Lesson One

Cells, Tissues and Organs

Aims

By the end of this lesson you should be able to:

- recognise these cell structures as seen with a light microscope and with an electron microscope: nucleus, chromosomes, cell membrane, mitochondria, endoplasmic reticulum and ribosomes
- describe the functions of these cell structures: nucleus, chromosomes, cell membrane, mitochondria, endoplasmic reticulum and ribosomes
- understand that cells are grouped into tissues, and that tissues are organised into organs
- describe the structure of these tissues: bone, muscle (voluntary, involuntary and cardiac), blood, nervous tissue and epithelium (squamous and ciliated, with reference to cells lining the cheek and trachea)
- use scientific units of length

Context

This lesson covers elements 1.1 – 1.2 and 1.14 – 1.15 of the Edexcel specification.

Edexcel International GCSE (9-1) Human Biology Student Book, pages 4-5, 13-15 and 21.

Introduction

If you look at a thin slice taken from any plant or animal under a microscope, you can see it is made up of small boxes called **cells**. Most cells are too small to see with the naked eye, so they were only discovered in the seventeenth century following the invention of the **light microscope** (the normal sort of microscope). We now know that all **organisms** (living things) are made up of one or more cells, including human beings.

Most of the activities of life go on inside the cells of organisms, so understanding them is vital. In this lesson we will look at the **structure** of cells (the parts they are made of) their **functions** (jobs), and how cells fit together to make whole organisms. We will return to the ideas introduced here repeatedly throughout the course.

This lesson also introduces some key vocabulary, measurements and command terms, and you will need to familiarise yourself with these. 'Command terms' are the kinds of words or phrases that frequently appear in exam questions as part of the instructions.

Twig	Log on to Twig and look at the film titled: **What Is a Cell?** www.ool.co.uk/1041ry Every living thing on our planet is made up of one or more cells. Cells are the building blocks of life, but what are they and how do they work?

Activity 1	**Extension work**
	If you are interested, you can find out about the discovery of cells by visiting this web page: www.ool.co.uk/hb0102.

Cells under the Light Microscope

The light microscope can magnify up to about 600X (600 times). At this magnification **animal cells**, including human cells, each appear to be made of only three parts:

- A central **nucleus**. This has two main functions:

  (1) It *controls* the activities of the rest of the cell.

  (2) It stores the genetic *information* needed to make new cells and, indeed, the whole organism.

- The rest of the cell is filled with a grainy, jelly-like **cytoplasm**. This is where most of the chemical reactions of life called **metabolism** go on.

- The cell is surrounded by an extremely thin, fragile layer called the **cell membrane** (or **cell surface membrane** or **plasma membrane**) made of lipid (fat) and protein. This membrane controls what enters and leaves the cell, so that the composition of the inside can be kept constant.

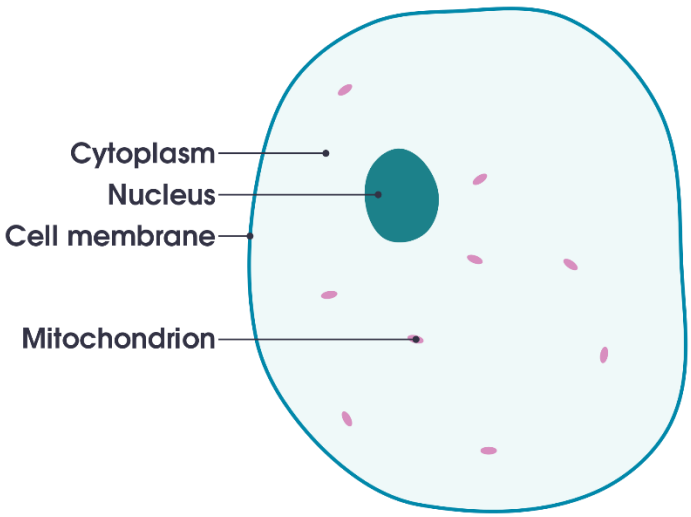


Diagram 1: The parts of an animal cell as seen down a light microscope
See also Figure 1.1 on page 4 of the textbook.

When the cell is dividing (and only then), the nucleus is seen to contain several thread-like **chromosomes**. These carry the genetic information, as we shall see in a later lesson.

