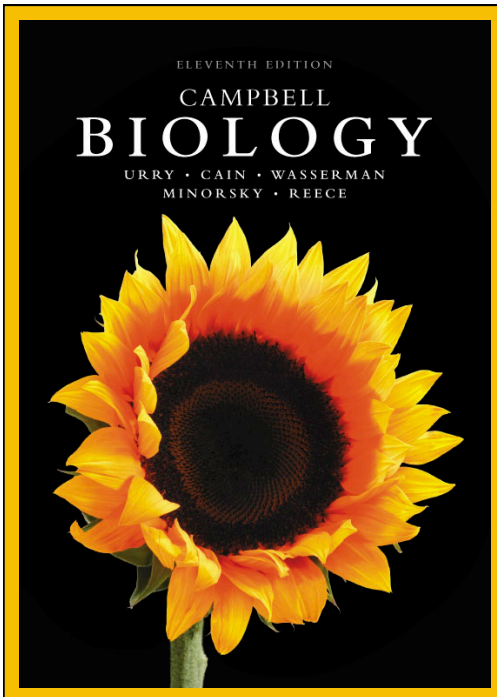


Chapter 1

Themes of Biology

Dr. C. Doumen

What is Biology

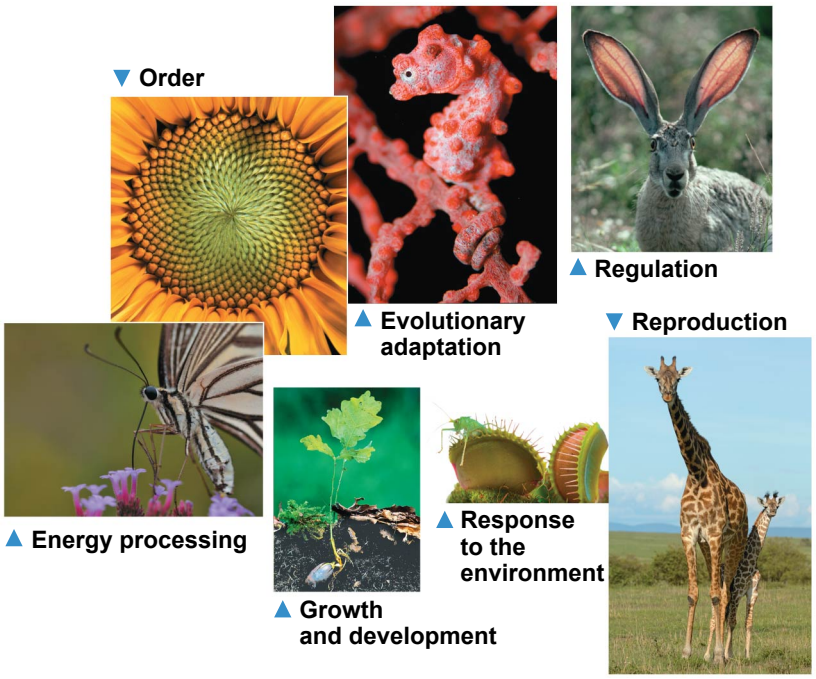
- **Biology** is the **scientific study** of **life**
- Biology is a quest, an ongoing inquiry about the nature of life
- Life defies a simple, one-sentence definition
- Life is better explained by what living things do

Properties of Life

Living things

- ✓ display order in their organization
- ✓ process energy
- ✓ grow and develop
- ✓ reproduce
- ✓ respond to their environment
- ✓ regulate their internal environment
- ✓ adapt and evolve

Figure 1.2



Concept 1.1: The study of life reveals unifying themes

- Biology is a subject of enormous scope with new and exciting discoveries on a daily basis
- There are five unifying themes
  - (1) Organization
  - (2) Information
  - (3) Energy and Matter
  - (4) Interactions
  - (5) Evolution

