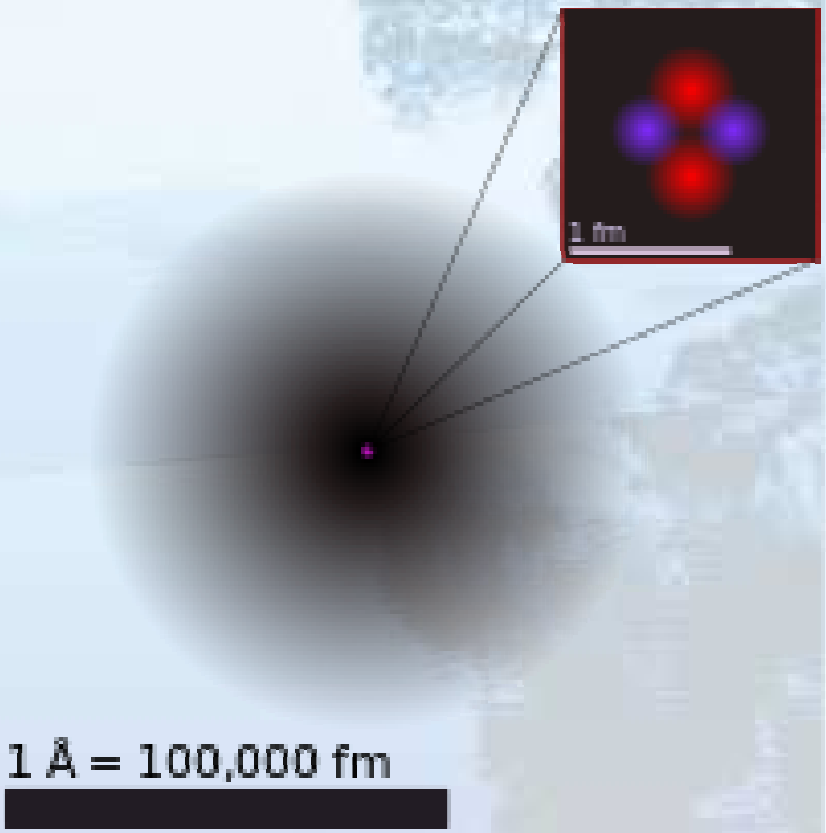
UGFN1000
In Dialogue with Nature
與自然對話

Supplementary lecture on Chemistry

Atomic theory (原子理論)

- What are matters made of?
  - Most people in the past (such as Aristotle) believed that matters are continuums – i.e., there are no gap, just as what we see.
  - But in the 20th century, experiments have shown that physical objects are made of atoms – which are extremely tiny and **mostly empty**!



http://en.wikipedia.org/wiki/Atomic_theory

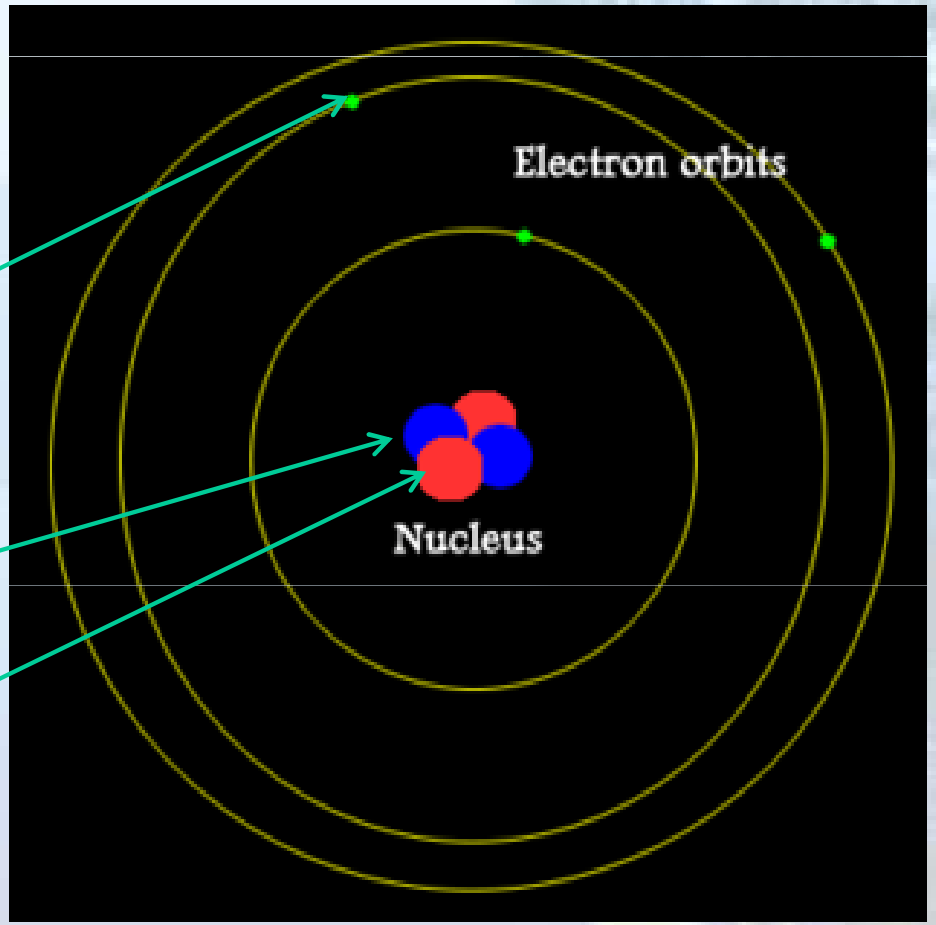
Neutron, Proton and Electron (中子, 質子,電子)

- Atoms is composed of subatomic particles: Protons, Neutrons and Electrons.

