indicazioni operative

guidelines

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STEM

in accordo con il
Ministero dell'Istruzione, Università, Ricerca
e sulla base delle
Politiche Linguistiche della Commissione Europea
Premio Label europeo

percorso formativo a carattere
tematico-linguistico-didattico-metodologico
scuola secondaria di secondo grado

a cura di

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INDICAZIONI DEL PERCORSO LINGUISTICO-DIDATTICO-METODOLOGICO

CLIIL IN ACTION

STEM

INDICE

NOTE METODOLOGICHE	Pag. 3
Strategies before BIOMOLECULES	Pag. 6
Strategies during BIOMOLECULES	Pag. 7
Strategies after BIOMOLECULES	Pag. 10
Strategies before EARTH	Pag. 15
Strategies during EARTH	Pag. 17
Strategies after EARTH	Pag. 19
Strategies before GMO	Pag. 24
Strategies during GMO	Pag. 26
Strategies after GMO	Pag. 31
Strategies before HYDROCARBONS	Pag. 36
Strategies during HYDROCARBONS	Pag. 38
Strategies after HYDROCARBONS	Pag. 42
Strategies before POLYMERS	Pag. 46
Strategies during POLYMERS	Pag. 48
Strategies after POLYMERS	Pag. 52
Strategies before STARS	Pag. 58
Strategies during STARS	Pag. 59
Strategies after STARS	Pag. 64

Note Metodologiche

Questo progetto, rivolto alle **scuole secondarie di secondo grado** all'interno di un protocollo di intesa tra eni e Miur, corrisponde ai requisiti previsti dalla "**scuola digitale**" in un contesto **web 2.0** e in un'ottica **CLIL** (Content and Language Integrated Learning) funzionale all' apprendimento integrato di **lingua inglese e contenuto scientifico** (*physics, chemistry, geoscience, biology*).

Come ambiente di apprendimento "clil in action" è stato concepito per facilitare l'approccio graduale al CLIL dei docenti disciplinaristi con il pieno coinvolgimento, attivo e responsabile, degli studenti che partecipano al percorso formativo.

Clil in action si compone delle seguenti risorse:

- **Note metodologiche**: documento fondamentale per applicare il progetto in modo ottimale dal punto di vista didattico-linguistico;
- **Griglie di valutazione**: documento strutturato che facilita l'approccio docimologico a lingua e contenuto;
- **Schede di monitoraggio**: documento che permette di mappare in modo organico i processi di insegnamento/apprendimento.
- **Moduli/Uda Clil (livelli B1-B2-C1):** basati sui video delle seguenti aree tematiche STEM:

✓ 🧬 **Biomolecules**

✓ 🌍 **Earth**

✓ 🌱 **GMO**

✓ 🛢 **Hydrocarbons**

✓ 🧪 **Polymers**

✓ ⭐ **Stars**

Clil in action si sviluppa attraverso delle **unità di apprendimento** a loro volta articolate in diverse sezioni che fanno riferimento a: **strategie "before"** (propedeutiche all'intero modulo), **strategie "during"** (basate sulla struttura che rappresenta il tema trattato), **strategie "after"** (organizzate con esercitazioni, anche in autocorrezione, di tipo linguistico, disciplinare e concettuale).
Per fruire al meglio del percorso formativo di ogni singolo modulo CLIL, **è necessario seguire l'indice che segue:**

Strategies – BEFORE

- *Prerequisites*
- *Linking to Previous Knowledge and Predicting*
- *Italian/English Glossary*

Strategies – DURING

- *Structure*: testo e video con trascrizione su cui si basa il tema trattato
- *Exercise*:
  - *Keywords*

Strategies – AFTER

- *Drill exercises:*
  - *Multiple Choice*
  - *Matching*
  - *True or False*
  - *Cloze*

- *Soft skills exercises:*
  - *Flow Chart*
  - *Think and Discuss*
  - *Compendium*
  - *Problem Solving*

Griglie di valutazione: integrano gli esiti delle verifiche sia dal punto di vista disciplinare che da quello linguistico.