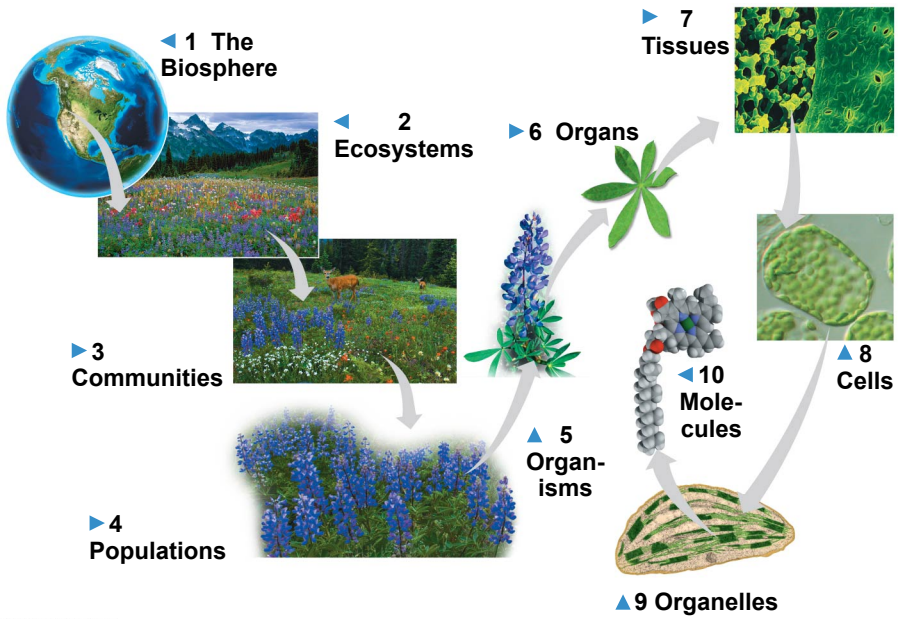
Theme (1)

New Properties Emerge at Successive Levels of Biological Organization

Theme (1): New Properties Emerge at Successive Levels of Biological Organization

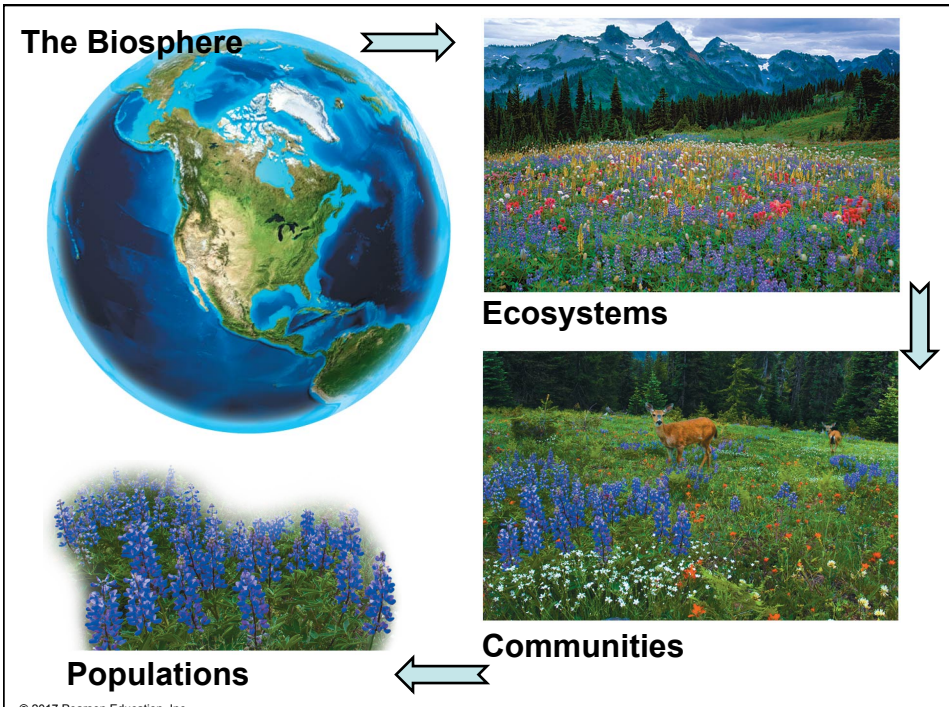
- Life can be studied at different levels, from molecules to the entire living planet
- This enormous range can be divided into different levels of biological organization (hierarchies), going from the more complex to the less complex (or from simplest to more complex)
- The most complex system is obviously our total planet earth with everything that is alive on and in. We call this our BIOSPHERE