Electrons (-ve)

Protons (+ve)

Neutrons



http://reich-chemistry.wikispaces.com/Fall.2010.MMA.Neil.atomictimeline

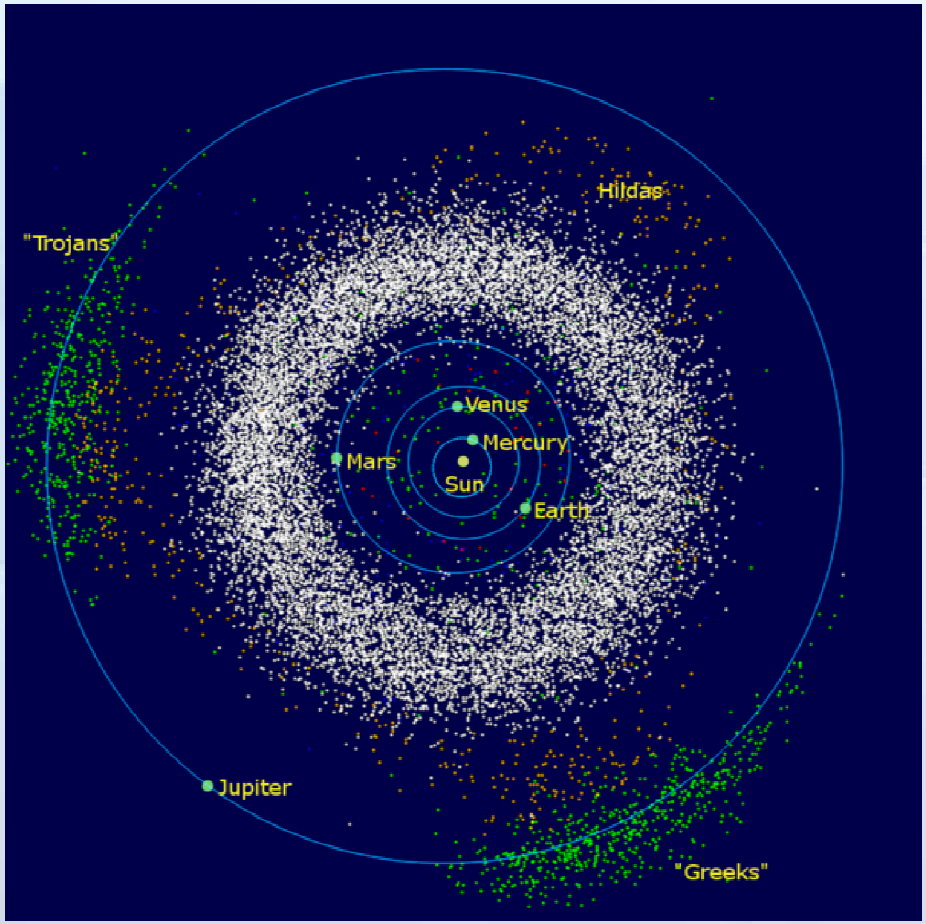
Question

- If we shoot some atoms at a very thin foil (with thickness of only a few atoms) What would happen?
  a) Most of the atoms will bounce back
  b) Most of the atoms will penetrate through the foil
  c) Most of the atoms will be absorbed.

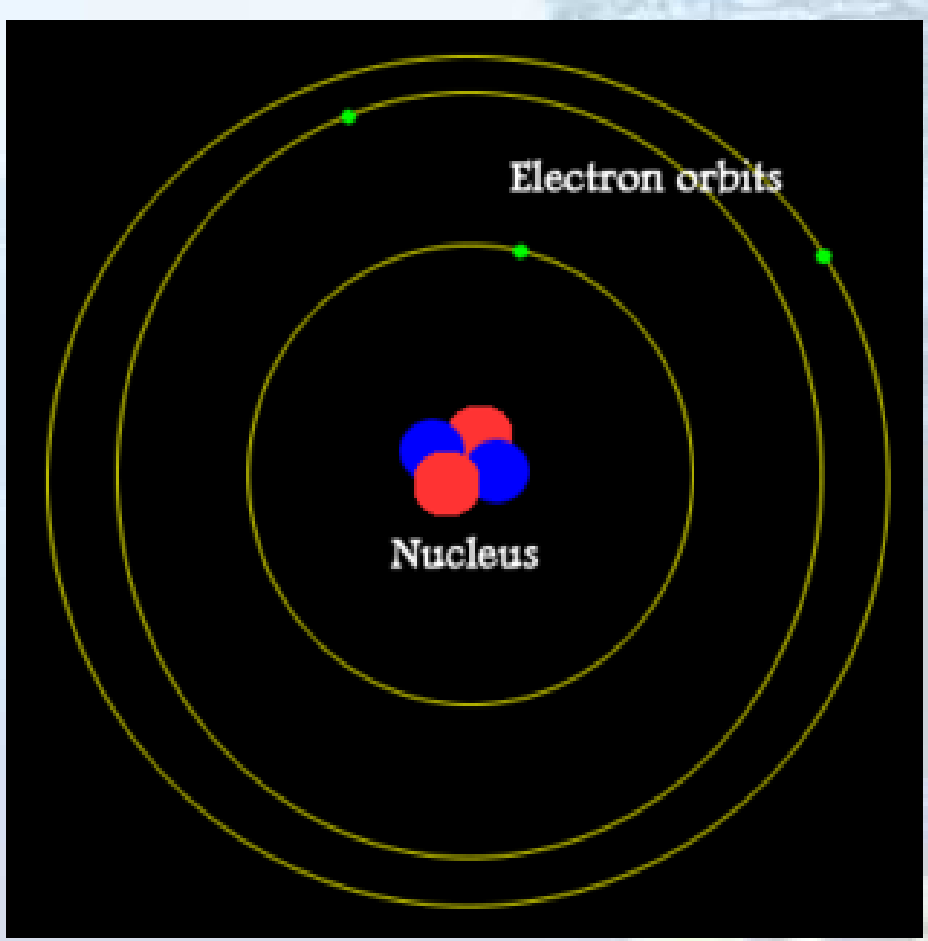
Question

- Where else do we have a similar model like the atomic model?
  a) Cells
  b) Organisms
  c) Ecosystems
  d) Planets