Schede di monitoraggio: costituiscono una sorta di "diario di bordo" che permette di riflettere in modo organico sul percorso formativo.

- **Video di David Marsh (co-autore del QCER)**: introduzione agli sviluppi della metodologia Clil da un punto di vista storico e scientifico; https://www.youtube.com/watch?v=d7BPArQewUk

David Marsh is a leading figure in the development of CLIL in Europe. Acting as a driving force in the 1990s introductory phase and launching the term CLIL in 1994, he has continued to be actively involved with the global CLIL community. Most recently he has worked on linking evidence from the educational neurosciences with aspects of CLIL practice.
Born in Australia, educated in the UK and operating from Finland, he has experience of teacher development, educational capacity-building, research and consultancy in a range of different countries like Africa, Asia, the Middle East and South America. Having published extensively, he is co-author, among others, of European Framework for CLIL Teacher Education (2011).

Online References

1. MIT BLOSSOMS
Website: https://blossoms.mit.edu https://oercommons.org/hubs/NSDL
Focus: Engineering, applied math and science
2. National Geographic Education
Website: https://education.nationalgeographic.org
Focus: Science, Earth science, biology, geography
3. NASA Education
Website: https://www.nasa.gov/stem
Focus: Space science, physics, Earth science
4. HHMI BioInteractive
Website: https://www.biointeractive.org
Focus: Biology, life sciences
5. TeachEngineering
Website: https://www.teachengineering.org
Focus: Engineering lessons and design challenges

6. NRICH (University of Cambridge)
Website: https://nrich.maths.org
Focus: Problem solving and mathematical reasoning
7. BBC Bitesize
Website: https://www.bbc.co.uk/bitesize https://www.stem.org.uk/
Focus: STEM
8. Science News for Students
Website: https://www.snexplores.org
Focus: Current science topics explained for students
9. MIT App Inventor
Website: https://appinventor.mit.edu
Focus: App development, computational thinking
10. CODE
Website: https://code.org/en-US/students/middle-and-high-school
Focus: Introduction to AI, data, cybersecurity
11. CLEAN
Website: https://cleanet.org/index.html
Focus: Energy and climate
12. TECH-DICO
Website: https://www.techdico.com/translation/italian-english/
Focus: Technical and scientific terminology

BIOMOLECULES

BIOMOLECULES-BEFORE

Prerequisites

Biology
• Cells as basic units of life
• Living organisms need energy and matter
• Basic concept of metabolism
Chemistry
• Atoms and molecules
• Simple chemical bonds
• Organic compounds

Linking to Previous Knowledge and Predicting

• What do living organisms need to survive?
• What is food made of?
• Why do we need energy?
• Are all substances in living organisms the same?
• Can you name substances found in food?

What are Biomolecules?
Biomolecules are organic molecules found in living organisms. They are essential for structure, energy storage, and life processes.

Scientific Areas Involved
• Biology
• Biochemistry (basic level)
• Nutrition
• Organic chemistry

GLOSSARY

Biomolecola	Biomolecule
Acido grasso	Fatty acid
Acido nucleico	Nucleic acid
Amido	Starch
Amminoacido	Amino acid
Anticorpo	Antibody
Apolare	Apolar (hydrophobic)
Aterosclerosi	Atherosclerosis
Carboidrato	Carbohydrate
Cellulosa	Cellulose
Condensazione	Condensation
Disaccaride	Disaccharide
DNA	DNA (Deoxyribonucleic acid)
Doppio strato lipidico	Lipid bilayer
Emulsionante	Emulsifier