Plant cells also have cytoplasm, a cell membrane and a nucleus, just like animal cells. But they have extra structures as well:

- A thick, tough, additional layer outside the cell membrane called the **cell wall**. This is made of the material **cellulose**, and provides much of the roughage/fibre in our diets.
- Leaf cells also have green structures in the cytoplasm called **chloroplasts**, which absorb light energy to make the plant's food in a process called **photosynthesis**.
- Many plant cells also have a large internal space, surrounded by a membrane and filled with non-living solution, called a **vacuole**.

Activity 2	View many pictures of animal cells, as seen down a light microscope, by entering "animal cells under light microscope" into a Google search box and selecting the "Images" option. Then repeat using the search term "plant cells under light microscope". Then repeat using the search term "dividing cells onion root tip" to see cells with chromosomes.
	

	*Get it right!* The outer layer of an animal cell is called the "cell membrane", *not* the "cell wall". A plant cell has both, but the cell membrane is immediately inside the cell wall and is often invisible.

Log on to Twig and look at the film titled: **History of the Microscope**

www.ool.co.uk/1046pk

A brief history of how the microscope has transformed from simple magnifying glasses to the powerful instruments of today.

Cells under the Electron Microscope

In the 1930s, the discovery of the **electron microscope** let us see cells under magnifications of 500,000X or more, rather than the mere 600X allowed by the light microscope. We could then see that the cytoplasm contains many different sorts of structure called **organelles**, of which the nucleus and chloroplast are just the biggest examples. The detailed internal structure of organelles can also be seen under the electron microscope, which has helped biologists figure out exactly how they work.

These organelles include:

- **Mitochondria** (singular: mitochondri*on*): sausage-shaped organelles, containing internal membranes, where most of the energy of the cell is released in a process called **respiration**. Think of them as the "power stations" of the cell, providing the energy which the cell needs to do all of its other processes. See Diagram 1 and Figure 1.26 on page 21 of the textbook.

- **Endoplasmic reticulum** frequently abbreviated to ER: a network of membranes, similar in structure to the outer cell membrane, which runs throughout the cytoplasm. It both transports and modifies materials that are made by the cell.

- **Ribosomes**: very small round structures, often stuck on to the endoplasmic reticulum to form **rough endoplasmic reticulum** as in Figure 1.2 on page 4 of the textbook. This is where the cell constructs its **protein** molecules in a process called **protein synthesis**.

- **Golgi bodies:** stacks of ER membranes looking a bit like stack of dinner plates, also involved in the transport and modification of materials made by the cell. They are

especially numerous in cells dedicated to **secreting** (making and exporting) chemicals, like those in our glands.

The electron microscope also shows more detail in the cell membranes and nuclei of cells:

- The **cell membrane** is seen as two dark lines, very close together, with a lighter space in between them.

- The **nucleus** is seen to be surrounded with a double layer of membrane, and to contain a darker region called the **nucleolus**. See the bottom left corner of Figure 1.2 on page 4 of the textbook. Here is one way of showing it in diagrammatic form – there are many others:

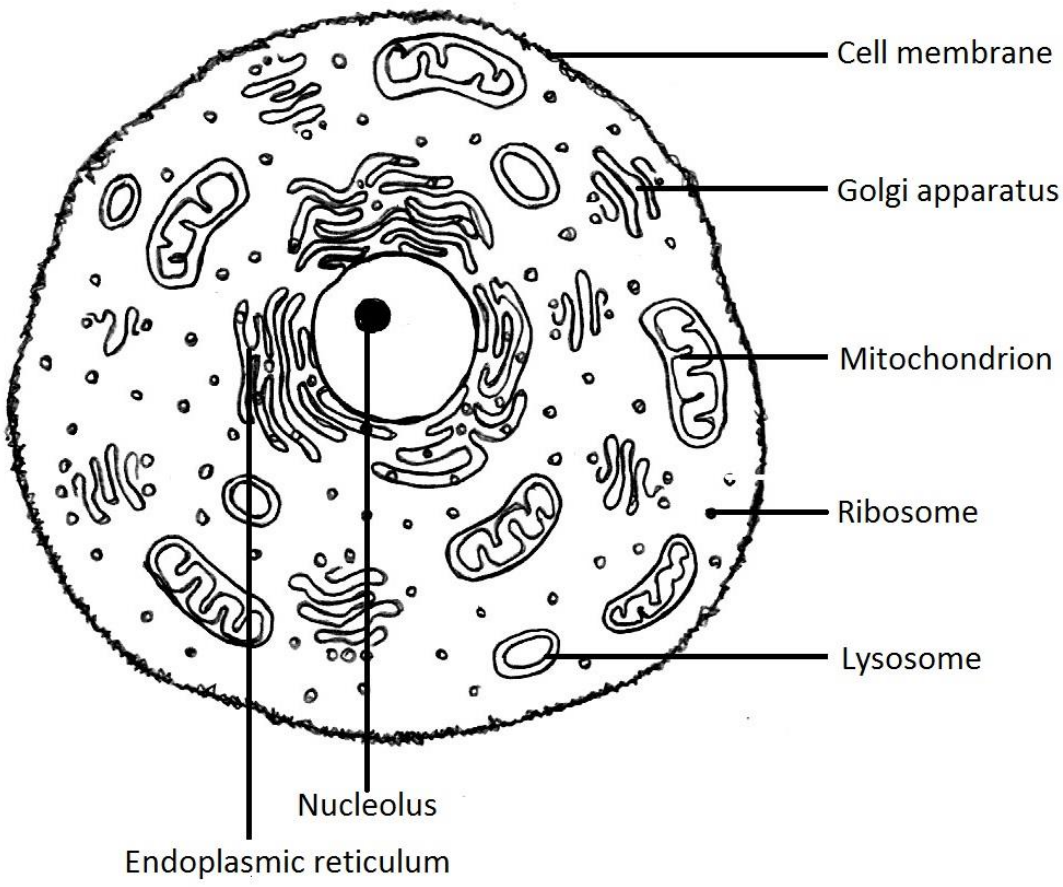


Diagram 2: The parts of an animal cell as seen down the electron microscope. See also Figure 1.2 on page 4 of the textbook.

Activity 3	Look at Figures 1.1, 1.2 and 1.3 in the textbook (pages 4-5). Notice that mitochondria can just be seen under the light microscope, although they look just like spots. Notice also the appearance of the nucleus, endoplasmic reticulum and mitochondria under the electron microscope. Enter the following terms into a Google search box, selecting the Images option in each case: • nucleus under electron microscope • mitochondria under electron microscope • endoplasmic reticulum under electron microscope • ribosomes under electron microscope • cell surface membrane under electron microscope You need to be able to recognize these structures as seen under the electron microscope for your exam.
	

Measuring Very Small Objects

You need to be familiar with the **units** used to measure very small objects such as cells and organelles. You will already be familiar with those used to measure larger objects.

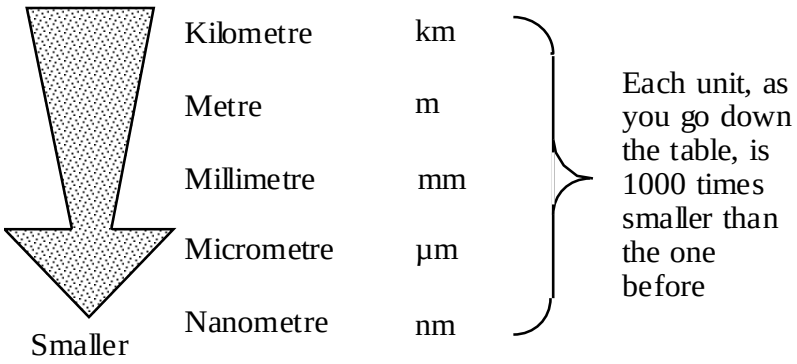
The units of **length** are all derived from the **metre**, which we abbreviate to **m**. You will already have encountered:

- the **kilometre**, or **km**. This is 1000m.
- the **millimetre**, or **mm**. This is $\frac{1}{1000}$ m.
- the **centimetre**, or **cm**. This is $\frac{1}{100}$ m, or 10mm.

Smaller sizes and distances are measured using:

- the **micrometre**, or **micron** written **µm**. This is $\frac{1}{1000}$ mm. You cannot see anything this small with the human eye. You need a light microscope.

- even smaller is the **nanometre**, written **nm**. This is $\frac{1}{1000}$ µm, and is mainly used for measuring objects seen under an electron microscope.