Figure 1.3



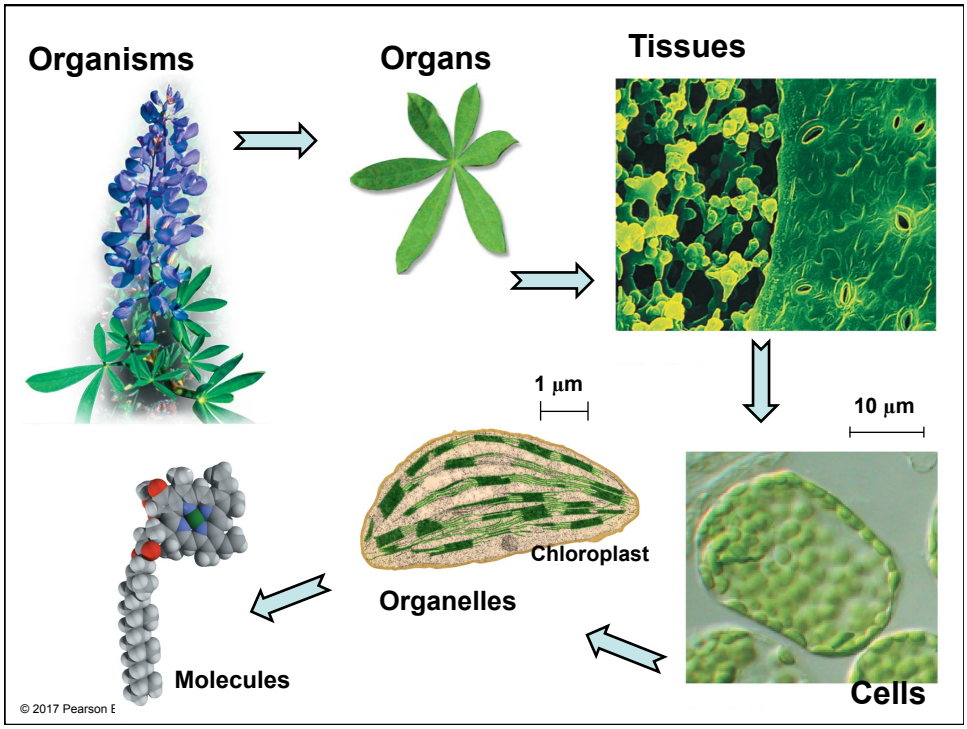
Top down Hierarchy of Organization

- At each level down, the system becomes less complex with less parts in it
  - **Biosphere** = all life on earth and all places where life exists
  - **Ecosystems** = all living things in a particular area, including the non-living elements with which life interacts (soil, water, gases, light,…)
  - **Communities** = The array of living organisms inhabiting a particular ecosystem (a collection of different populations)
  - **Population** = all the living individuals of a specific species within a certain area
  - **Organism** = individual living thing is called an organism



Top down Hierarchy of Organization

- **Organs** = part of an organism, made up from different tissues and with a specific function for that organism. Within each organ, each tissue has a specific arrangment and contribution
- **Tissues** = A grouping of similar cells, working together to perform a specific function.
- **Cells** = basic functional unit of life. Some organisms are just one cell (for example bacteria, protista), others are multi=cellular.
- **Organelles** = A functional component within the cell (for example, the nucleus or mitochondria)
- **Atoms and Molecules** = the basic molecular composition of all matter, including living things



Emergent Properties

- When we start from the smallest to the more complex, new properties emerge that were not present at the previous level
- **Emergent properties** result from the arrangement and interaction of parts within a system
- For example : different tissues create the heart, an organ with certain properties. A different combination of tissues creates the liver, with it own specific function.
- If we delete a certain amount of cells, tissues from those organs, they may not function properly and the whole organisms may suffer

Emergent Properties

- Emergent properties is characteristic of biological entities, but also exists in non-biological machinery
- For example, a functioning car emerges only when all of the necessary parts connect in the correct way
- But, medicine and biology is a little bit more that just understanding the parts and putting it back together in the correct place
- But it helps when we can simplify things in order to study. The breaking down the larger system into its working parts and then studying these isolated parts is called **Reductionism**