Fosfato	Phosphate
Fosfogliceride	Phosphoglyceride
Fosfolipide	Phospholipid
Glicerolo	Glycerol
Glicogeno	Glycogen
Globulo rosso	Red blood cell
Grasso saturo	Saturated fat
Idrofilo	Hydrophilic
Idrolisi	Hydrolysis
Insolubile	Insoluble
Legame chimico	Chemical bond
Legame peptidico	Peptide bond
Lipide	Lipid
Membrana cellulare	Cell membrane
Metabolismo	Metabolism
Monomero	Monomer
Olio	Oil
Polare	Polar
Polimero	Polymer
Polisaccaride	Polysaccharide
Proteina	Protein
Riserva energetica	Energy reserve
RNA	RNA (Ribonucleic acid)
Solubile	Soluble
Trigliceride	Triglyceride
Zucchero	Sugar

BIOMOLECULES-DURING

Biomolecules Video

Biomolecules are the main components of our body and of the bodies of all living organisms. They are complex molecules, very complex in some cases, but they are part of our everyday life, although most of us are not aware of this. In fact, together with vitamins and minerals, they are at the basis of our nutrition.
Carbohydrates, for example, include sugars and polysaccharides.
Sugars are compounds that can be found in fruit, but also in milk and in many other types of food. Generally, they are easily recognized by their sweet taste.
Polysaccharides are not sweet, although they are made of sugars. However, they are the nutritional base for most human beings. They are the basic components of all starchy foods such as wheat, potatoes, corn and rice, but also pasta, bread and polenta.
They can be found in many other kinds of food, for example legumes such as beans, chickpeas, lentils and the like.
Lipids are fatty substances, for example condiments such as oil and butter, but they can also be found in high quantities in certain types of meat, in eggs, and in several vegetables such as avocados.
Their main role is that of energy reserves, since they are very rich in energy-producing molecules.
Proteins are perhaps the most varied and complex class of biomolecules. This is why several foods contain a certain amount of them. In our diet, however, the foods that are richer in proteins are meat, eggs, fish and their by-products such as ham and salami.
Among vegetables, legumes are an important source of protein.

The final class of biomolecules is that of nucleic acids.
These include RNA and the well-known DNA. All cells contain a certain amount of DNA because, as you probably know, it works as hereditary memory.
Each cell has its own quantity of DNA, although it is not stored in a specific part of a living organism, so it is not particularly important as an alimentary source.
In spite of that, all living beings contain it. We will look for DNA in a banana. This will be an opportunity to carry out a simple and amusing laboratory experiment.

Carbohydrates – Sugars

All sugars have some characteristics in common: they are ring-shaped, with an oxygen atom at one of the vertices and several –OH groups bound to this ring. The presence of these groups ensures that sugars are water-soluble. Their common structure is the reason why we perceive them as sweet.
These characteristics are preserved even when a sugar is made up of two molecules bound to one another, thus forming a disaccharide.

Polysaccharides

Polysaccharides are large molecules resulting from the binding of sugar molecules, from several dozens to many thousands. Because of their large size, they are not water-soluble, and that is why they do not taste sweet.
Among other things, they are components of starchy foods, and they represent the nutritional base in nearly all human cultures. This is because they contain many molecules that are easily assimilated by our bodies, after the large molecule in which they are found has been broken down.
Thus, polysaccharides form energy reserves that are ready for use. That is why our muscles are rich in glycogen.

Fatty acids

Fatty acids are themselves lipids and are components of other categories of more complex lipids, such as triglycerides, phospholipids and glycolipids, among others.
Because of their long carbon chains, their molecules can be digested; thus, a great amount of energy is made available. The chains themselves are the reason why fatty acids cannot be dissolved in water.
Their characteristics make them particularly suitable as energy reserves, slower to be used compared to polysaccharides, but yielding much more energy per unit of weight.

Triglycerides

Triglycerides are a type of simple, naturally occurring fat, consisting of three molecules of fatty acids bound to glycerol.
They are the main constituents of vegetable oils and animal fats.
Triglycerides are stored in fat cells (adipose cells) and released to provide energy between meals.
The normal level of blood triglycerides is indicated as less than 150 mg/dl.
Increased triglyceride levels have been linked to atherosclerosis and to an increased risk of heart disease and stroke.