Regular patterns in the extremely large and extremely small



http://en.wikipedia.org/wiki/Solar_System



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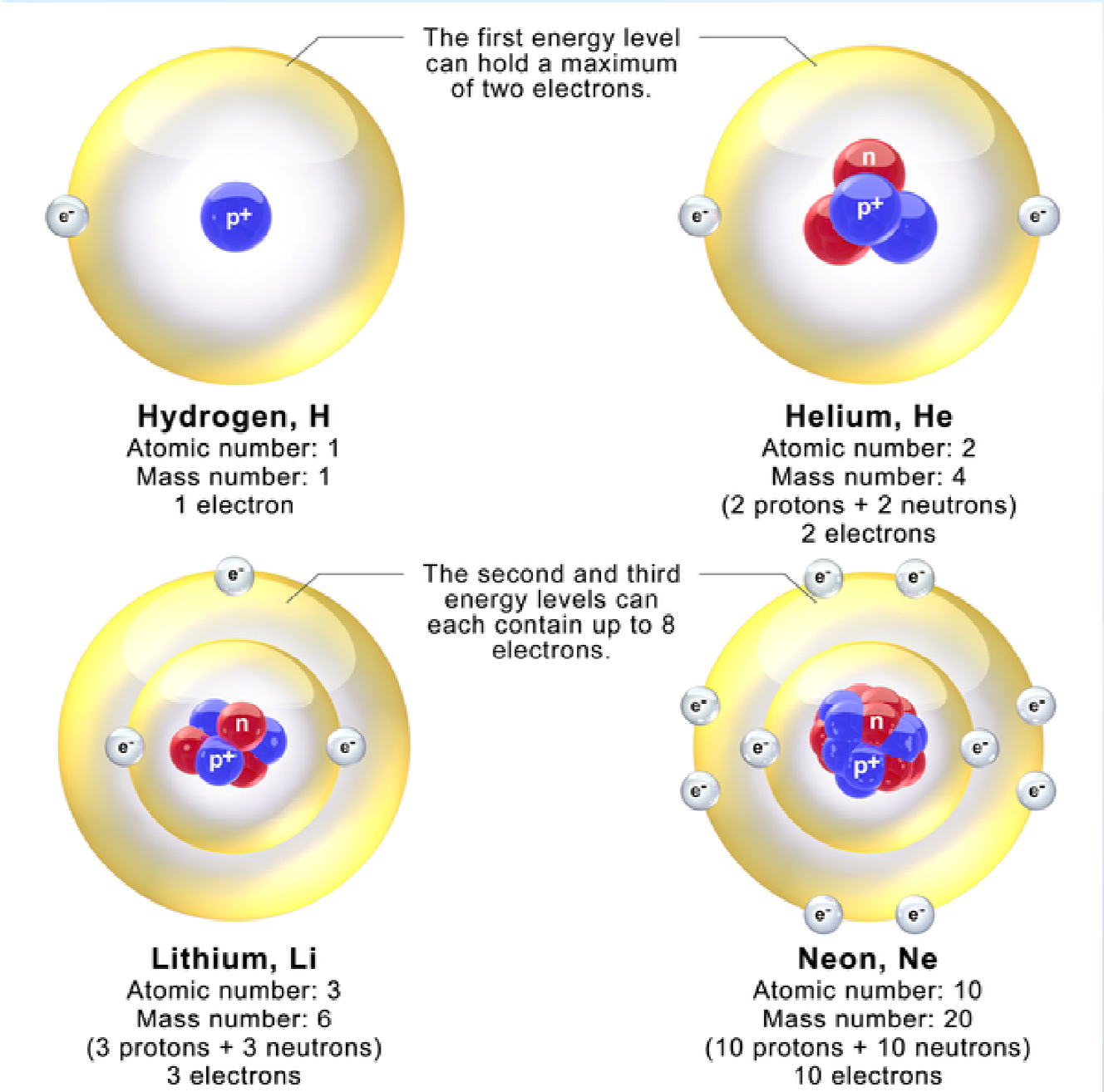
Different number of subatomic particles



The number of **protons** determines what element this atom is.