To relate this to the structure of cells:

- A human cheek cell is about 0.03mm (30µm) across

- Its nucleus is about 0.006mm (6µm) across

- A mitochondrion is about 0.001mm (1µm) long

- The thickness of the cell membrane is about 0.0000075mm (7.5nm)

Notice the **scale line** in Figure 1.1 on page 4. This shows a length of 10µm on the scale of the diagram, so the cell drawn there is about 3 x 10 = 30µm across.

Activity 4

Using a ruler, and the information above, see if you can work out (a) the width of your thumb nail in µm (b) the width of a full stop in your course file in µm (c) how many cheek cells laid end to end would cover 1mm (d) how many times a mitochondrion is longer than the cell membrane is thick.

Specialised Cells, Tissues and Organs

So far we have looked at the structure of a "standard" animal cell. But in our bodies most of the cells are **adapted** (changed) to become **specialised** or **differentiated** cells. These cells perform just one particular function well, and rely on the other cells in the body to do other jobs for them.

In this respect, the cells in our bodies are rather like people in modern society. People specialise as teachers, bricklayers, policemen and so on, and rely on the other people in society to do the other jobs for them. Similarly, some cells carry electrical messages, others make digestive enzymes, and so on. Both people in societies, and cells in organisms, show **division of labour**.

A group of similar cells which are all specialized to perform the same particular function is called a **tissue**. A good example is the layer of cells which lines the **trachea** or windpipe in a human being. These grow hairs called **cilia** which beat rhythmically to sweep dirt particles up away from the lungs, passing the dirt from cell to cell along the trachea like a chain of people passing bricks or buckets of water. This tissue is called **ciliated epithelium**:

- "ciliated" because the cells all have cilia, and
- "epithelium" because that is the name for any tissue lining a surface.

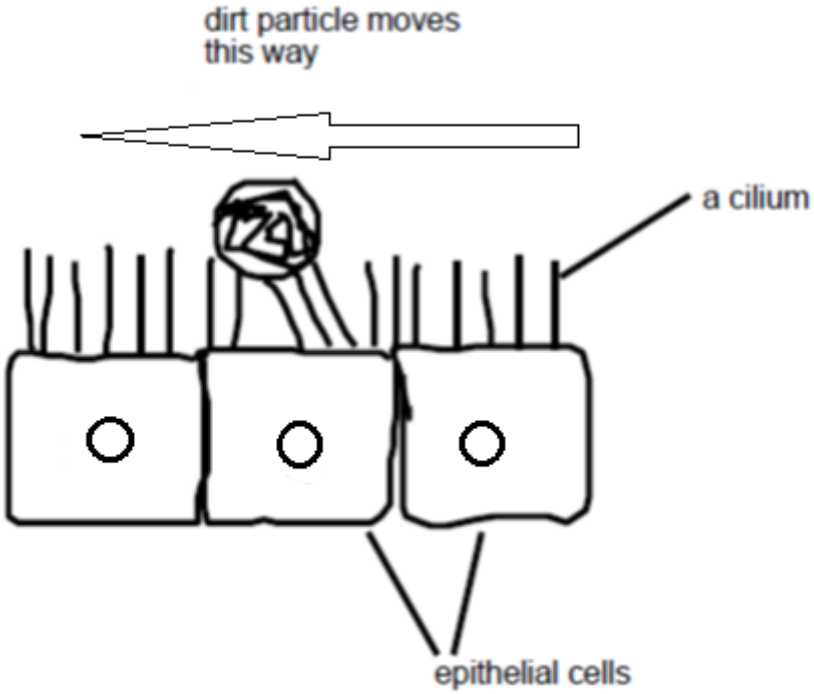


Diagram 3: Ciliated epithelium
See also Figure 5.5 on page 79 of the textbook

A group of different tissues joined and working in co-operation is called an **organ**, and when groups of organs work together to perform a particular function they form a **system**. Many systems are needed to form the living **organism**.

So, for example, several sorts of tissue (muscle, valve tissue etc.) combine together to form the human heart (an organ), and the heart plus the blood and blood vessels forms **the circulatory system**, which is one of the systems in a human being.

organelles → cells → tissues → organs → systems → organism

Get it right!

- An "organ" is usually (but not always) a visible lump which can be cut out of the organism, like the heart or the brain.
- A "tissue" is a collection of similar cells. Most organs are made up of several different sorts of tissue combined together.
- "Systems" are collections of organs which cooperate to perform some major life process, like excretion or digestion.

