CHEMISTRY

The Periodic Table

The periodic table organises the chemical elements into a grid, reflecting various chemical properties. Foremostly, the elements are arranged by *atomic number* (number of protons), from left-to-right and top-to-bottom, with Hydrogen ($AN = 1$) in the top left and synthetic element ununoctium (AN=118) in the bottom right. The first 94 are naturally occurring, the others produced in laboratories. Efforts to produce yet heavier elements persist.

Other properties are associated with the row (period) and column (group). For example, elements become more metallic towards the left of the table. This *periodic trends* were historically used to predict properties of then undiscovered elements.

The colour shadings indicate groups, for example "noble gases" (elements with similar properties in a gas state. N.B. noble gases still have liquid and solid forms, as do all elements, this being a question of the combination of temperature and heat exerted on them). Other groupings such as "heavy metals" (metals with relatively high atomic number) are more loosely defined, and have less regular patterns in the table.

Atoms

Atoms are the smallest unit of matter having the properties of a chemical element. This would imply that any chemical substance consists of one or more atoms. Substances take on one of four states–solid, liquid, gas, and plasma. Atoms are so small that their behaviour is influenced by quantum effects (unlike, in general, macroscopic objects). All atoms consist of a nucleus, to which are attached electrons by *electromagnetic force*. The nucleus comprises of $\geq$ 1 protons and *a similar number of neutrons*, bound by a *nuclear force*. Protons have a positive electric charge, electrons a negative electric charge. Equality implies electrical neutrality, otherwise it is positively or negatively charged (depending on the differential), and is called an ion. The number of protons specifies the chemical element. The number of protons specifies the element's *isotope*. For example, we might compare carbon-12, carbon-13, and carbon-14. All are atoms of the element carbon with 6 protons, but have 6, 7, and 8 respectively.

Radioactivity or radioactive decay occurs when an excess of protons or neutrons in a nucleus overcomes the ability of the nuclear force to hold it together. The nucleus loses particles and transforms There are three types of radioactivity: alpha, beta, and gamma, and the process emits electromagnetic radiation, either as light (on the infrared/ultraviolet spectrum), or gamma rays. According to quantum physics, the process is inherently stochastic and cannot be predicted. However, large groups of radioactive isotopes (atoms with inbalanced nucleii) have a predictable *half-life*, that is, the time taken for the radioactive substance to halve. Half-lives vary wildly across the elements, from moments to billions of years. The radiation from the decay can pose health risks. Radiation poisoning is an immediate risk form overexposure, whereby organs are damaged by the radiation. This can, however, be treated, provided the dosage is limited. Longer-term risks are cancer caused be long-term–though possibly minute–exposure. Background radiation exists at harmless levels everywhere on Earth.

Nuclear fission and nuclear fusion are two ways of unlocking huge amount of energy from atoms. Both are used in nuclear weaponry (resp. atomic and hydrogen bombs), but only fission is yet used for producing energy (fusion is in experimental stages). An atom bomb works by firing particles at an unstable isotope, which itself fires off particles, in a chain reaction.

Molecules

Molecules are groups of ≥ 2 atoms bound together with *chemical bonds*. They are specifically electrically neutral, otherwise they are known as ions. Molecules may be homonuclear (H_2), or heteronuclear (H_2O). The word itself comes from the Latin *mole* meaning *mass*. Note the term mole is used to describe same the number of atoms of a given chemical element as there are in 12 grams of electrically neutral carbon (carbon-12) (^{12}C). This is $\approx 6.02x10^{23}$ atoms, a figure known as Avogadro's constant. Though molecules are common in nature and biology, not all matter is constructed from recognisable molecules.

The chemical bonds that bind atoms together come in different forms and different strengths. Bonding may be done with the attracting electrostatic force between atoms of opposite charge, or with the covalent bond of sharing electrons.

Chemical Equations

Chemical equations are used to model chemical reactions. A chemical reaction is a rearrangement of molecules into a product substance when two or more reactant substances are combined. Solving the equations balances the mass of each element, following the law of conservation of mass. They do not, however predict the molecular form of the new substance.

We start with the chemical formula representation of our reactants, which indicate the proportion of atoms in the molecules. For example,

$C_5H_12andO_2$

The chemical reaction is denoted with a plus (+) sign and an arrow (-¿),

$C_5H_12 + O_2 - > CO_2 + H_2O$,

where the chemical products on the right hand side are known in advance. Now we address each element in turn. There are five carbon atoms on the left, and only one on the right. Therefore we update to,

$C_5H_12 + O_2 \rightarrow 5CO_2 + H_2O$

Now we require 12 Hydrogen atoms on the right,

$C_5H_12 + O_2 \rightarrow 5CO_2 + 6H_2O$,

but now there are 16 oxygen atoms, therefore we modify the left hand side to,

$C_5H_12 + 8O_2 \rightarrow 5CO_2 + 6H_2O$,

and we have achieved balance.

MOLECULAR BIOLOGY

[From Kernel Methods in Computational Biology]

The cell is the atomic unit of living organisms. It is roughly a fluid solution comprising of certain molecules, surrounded by a fat membrane. They range in size from 1?m to 100?m (micro meters). N.B. cells are three-dimensional, but are usually depicted by a cross-section. Cells have various properties: metabolism, replication, reaction to environment, etc. Viruses have some of the same properties, but have no metabolism (relying on the host) and are usually not considered to be alive. Thus, they are in a grey area between life and chemical matter.