Phosphoglycerides

In phosphoglycerides, one fatty acid molecule is replaced by a phosphate group; this results in phosphoglycerides having a polar head and two non-polar tails.
This characteristic allows them to form the lipid bilayer coating that is typical of biological membranes.
For the same reasons, phosphoglycerides are used as emulsifiers in various types of foods, that is, as additives that make the dispersion of alimentary fats in water more stable.

Protein functions

Amino acids are the building blocks that join together to form larger, complex molecules called proteins, the worker molecules inside all cells.
Some proteins you may have heard of:

- Haemoglobin, found inside blood cells, is a protein. Its job is to pick up oxygen molecules and carry them around our body.
- Antibodies are proteins. They are dispatched by our immune cells to attack foreign invaders.
- Hair and nails get their structure from keratin: that is a protein too.

There are literally thousands of weird and wonderful types of proteins, frantically busy carrying out all the activities that make cells alive. All of these different proteins can be made by combining just 20 different amino acids.

Peptide bond

A peptide bond is formed between two amino acids by condensation between a functional amino group and a functional carboxylic group.

Protein structures

Proteins are single-chain polymers composed of monomers called amino acids.
A condensation reaction forms a peptide bond and releases water.
Each of the twenty amino acids has a unique shape and chemistry; some are hydrophobic, some are hydrophilic, some are big and some are small.
These 20 amino acids bind in different combinations to form many different proteins.
Primary structure is the amino acid sequence. Here we see a protein assembling one amino acid at a time.
Secondary structure refers to local sub-structures, such as helices and sheets, held together by hydrogen bonds.
Tertiary structure is the globular unit into which the amino acid chain folds. Each unit is held together by disulphide bridges and ionic bonds.
Quaternary structure describes the association between subunits; each subunit is a separate amino acid chain. Haemoglobin has four subunits forming a tetramer.
Specific function is due to specific shape. Here are two examples:

- Ribonuclease A is a monomer; its function is to chop RNA into smaller pieces. The active site is in this cleft region.
- Insulin is another example. It is stored in our bodies as a hexamer, but its functional unit is a monomer.

How to extract DNA from a banana

Add 5 g of sodium chloride (salt) to a glass.
Dissolve the salt in a mixture of 50 ml of dishwashing liquid and 450 ml of water.
This solution is called a “lysis buffer”.
Take a banana and cut it into strips.
Add about 15–30 ml of the lysis buffer and mash it.
Filter the mixture through a coffee filter. This can take a while.
Add 15 ml of water to the filtered solution.
This is now your solution containing the banana DNA.
Then add about 75 ml of ice-cold isopropanol to the banana DNA solution.
You may be able to see the DNA.
Here are some pictures I took of the extracted DNA.

(Voice and reading here: https://luvvoice.com/it)

KEYWORDS

1) Which of the following terms are associated with biomolecules?

cartilage – α helix – glycerine – glycogen – water – ion – cell – nucleic acid – lipid – triglyceride

Solutions:
The terms associated with biomolecules are:
- cartilage (made mainly of proteins and polysaccharides)
- α helix (secondary structure of proteins)
- glycerine (component of lipids)
- glycogen (a polysaccharide)
- nucleic acid
- lipid
- triglyceride

Not associated directly with biomolecules:
- water
- ion
- cell

2) Select the sugars:

fructose – galactose – saccharin – glucose – sucrose – amylose – glycoside – cellulose

Solutions:
Sugars are:
- fructose
- galactose
- glucose
- sucrose
- amylose
- cellulose

Not sugars:
- saccharin (artificial sweetener)
- glycoside (general type of compound, not a sugar itself)

BIOMOLECULES-AFTER
DRILLS

Multiple Choice
Select the single correct choice to make natural sentences.
1. All biomolecules are formed by a type of reaction called:
a. redox
b. condensation
c. catalysis
d. hydrolysis

2. Most polysaccharides are:
a. a reserve of energy
b. water-soluble
c. very slow to digest
d. made up of C, H, O and N

3. Triglycerides are made up of:
a. glycerol, phosphate and fatty acids
b. fats and oils
c. fatty acids and glycerol
d. fatty acids and cholesterol

4. Amino acids are:
a. all hydrophobic
b. all hydrophilic
c. some hydrophobic, some hydrophilic
d. all of them partly hydrophobic and partly hydrophilic

5. The nitrogenous bases of DNA are:
a. A, C, G, U
b. A, G, T, U
c. A, C, T, U
d. A, C, G, T

Matching
Match the words on the left with the correct definition on the right.