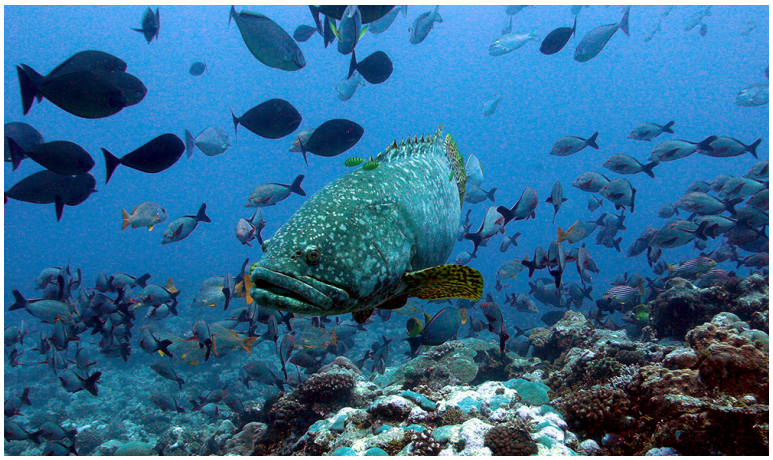
Reductionism

- The reductionist approach studies the isolated components of living hierachical systems in order to understand their contribution to the whole
- For example :
  - Cell biologists study isolated cells in order to understand their contribution to tissues and organs
  - Organ physiologists study organs to understand their meaning for the whole body
  - Population biologist study populations in order to grasp their meaning/function in the communities and ecosystems.

Reductionism

- But since new properties emerge when we go up a level in the hierarchy, biologists complement reductionism with **systems biology**, analysis of the interactions among the parts of a biological system
- For example, ecology has identified keystone species. Eliminating the wolf out of an ecosystem can have damaging effects on that ecosystem.
- Systems biology can be used to study life at all levels
- For example, what are bacteria doing in your body ?

Systems Biology



A recent Australian study has shown that, despite high species richness, more than 40% of functional entities of a coral reef ecosystem are served by a single fish species such as the giant grouper (keystone species), making functional diversity highly vulnerable to single species loss

Structure and Function

- At each level of the biological hierarchy we find a correlation between structure and function
- Analyzing a biological structure gives us clues about what it does and how it works
- Conversely, knowing the function of something provides insight into its structure and organization
- For example, if we think of an organisms that flies (function), what structures do we need ?
- Or, if you see those structures, what does this imply for function ?

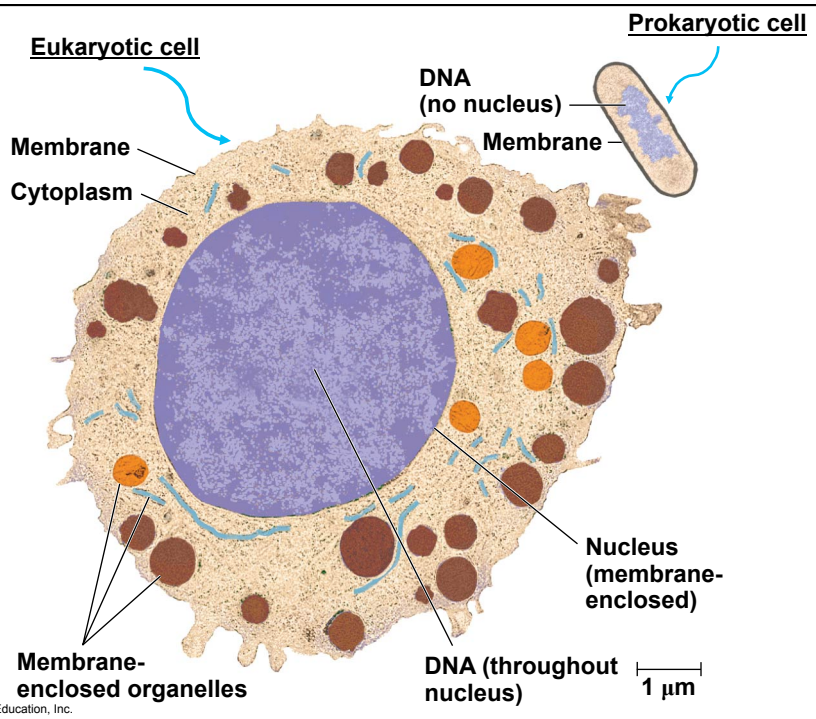
The Cell: An Organism's Basic Unit of Structure and Function

- The cell is the smallest unit of organization that can perform all activities required for life
- The **Cell Theory** states that all living organisms are made of cells, (and cells always arise from other cells)
- Every cell is enclosed by a membrane that regulates passage of materials between the cell and its environment