Living organisms are either: prokarya (single-celled organisms); or eukarya (everything else). Eukaryotic cells are more complex, containing hereditary information and mitochondria (energy suppliers). Three polymers (covalently linked monomers i.e. sharing electrons) feature in cells: DNA, RNA, and proteins (polypeptides).

Polymers are the bridge between chemical matter and that which can be described as living. They are macro-molecules, the smallest scale at which variation exists in the same structures (e.g. a water molecule is a water molecule, but there are many forms DNA can take on) which ultimately leads to the diversity within and without living organisms. Cells of the same type can have very different morphologies and inaccuracies in their replication–something that can lead to problems.

DNA molecules make up the cell's *genome*–heritable information. DNA consists of linearly linked nucleotides (small chemical compounds), adenine, cytosine, guanine, and thymine. A and T bind together to make base pairs with hydrogen bonds, as do C and G, making them *complementary nucleotides*. DNA consists of two linear chains of nucleotides arranged in a double helix. This improves stability (amongst other things).

The human genome consists of 3 billion nucleotides, separated into 23 separate DNA molecules called chromosomes. In sexual organisms, two (or more) versions of chromosomes are in each cell, one from each parent.

RNA is *ribonucleic acid*–similar to DNA but single-stranded and with uracil (U) rather than thymine. RNA is produced by substrings of the genome called *genes*, in a process known as *gene expression*. This is the mechanism by which genetic information (indirectly) specifies an organism's properties. The RNA is a complement of part of the gene. The majority of genes encode information to produce proteins, following the flow:

DNA-¿messenger RNA (mRNA)-¿protein

Proteins or *polypeptides* are polymers made up of amino acides (as opposed to nucleic acides) amino and carboxyl acids, which form peptide (special covalent) bonds. They link together to form the protein backbone. Proteins fold themselves into a spaghetti-like mess. This mess has some structure, however–for example the alpha helix and the beta sheet. These superstructures determine the range of molecules they can bind to.

Proteins have a diverse range of functions in cells. For example:

* metabolism: special proteins called *enzymes* catalyse reactions to create small molecules to refresh the cells contents e.g. DNA, RNA, lipid membrane etc. Thus, cells are like chemical factories.

* energy, communication, and reproduction

Eukaryotic cells are divided into many compartments called *organelles*, each with their own membrane. The nucleus is the most prominent part, in which is stored the (tightly packed) genome. The non-nuclear parts are known collectively as the cytoplasm–comprising of the organelles and the cytosol liquid solution. The cytoplasm is structured by the *cytoskeleton*. Microtubules, which are essentially polymers shaped as hollow tubes, are an important component of the cytoskeleton, giving the shell its shape.

Gene and protein expression are complex chemical reactions that probably require a great deal of time to appreciate. Regulation is another cell behaviour, where protein levels are moderated by other complex mechanisms.

Cells can communicate on massive scales. Cells that go without communication for too long commit *apoptosis*. This helps to prevent cancer. An example of signaling is when sex hormones enter a cell. These are bound to various proteins, which acquire a genetic response from the

Remember, a level above all this are the components of the bodies' organs: muscle, tissues (of which there are four main types), skin and blood. A level above this are the bodies' organs, and finally the body itself. There, we are about 5-6 abstractions away from the molecular level.

When it comes to evolution, mutation refers to the modification of the genome of *reproductive* cells. This is an organisms *genotype*, as opposed to its *phenotype*, the observable characteristics of the organism. Some mutations are said to be *lethal*. Many are *silent*, having no effect, and most have visible but make no selective difference. These different coexisting genotypes/phenotypes are known as polymorphisms.

The simplest mutation is the point mutation–single nucleotide polymorphisms (SNPs), where a single nucleotide is modified. Other possibilities are insertion, deletion, inversion, translocation (piece of DNA moved to another location), and duplication.

Mutations cause the genetic diversity in a population, i.e. the number of *polymorphisms* present.

Mitosis = nuclear division + cytokenesis = two daughter cells

MOLECULAR BIOLOGY MEASUREMENT DATA

The authors describe the forms of data found in computational biology: sequences (polymers), graphs (molecular structures), vectors, and even natural language (for processing scientific literature–this is a bit dubious, but it fleshes out the table a little more).

The chapter goes over the main data types and internet data sources, and finally the main challenges in computational biology. Systems biology is (was, in 2004) a ripe area of research. This looks at simulating biological systems rather than experimenting on live specimens.

FURTHER NOTES ON CELLS

* A cell culture is a collection of cells extracted from a plant or animal and grown in an artificial environment.

* A cell line is a cell culture from a single initial cell.

* An immortalised cell line is one that has undergone a certain such a mutation that it can continue in perpetuity, usually in vitro. The first such cell line came from the tumour of Henrietta Lacks, an American woman who died in 1951, and is known as the HeLa cell line.

* Life -¿ Domain (prokarya, eukarya) -¿ kingdom (plant, animal), phylum, class, order, family, genus, species

* Cancer are a group of diseases involving abnormal cells growth. If cancer is malign, it means it spreads to other parts of the body. There are over 100 types, the most common cause being tobacco smoking, infections such as hep B and hep C, and poor eating/lifestyle. Cancer is first detected by screening, then by further imaging and biopsy (extraction of sample cells or tissue). Cancer is treated by some combination of radiation therapy, chemotherapy, and surgery. Palliative care (providing relief) is a big part of treatment. The average five-year survival rate is in the order of $66\% - 80\%$.

- assay
- biomarker
- antigen/antibody/pathogen
- histone
- kinase
- chromatin = DNA + histone
- pleitropic
- carcinogenesis
- cell cycle