Sugars	a) Monomers
Amino acids	b) Proteins
Fatty acids	c) Phospholipids
Monomers	d) Polymers
Nucleotides	e) DNA

True or False
State if the following sentences are True or False.
1. All biomolecules are polymers.
2. The α-helix is one type of secondary protein structure.
3. The only nucleic acids are DNA and RNA.

Cloze
To complete the text, use the correct words from the list:
a phosphate group – emulsifiers – two – membranes – unsaturated

Phospholipids are a particular type of lipid. In contrast to triglycerides, a molecule of fatty acid is replaced by _____ [1].
This fact results in phospholipids having a polar head and _____[2] nonpolar tails, made up of the carbon chains of fatty acids. These can be _____[3]: in this case, at room temperature, a phospholipid behaves like a liquid, that is to say an oil.
The fact of having a hydrophilic and a hydrophobic part makes phospholipids capable of forming the double-layer coating which is typical in _____[4].
For the same reasons, phospholipids are often used as _____[5] in food, namely additives that make the dispersion of alimentary fats in water more stable.

Solutions:
Multiple Choice: 1b, 2a, 3c, 4c, 5d
Matching: Sugars–a, Amino acids–b, Fatty acids–c, Monomers–d, Nucleotides–e
True / False: 1 F; 2 T; 3 T
Cloze: 1. a phosphate group; 2. two; 3. unsaturated; 4. membranes; 5. emulsifiers

SOFT SKILLS

Flow Chart

Proteins are complex molecules whose structure can be studied at various levels.
Complete the diagram below, which concerns this family of biomolecules.

The monomers of proteins are: [ ]

They are bound together by means of: [ ]

Write the general condensation reaction between two monomers:

[ ] + [ ] → [ ] + [ ]

By repeating this reaction with all the necessary molecules, the

[ ] *of the protein can be obtained, that can later coil in various ways*

The tertiary structure is obtained through interactions between

[ ]

Solutions:

The monomers of proteins are called *amino acids.*
They are bound together by means of *peptide bonds*.
Write the general condensation reaction between two monomers:
Amino acid 1 + Amino acid 2 → Dipeptide + H_2O
By repeating this reaction with all the necessary molecules, the *primary structure* of the protein can be obtained. This may subsequently coil in various ways.
The tertiary structure is obtained through interactions between *the side chains of amino acids.*

Think and Discuss

The following activities can be performed in written or oral form. The teacher will choose the method, depending on the skill (writing, speaking, interacting) to be developed.
The task will be presented to the students within the following contexts:
A) the student writes an article about biomolecules
B) the student prepares for an interview on a local TV programme about biomolecules
The student should:

1. Choose one of the following topics:
   - Describe a class of biomolecules
   - Describe the typical characteristics of all biomolecules
   - Different kinds of bonds in biomolecules
2. Prepare an article or a debate, outlining the main points of one topic, on the basis of what has been studied.
3. For the written activity, the student should provide an article, indicating the target readership and the type of magazine, newspaper or school magazine in which the article would be published.
4. For the oral activity, the student should present the point of view on one topic to the whole class, and a debate may star at the end of the presentation.

Compendium

Biomolecules are organic compounds of crucial importance in biology. They include both simple molecules and large molecules known as polymers. Polymers are formed by the union of simple molecules, called monomers, through condensation reactions, during which water is released.

Carbohydrates are biomolecules composed mainly of carbon, hydrogen and oxygen. They include sugars, which are made of one or two sugar molecules bound together, and polysaccharides, which are large molecules formed by many sugar units. Examples of polysaccharides are starch, glycogen and cellulose. Polysaccharides represent an important nutritional base for humans and are also used as energy reserves or structural components.