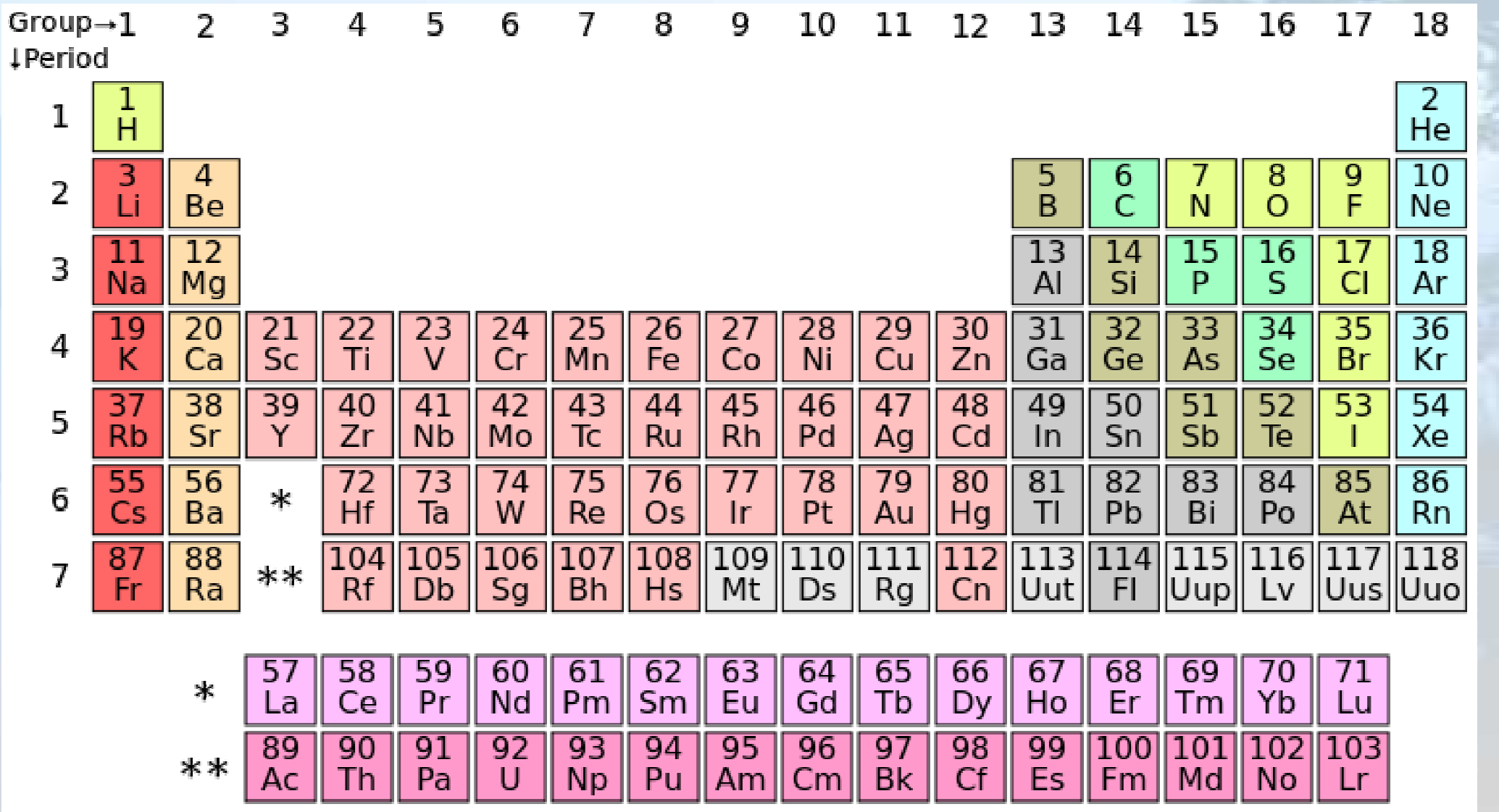
The number of **neutrons** usually increases as the number of protons increase.

The number of **electrons** also usually increases as the number of protons increase. But electrons adds **in layers**.

http://en.wikipedia.org/wiki/Bohr_model

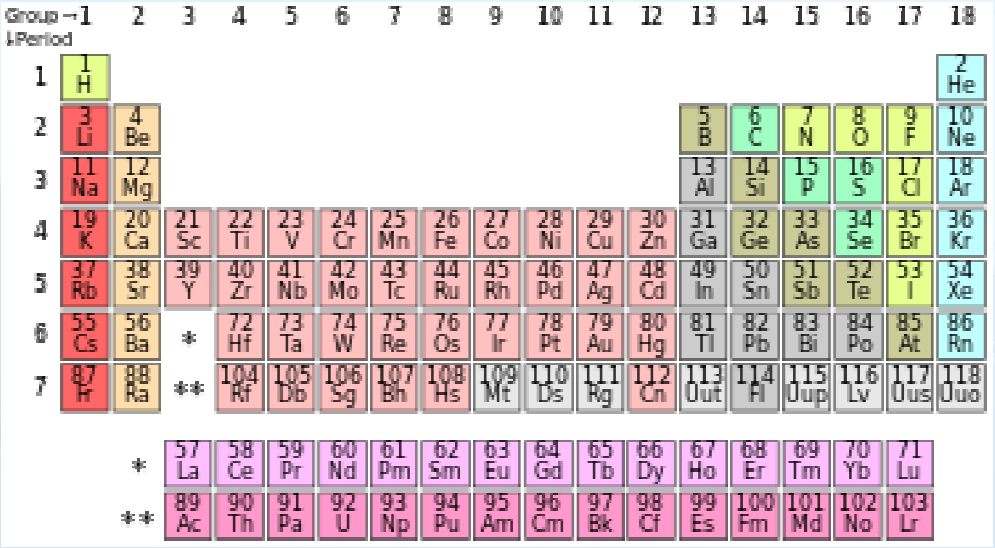
Periodic Table (元素週期表)

Periodic Table is a list of all kinds of elements organized on the basis of their **atomic number** (number of protons in the nucleus).



http://en.wikipedia.org/wiki/Periodic_table

Electron configuration



- The **rows** and **columns** are roughly arranged according to layers that the last electron will be added to.

- The colours represent some basic properties of the element. (Not to discuss in here).