Prokaryotic and Eukaryotic Cells

- A **eukaryotic cell** has membrane-enclosed organelles (such as mitochondria, lysosomes…); the largest of which is usually the nucleus
- By comparison, a **prokaryotic cell** is simpler and usually smaller and does not contain a nucleus or other membrane-enclosed organelles
  - Typical prokaryotic unicellular organisms are bacteria and archea

Figure 1.4



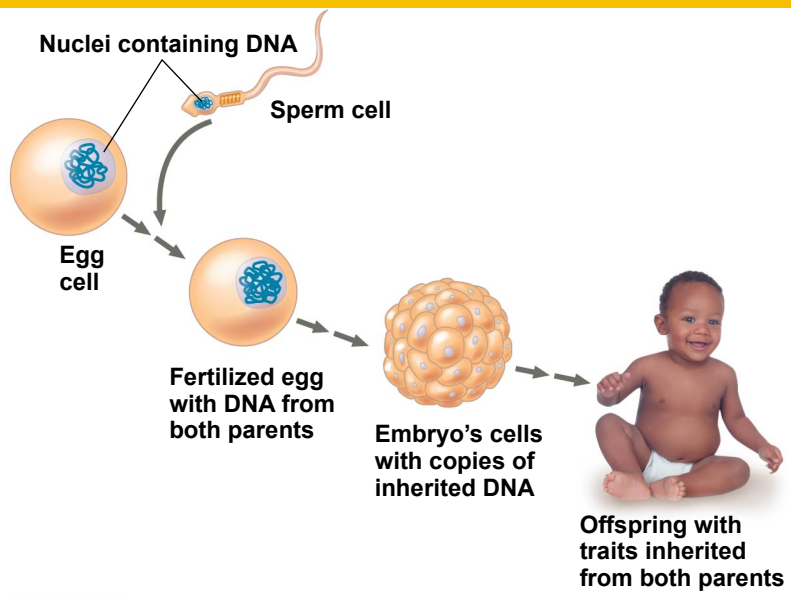
Theme (2)

Life's Processes Involve the Expression and Transmission of Genetic Information

DNA, the Genetic Material

- Within cells, structures called chromosomes contain genetic material in the form of **DNA (deoxyribonucleic acid)**
- Each chromosome contains one long DNA molecule with hundreds or thousands of genes
- **Genes** are the units of inheritance
- They encode information for building the molecules synthesized within the cell
- The genetic information encoded by DNA directs the development of an organism

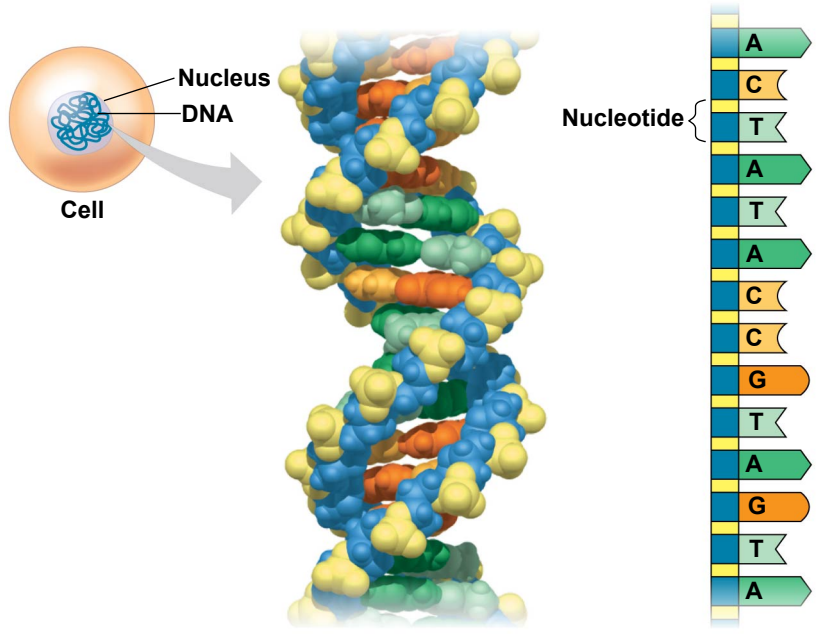
DNA, the Genetic Material



DNA, the Genetic Material

- The molecular structure of DNA accounts for its ability to store information
- Each DNA molecule is made up of two long chains arranged in a double helix
- Each chain is made up of four kinds of chemical building blocks called nucleotides and abbreviated A, G, C, and T

Figure 1.7



(a) DNA double helix (b) Single strand of DNA

Gene Expression

- For many genes, the sequence provides the blueprint for making a protein
- Protein-encoding genes control protein production indirectly
- DNA is transcribed into RNA, which is then translated into a protein
- **Gene expression** is the process of converting information from gene to cellular product

A lens cell uses information in DNA to make crystallin.