Lipids are a heterogeneous group of biomolecules that are generally insoluble in water. They include fatty acids, triglycerides and phosphoglycerides. Triglycerides are mainly used as energy reserves, while phosphoglycerides, characterized by a polar head containing a phosphate group and non-polar tails, are the basic components of biological membranes.

Proteins are biomolecules formed by the union of twenty different types of amino acids linked together by peptide bonds. Proteins can be very large molecules and show different levels of structural organization. The primary structure corresponds to the sequence of amino acids, the secondary structure includes local arrangements such as α-helices and sheets, the tertiary structure refers to the three-dimensional folding of the protein, and the quaternary structure results from the association of different protein subunits. The specific structure of a protein determines its function, such as transport, defence or catalysis.

Nucleic acids are biomolecules made up of nucleotides. The two main types of nucleic acids are DNA and RNA, which are responsible for the storage, transmission and management of genetic information in living organisms.

1) Answer the following questions.

The answers can be given in written or oral form, depending on the teacher's objectives.

A) A biochemist performs a complete hydrolysis of a sample of DNA, one of RNA, and one of lecithin (a phospholipid). On the basis of your knowledge, answer the following questions:
a.1) Which chemical species, if any, is released in all three test tubes?
a.2) How can the test tube containing DNA be distinguished from the one containing RNA?
a.3) In which test tubes are compounds that are insoluble in water released?
a.4) In which test tubes, on the contrary, are compounds that are water-soluble released?

B) Describe the typical structures of proteins.

C) State the nutritional value of the various classes of biomolecules.

D) Describe condensation and hydrolysis reactions, providing an example of your own choice to illustrate your point.

E) Outline the differences between saturated and unsaturated fatty acids.

2) *Write a short abstract of the Compendium (maximum 150 words) highlighting the main points about biomolecules.*

Problem Solving

The following activities can be carried out at school, if a computer room is available, or at home. Students are invited to use the web references listed above.

***1**) Individual activity*

Choose one of the following roles and write your report.

a) You are a biologist writing an article titled *"What Are Biomolecules?"*.

b) You are a biologist working for a biochemical company. Write an article on the most important dietary sources of biomolecules.

c) You are a biologist writing an article on the synthesis reactions of biomolecules.

***2**) Small group activity*

Choose one of the following topics, use the web references listed above, create a PowerPoint presentation and present it to your classmates.

Topics:

a) Compare the structures and functions of cellulose and starch.

b) Choose some amino acids and explain what they have in common and what the differences between them are.

c) Explain the importance of phosphoglycerides.

3) *Class project.*

Prepare a poster and a brochure describing the different biomolecules. You can pin up the poster in your school and distribute copies of the brochure to your schoolmates and friends.

EARTH

EARTH-BEFORE

Prerequisites

Geography / Earth Science
• Earth as a planet
• Lithosphere, hydrosphere, and atmosphere
• Land, water and atmosphere
• Day and night
Physics
• Gravity
• Rotation and revolution

Linking to Previous Knowledge and Predicting

• What kind of planet is Earth?
• What is the Earth made of?
• Why does Earth support life?
• Why do day and night occur?
• Is the Earth a dynamic system?

What is Earth?
Earth is a terrestrial planet located in the Solar System. It is currently the only known planet capable of supporting life due to the presence of liquid water, a suitable atmosphere, and a magnetic field.