Question

- How can you change an atom from one element to another?
  a) Adding/removing some protons
  b) Adding/removing some electrons
  c) Adding/removing some neutrons

Phases

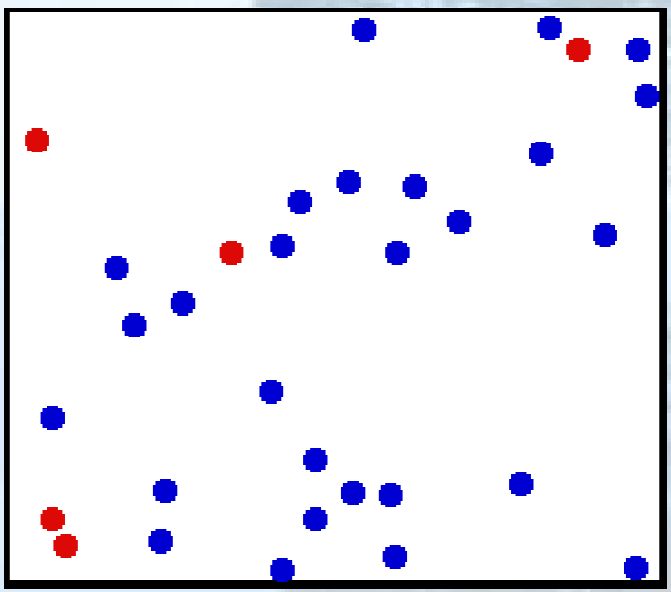
- The commonly known phases (states of matter) include:
  - **Solid**
  - **Liquid**
  - **Gas**

- Changing phase is a kind of **physical change**. i.e., it's **chemical composition** hasn't changed (e.g. water is still water, although changed from ice to liquid water).

- **Change in temperature and/or pressure** can change the phase of a substance. i.e. substance **change phase** from liquid to gas (the boiling point) and from solid to liquid (the melting point).

Kinetic theory of gas

- How does atoms interact?
- When atoms are in the gas state, they can move **freely**.
- The **kinetic theory of gases** describes a gas as a large number of particles, all of which are in constant, **random motion**.



http://en.wikipedia.org/wiki/Kinetic_theory

- Kinetic theory explains properties such as pressure, temperature, by considering the motion of particles.

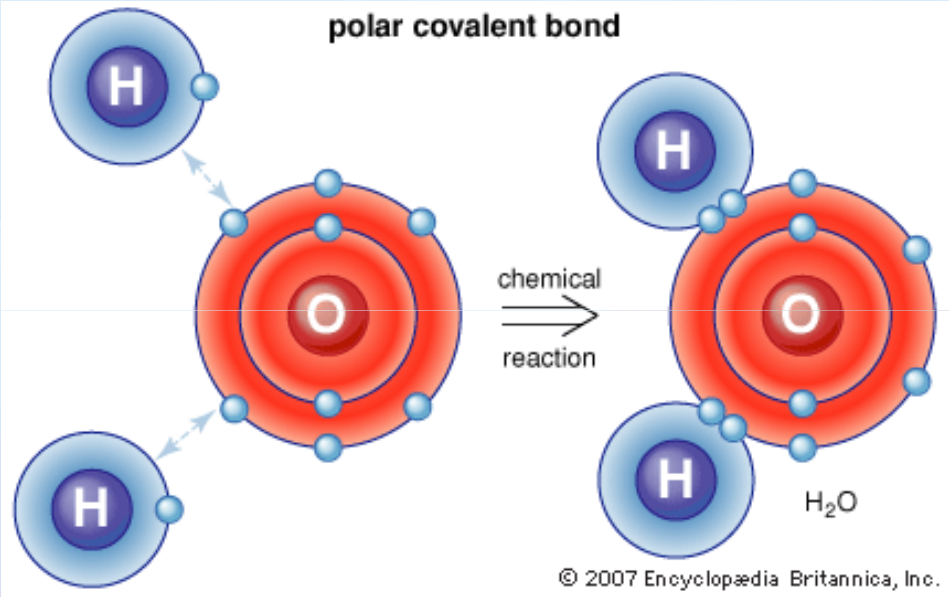
Question

- Water boils at 100˚C? Is this always the case?
  a) Yes
  b) No

Molecule (分子)

- Atoms very often, doesn't exists alone. They are bonded to form a **molecule**.

- Examples:
  - Water – H_2O
  - Carbon dioxide – CO_2



http://blogs.britannica.com/2012/06/molecular-nature-water/

Chemical bonds

- Molecules are formed by **bonding** atoms together. Bonds are really an electrical force linking electrons and protons between varies atoms.

- There are varies types of chemical bonds:
  - Covalent bond
  - Ionic bond
  - Metallic bond
  - Hydrogen bond
  - Van der Waals forces

  Strong bonds

  Weak bonds

- We won't discuss here the differences between the types of bonds.

Nuclear reactions

- **Nuclear reactions** is a reaction that involves the change of nucleus (i.e. adding or reducing the number of protons in an atom).

- Nuclear reaction changes **the type of element** it is.