Twig	Log on to Twig and look at the film titled: **Types of Cell** www.ool.co.uk/1042df Skin cells, sperm cells and nerve cells are just some of the cell types that perform specific functions in our bodies. What are they and what do they do?

Activity 5	Spend a few minutes thinking about the human body and write down as many organs as you can think of.
	

Types of Tissue

In human beings, there are five main classes of tissue:

- **Skeletal or Connective tissue**: tissues which join together or support other tissues and organs. These include **bone** and **blood**.
    - Figure 7.4 on page 127 of the textbook shows a thin section of bone as seen down the light microscope, while Figure 7.3 shows how this relates to a whole bone. Bone has scattered **bone cells** arranged in rings, central **Haversian canals** containing blood vessels and nerves, and much non-living material in between rich in protein and **calcium** salts.
    - Figure 6.14 on page 102 shows a human blood smear as seen under a light microscope. Blood contains **red blood cells** which carry oxygen, **phagocytes** and other **white blood cells** involved in defence against disease, and small cell

fragments called **platelets** involved in blood clotting.

In addition to living cells, connective tissues contain a great deal of background substances. In bone this is calcium salts deposited around the bone cells, making the bone hard. In blood it is the fluid or **plasma** in which the cells float.

- **Muscular Tissue**. The cells composing muscular tissue have the power to alter their shape: they can **contract** to become shorter and thicker, enabling the parts of the body to move. Muscular tissue is of three sorts:
    - **Voluntary** muscle, also called **striated** or **skeletal** muscle, forms the muscles connected bones which move the skeleton around. Voluntary muscle is under the control of the will (you can tell it what to do) and its fibres appear striped under the microscope. See the top of Table 1.2 on page 14 of the textbook.
    - **Involuntary** muscle, also called **smooth** muscle, is found in places like our digestive system, where it moves the food along. It is not under the control of the will and does not appear striped under the microscope. See the middle of Table 1.2.
    - **Cardiac** muscle is only found in the heart. Its fibres appear striped under the microscope, and its fibres are branched unlike those of voluntary muscle. Cardiac muscle is not under the control of the will – you cannot tell your heart to beat faster or slower. See the bottom of Table 1.2
- **Nervous Tissue**: composed of highly specialised cells or **neurones**, adapted to carry **electrical impulses** from one place to another. The brain is made up many different types of neurone. Figures 9.2 and 9.3 on pages 150-151 of the textbook show the structure of some of these cells.
- **Epithelium:** cells which line the inside and outside surfaces in the body, such as the skin and the lining of the gut, are called epithelial cells. There are many different sorts of these, doing different jobs, for example:
    - We met **ciliated epithelium** above.

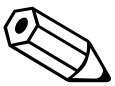
- The cells lining the inside of your cheek form a different sort of epithelium called **squamous epithelium**. In this case the cells are thin and flat, and have no cilia. Figure 1.3 on page 5 of the textbook shows some of these cheek cells as seen down a light microscope. They have been **stained** to make the cells' nuclei show up as darker round ovals inside the cells.

- **Reproductive tissue**: concerned with making new human beings. This includes the testes in men which makes sperms, and the ovaries in women which make eggs.

We will meet all of these types of tissue again as we work though the course and look at the organs and systems they contribute to. For now, just notice the many different forms cells can take, and the many different functions they can perform.

Activity 6	Enter the following terms into a Google search box, selecting the Images option in each case:
	• 'bone under microscope' • 'blood under microscope' • 'muscle under microscope' • 'neurones under microscope' • 'ciliated epithelium under microscope' • 'squamous epilithelium under microscope'.

Activity 7	List all the systems that you can think of in your body. You should be able to list eight, but don't worry if you can't come up with that many.



1.

2.

3.

4.

5.

6.

7.

8.

Now is the time to read pages 4-5, 13-15 and 21 of your textbook. This covers the same topics as the lesson, so will add to your understanding of the material.

Keywords

Cell
Structure
Function
Organism
Organ
Organelle
Tissue
System
Differentiated
Specialised
Ribosome
Cytoplasm
Organelle
Epithelium
Endoplasmic reticulum
Cell membrane
Microscope
Ribosomes
Mitochondrion
Nucleus
Microscope

Make sure you understand what these terms mean before you go on to Lesson Two.