Scientific Areas Involved
• Earth science
• Geography
• Geology (basic level)
• Astronomy
• Environmental science (basic level)

GLOSSARY

Acqua	Water
Astenosfera	Asthenosphere
Atmosfera	Atmosphere
Basalto	Basalt
Campo magnetico	Magnetic field
Centro della Terra	Center of the Earth
Comportamento	Behaviour
Composizione	Composition
Conduzione elettrica	Electrical conduction
Convezione	Convection
Crosta	Crust
Crosta continentale	Continental crust
Crosta oceanica	Oceanic crust

Cristallo	Crystal
Densità	Density
Discontinuità di Gutenberg	Gutenberg discontinuity
Discontinuità di Lehmann	Lehmann discontinuity
Discontinuità di Mohorovičić (Moho)	Mohorovičić discontinuity (Moho)
Discontinuità sismica	Seismic discontinuity
Epicentro	Epicenter
Ferro	Iron
Fluido	Fluid
Fuso	Molten
Gabbro	Gabbro
Gradiente geotermico	Geothermal gradient
Gravità	Gravity
Idrosfera	Hydrosphere
Liquido	Liquid
Litosfera	Lithosphere
Mantello	Mantle
Mantello inferiore	Lower mantle
Mantello superiore	Upper mantle
Mesosfera	Mesosphere
Meteorite	Meteorite
Nucleo	Core
Nucleo esterno	Outer core
Nucleo interno	Inner core
Nichel	Nickel
Onda sismica	Seismic wave
Onda P	P-wave
Onda S	S-wave
Onda superficiale	Surface wave
Peridotite	Peridotite
Placca tettonica	Tectonic plate
Pressione	Pressure
Raggio	Radius
Riflessione	Reflection
Rifrazione	Refraction
Rivoluzione terrestre	Earth's revolution
Roccia effusiva	Extrusive rock
Roccia intrusiva	Intrusive rock
Roccia ultramafica	Ultramafic rock
Rotazione terrestre	Earth's rotation
Sistema dinamico	Dynamic system
Strato	Layer
Struttura	Structure
Superficie terrestre	Earth's surface
Temperatura	Temperature
Terra	Earth
Terremoto	Earthquake
Velocità sismica	Seismic velocity
Zona a bassa velocità	Low-velocity zone
Zona d'ombra	Shadow zone

EARTH-DURING

Earth Video

The Earth's Radius and Density

The Earth's radius is 6,371 km. How do we know what lies beneath the thin surface of the Earth if we cannot see it? Isaac Newton was one of the first scientists to theorize about the structure of the Earth. Based on his studies of the force of gravity, Newton calculated the average density of the Earth and realized that its interior had to be much denser than the outer surface. The average density of the Earth is 5.52 g/cm^3, while the density of surface rocks ranges from 2.7 to 3.0 g/cm^3.

Rare Rocks

Where is the denser material?
Volcanoes occasionally bring material to the surface from depths of up to 100 km. Volcanic rocks, such as peridotites (which are very difficult to find), provide insight into the study of the Earth's structure. These rocks have a slightly higher density (about 3.4 g/cm^3) compared to surface rocks.
Studying earthquakes is also helpful for understanding the internal structure of the Earth, because variations in density cause different seismic vibrations.

Earthquakes and Seismic Waves

An earthquake consists of vibrations of the Earth's surface followed by the release of energy waves called seismic waves. There are three basic types of seismic waves: P-waves, S-waves, and surface waves. P-waves and S-waves are usually referred to as body waves. These waves travel through the Earth at different velocities depending on the materials they pass through.

Propagation of Seismic Waves

P-waves and S-waves are subject to reflection and refraction when traveling through rock layers with different densities, chemical compositions, and physical states. Seismic wave velocity generally increases as density increases. Another important difference is that S-waves cannot travel through liquids, whereas P-waves can.
The indirect study of seismic waves has demonstrated the presence of three main discontinuities in the Earth's interior: the Moho, the Gutenberg, and the Lehmann discontinuities.

The Moho Discontinuity

In 1909, Mohorovičić defined the first major boundary within the Earth's interior: the boundary between the crust, which forms the Earth's surface, and a denser underlying layer called the mantle. Seismic waves travel faster in the mantle than in the crust because the mantle is composed of denser material.
The Mohorovičić discontinuity, commonly called the Moho, is the official name for the crust–mantle boundary and lies at an average depth of about 30 km.