Question

- Guess which type of change involves most energy?

a) physical change
   – i.e. changing phase

b) chemical change
   – i.e. changing chemical bondings

c) nuclear change
   – i.e. changing the elements

Physical, Chemical and Nuclear change

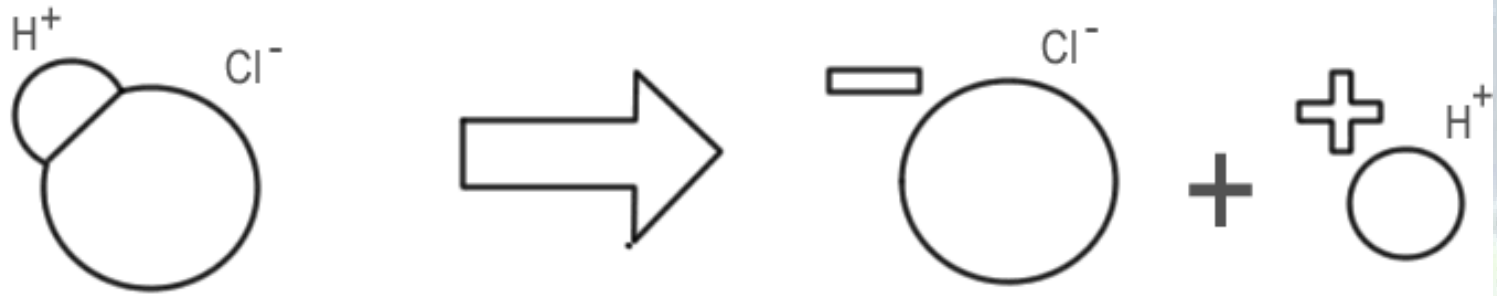
- A **physical change** - change between solid, liquid and gas.
  - Example: ice (solid H_2O) melts to liquid water (liquid H_2O).
- A **chemical change** - involves a reaction in which the products changed their chemical bonds. Significantly more energy needed than a physical change.
  - Example: Hydrogen (H) + Oxygen (O) becomes Water (H_2O).
- A **nuclear change** - involves changes of a nucleus of an atom. This involves about 1,000,000 times as much energy as a chemical change.
  - Example, Hydrogen (H) + Hydrogen (H) becomes Helium (He).

Acid (酸)

- An **acid** is a substance consists of molecules that are able to **donate a proton** (i.e., an hydrogen ions H^+).

- E.g.
  - Hydrochloric acid
  - Amino acid
  - Deoxyribonucleic acid (DNA)

Hydrochloric Acid (HCl, consists of only two elements H and Cl)



http://www.biologycorner.com/worksheets/acids_bases_coloring.html

Organic compounds

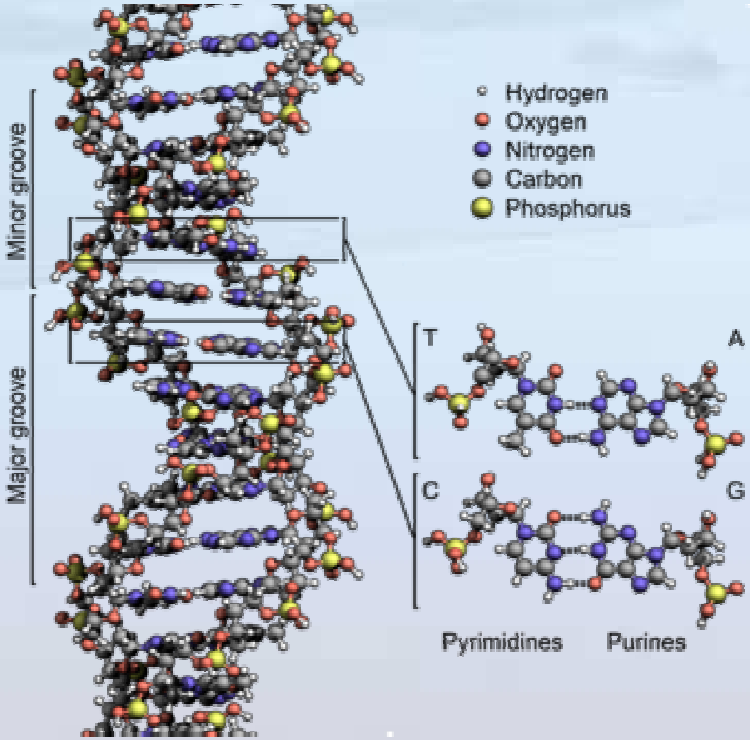
- The modern meaning of **organic compound** is any substances that contains molecules with a significant amount of **carbon**.

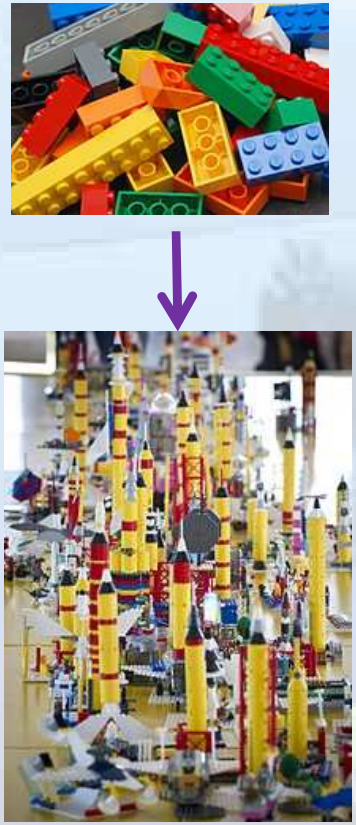
- Historically, organic compounds are thought to be consists of **vital force.** since things with life should be different to things without, right?

- However, with Watson's finding, organic compounds follows exactly the **same** chemistry and physics laws **as inorganic substances**.

Deoxyribonucleic acid (DNA, 脱氧核糖核酸)

- A giant molecule that carries the genetic code.
- Contains 4 chemical bases: **A**denine, **T**hymine, **G**uanine, **C**ytosine, the **building blocks** of DNA.