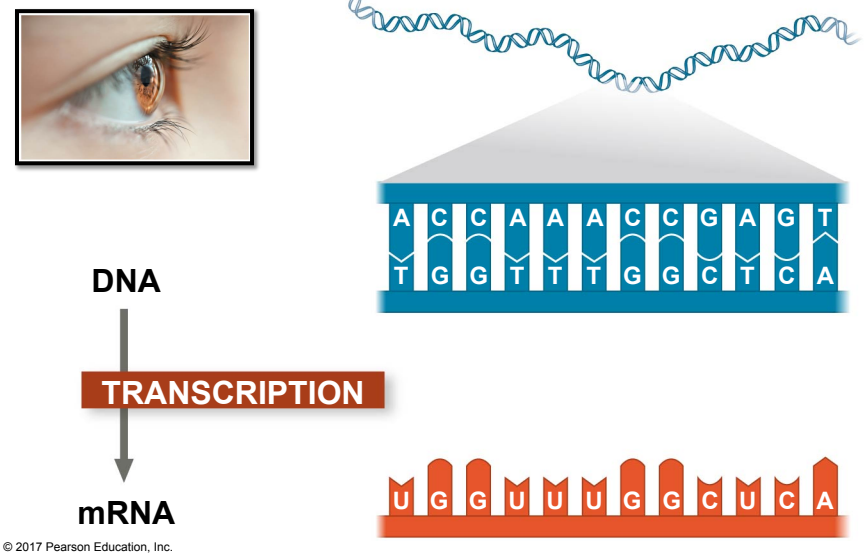
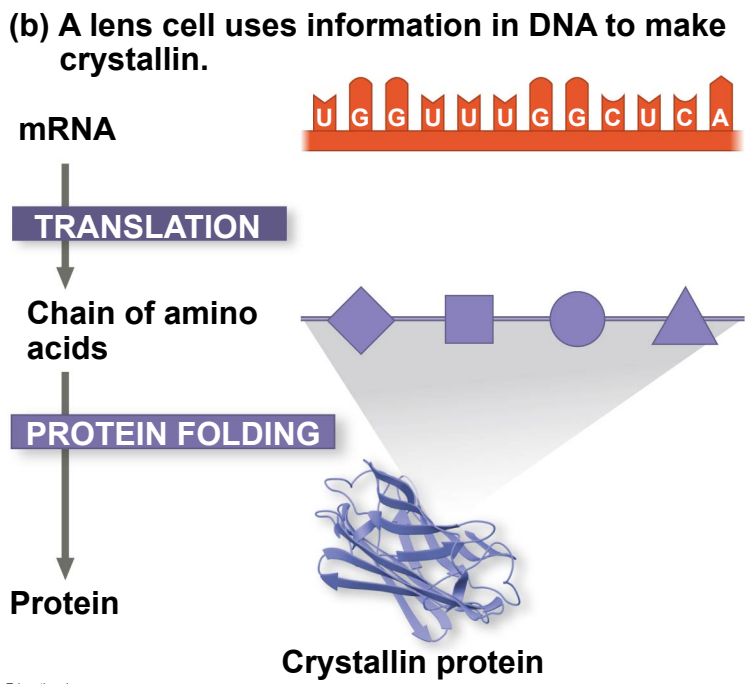


Figure 1.8c



Genomics: Large-Scale Analysis of DNA Sequences

- An organism's **genome** is its entire "library" of genetic instructions
- **Genomics** is the study of sets of genes in one or more species
- **Proteomics** is the study of whole sets of proteins and their properties
- The entire set of proteins expressed by a given cell, tissue, or organ is called a **proteome**

- The genomics and proteomic science is developing fast due to
  - "High-throughput" technology, which yields enormous amounts of data
  - **Bioinformatics**, which is the use of faster computational tools to process a large volume of data
  - Formation of Interdisciplinary research teams