Summary

Lesson One: Cells and the Tissues

Cells under the light microscope

Cells under the electron microscope

Measuring very small objects

Specialised cells, tissues and organs

Types of tissue

What you need to know

- that cells are made up of organelles with individual functions
- the functions of each organelle
- that cells are organized into tissues, tissues into organs, and organs into systems

What you might be asked to do

- relate the structure of a cell to its function
- label a diagram of a cell
- recognize and name organelles as seen under light and electron microscopes
- convert measurements of length into different units
- describe the structures of the four main sorts of tissue

Command words in examination questions

Most examination questions start with a "command word" which tells you what you are required to do. It is important that you don't mix these up, or you will lose most of the marks by not giving the examiner what he/she has asked for. Some of the key command words are given below:

- **Describe** – state what you can see, or how things are. You don't need to explain *why* things are as they are or appear

- **Explain** – use your knowledge of biology to explain *why* things are as they are or appear

- **Compare** – bring out both the similarities and the differences between the two items being compared. Do NOT just write about one item followed by the other item: show HOW they are the same or different;

- **State** – give a concise (short) response, without any elaboration or explanation;

- **Calculate** – arithmetic is involved. Show your working, as well as your answer;

- **Name** – just give the name of the item requested. Do NOT also describe or explain it;

- **Suggest** – this refers to a new situation which you have not been taught about, so don't panic because you don't know the answer. Use the biological principles and concepts you have studied to suggest a possible response. There is usually more than one possible answer.

Try to use this information when tackling the self-assessment test which follows.

Self-Assessment Test: Lesson One

1. Describe the functions of (a) the nucleus (b) the cell membrane.

2. Compare the structure and function of a Golgi body and the endoplasmic reticulum.

3. State the four main types of tissue.

4. Explain the importance of the mitochondria in the cell.

5. Name the parts of a cell which are visible under (a) the light microscope (b) the electron microscope.

6. Calculate the number of micrometres in (a) 3 millimetres (b) 10 nanometres

7. Suggest why the ribosome was discovered about 300 years after the nucleus.

Answers to SATs are given at the end of the lesson.

Suggested Answers to Activities

Activity Four

(a) About 15mm, which gives 15,000µm

(b) About 0.1mm, which gives 100µm

(c) 1/0.03 = 33 ("about 30" is the best answer)

(d) 1000nm/7.5nm = 133 ("about 130 times" is the best answer).

Remember: 1µm = 1000nm!

Activity Five

Human organs include the brain, stomach, heart, lungs, pancreas, liver, kidneys, testes, ovaries, gall bladder, bladder, uterus and intestines.

Activity Seven

1. Respiratory system
2. Circulatory system
3. Skeletal-muscular system
4. Excretory system
5. Reproductive system
6. Sensory system
7. Nervous system
8. Immune system

However, there are alternative ways of naming and dividing up the systems.

Suggested Answers to Self-Assessment Test: Lesson One

1. (a) The nucleus controls the activities of the rest of the cell and stores the genetic information needed to make new cells and the whole organism.

   (b) The cell membrane controls what enters and leaves the cell, so that the composition of the inside can be kept constant.

2. Both the endoplasmic reticulum and the Golgi body are composed of membranes, but in the Golgi body these are stacked up in a pile instead of spread out. The endoplasmic reticulum transports materials within the cell, whereas the Golgi body sometimes exports materials to the outside of the cell.

3. Skeletal / connective, nervous, muscular and epithelial tissues.

4. Cells need energy for a variety of processes. This energy is released in a process called respiration. The mitochondria in a cell are where most of this respiration goes on, so they provide energy for the rest of the cell.

5. (a) Nucleus, cell membrane, cytoplasm, chromosomes, plus (in plant cells only) cell wall, chloroplast, vacuole.

   (b) All of the above plus mitochondria, Golgi bodies, endoplasmic reticulum, ribosomes. N.B. mitochondria could be in either list.

6. (a) $3 \times 1000 = 3000$

   (b) $10 / 1000 = 0.01$ (1/100 is also correct, but it is always best to use decimals rather than fractions in science).

7. The nucleus is much bigger than the ribosome. It is big enough to be visible under the light microscope, which was invented in the 17th century. Ribosomes are only visible under the more powerful electron microscope, which was invented in the 20th century, about 300 years later.