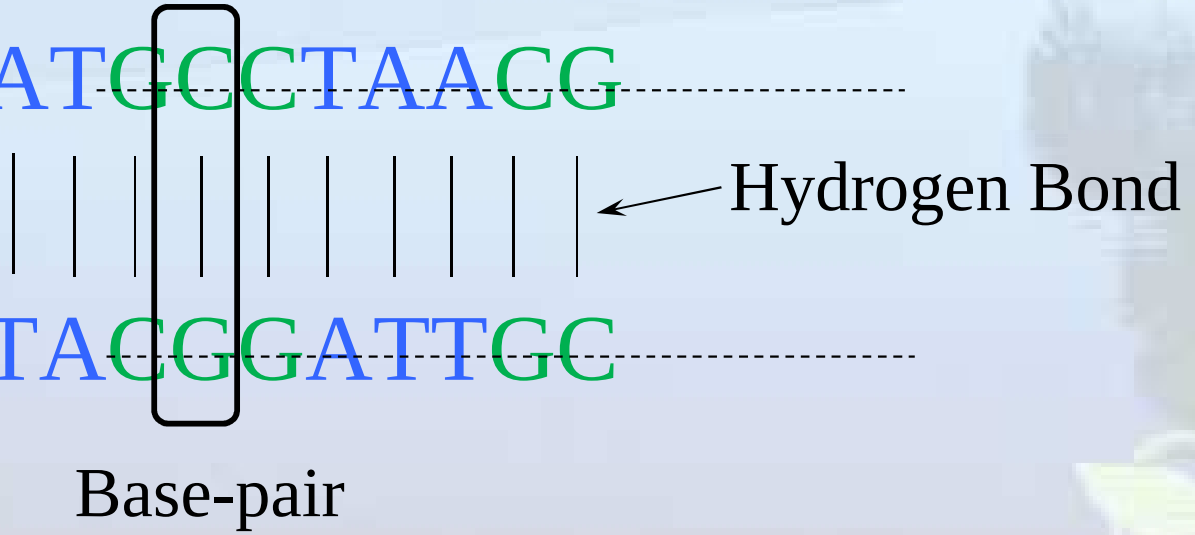


DNA: http://en.wikipedia.org/wiki/DNA

Lego: http://en.wikipedia.org/wiki/Lego

What is DNA?

- **One DNA has 2 strands**, each carrying a series of bases
- The 2 strands are bound together through **A-T** and **G-C** base pairing.
- The strands are said to be **complementary .**



What does DNA code for?

- DNA carries the genetic code but requires something else to decode the stored information.

DNA

…ATGGCTTCCAAATGGTTC…

Decoding Machinery

Protein 蛋白質

…Met-Ala-Ser-Lys-Trp-Phe…

Protein is made up of long sequence of amino acid 氨基酸

It is the protein, not the DNA, that help us to function our body.

Analogy

App written by an engineer

Convert and download

The installed app on your iPhone.

It is the app on your iPhone, not the app written by an engineer, that functions

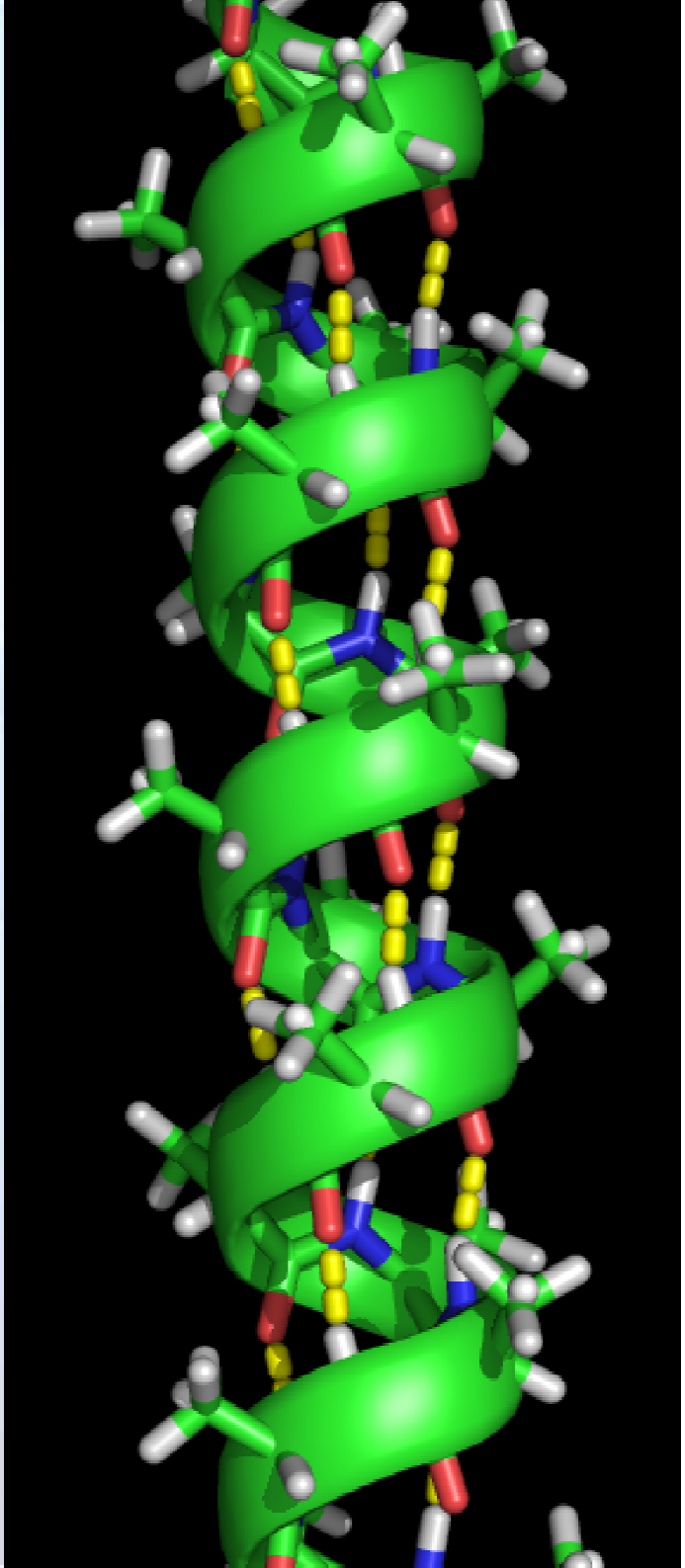
Question

- Suppose Susan was taking a photo of a beautiful scenery with a camera. Use this as an analogy, which of the following resemble the role of DNA?

a) Susan
b) The beautiful scenery
c) The camera
d) The photo

Protein (蛋白質) and Amino acid (氨基酸)

- There are **20 standard types of amino acid** in a protein molecule.
- A common structure found inside a Protein is **α-helix** form – discovered by Linus Pauling.



Question

- Guess which sequence has a larger combination?

  a) A sequence with 4 units, each can be of 20 choices.

  b) A sequence with 20 units, each can be of 4 choices.

Enzyme

- Many vital processes inside the body are performed by a **group of proteins, called Enzyme**.

- For example: energy production, DNA replication, food digestion, detoxification…etc.

- Examples of enzyme:
  - **DNA polymerase** (can replicate DNA)
  - **DNase** (can destroy DNA)
  - **RNase** (can destroy RNA)
  - **Trypsin**, **chymotrypsin** (can destroy proteins)

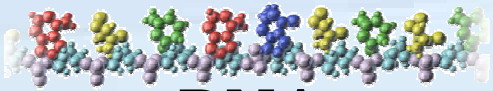
How is DNA decoded?

- The central dogma of life 生命的中心法則

ATGCCTAAC
TACGGATTG

DNA

Protein (enzyme)



RNA

AUGCCUAAC

Protein

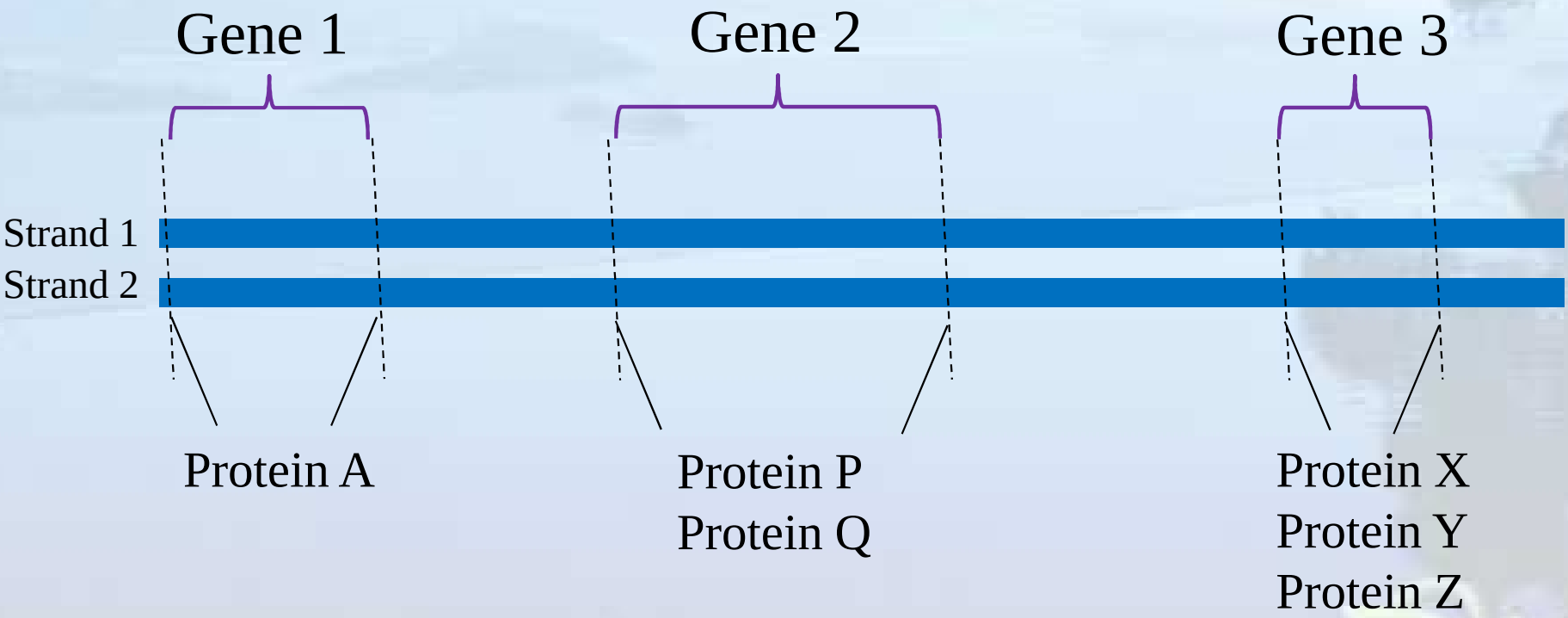
Protein

Met-Pro-Asn

http://www.publicdomainpictures.net/
http://en.wikipedia.org/wiki/RNA
http://en.wikipedia.org/wiki/Protein

What is the relationship between Gene 基因 and Protein?

- Each protein is encoded by a stretch of DNA, called **gene.**
- A single gene can codes for **one to several proteins**.



- In human, ~30,000 genes code for ~100,000 proteins

Question

- DNA sequence is the footprint of our identity. What about Protein sequence? Can the whole set of Protein sequence be possible to use as the footprint of our identity?

  a) Yes
  b) No