The Gutenberg Discontinuity

The core–mantle boundary, located at a depth of about 2,900 km, was discovered in 1913 by the seismologist Gutenberg. Seismologists observed that P-waves are not recorded at seismograph stations located between 11,000 and 16,000 km from an earthquake's epicenter. Gutenberg explained this "shadow zone" as the result of a core that slows down and bends P-waves.

The Lehmann Discontinuity

In 1936, the seismologist Lehmann discovered the boundary between the outer core and the inner core at a depth of about 5,170 km. The outer core is liquid, while the inner core is solid. S-waves cannot travel through the liquid outer core, whereas P-waves travel more slowly and are reflected within the inner core.

The Layers of the Earth

On the basis of these observations, geophysicists have created a cross-section of the Earth. It is composed of three main layers: the crust, the mantle, and the core.

Compositional Layers

The Crust

The crust extends from the Earth's surface down to the Moho and can be either oceanic or continental.

Oceanic crust: depth: 6–8 km

The oceanic crust has a density of approximately 3 g/cm^3 and is composed of a superficial layer of basalt overlying a layer of gabbro (mafic rocks).

Continental crust: depth: 30–70 km

This is the outer part of the Earth composed mainly of crystalline rocks such as granite. Its density is approximately 2.7 g/cm^3.

The Mantle

The mantle lies between the Moho and the Gutenberg discontinuity, down to a depth of about 2,900 km. Its density increases from approximately 3.3 g/cm^3 in the upper mantle to about 5.7 g/cm^3 at its base. Based on seismic data, the mantle is divided into an upper mantle and a lower mantle.

Upper mantle: depth: 10–700 km

Solid fragments of the upper mantle have been found in eroded mountain belts and volcanic eruptions. Ultramafic rocks such as peridotites are common. Between about 100 and 250 km beneath the Earth's surface, seismic waves slow down in a region known as the low-velocity zone, or asthenosphere. This layer is where basaltic magma is most likely generated and where rocks have relatively low strength, allowing them to flow.

Lower mantle: depth: 700–2,900 km

The lower mantle is believed to be composed mainly of silicon, magnesium, and oxygen, with smaller amounts of iron, calcium, and aluminum. These conclusions are based on the assumption that the Earth has a similar abundance and proportion of elements as those found in primitive meteorites.

The Core

The core extends from the Gutenberg discontinuity to the center of the Earth and is divided into a liquid outer core and a solid inner core, separated by the Lehmann discontinuity.

Outer core: depth: 2,900–5,100 km

The outer core is a hot, electrically conducting liquid composed mainly of iron and nickel. Combined with the Earth's rotation, this conductive layer generates a dynamo effect that produces the Earth's magnetic field. The outer core is less dense than pure molten iron, indicating the presence of lighter elements. Scientists suggest that about 10% of the outer core consists of elements such as sulfur and oxygen, which are abundant in the cosmos and dissolve readily in molten iron.

Inner core: depth: 5,150–6,370 km

The inner core is composed of solid iron and nickel and is suspended within the molten outer core. It is believed to have solidified due to pressure-induced freezing, which occurs when extreme pressure causes liquids to solidify.

Temperature and Pressure in the Earth

Temperature and pressure are fundamental for understanding the Earth's internal structure because they influence the physical state of materials. Temperature increases with depth according to the geothermal gradient, which averages about 3 °C per 100 m near the surface. This increase is not constant and tends to decrease with depth. The temperature at the center of the Earth is estimated to exceed 5,000 °C.

Pressure also increases with depth due to the weight of the overlying rocks. Pressure can be estimated from seismic wave velocities and reaches values in the core that are about 3.5 million times greater than atmospheric pressure.

Mechanical Layers

The compositional divisions of the Earth were understood long before the development of plate tectonics, the theory that explains the movement of large plates on the Earth's surface. By the 1970s, geologists realized that tectonic plates must be thicker than the crust alone. Plates consist of the crust and the uppermost part of the mantle, forming a rigid layer called the lithosphere, which ranges from about 10 to 200 km in thickness.

Lithospheric plates "float" on the asthenosphere, a partially molten layer that behaves like a very dense fluid. At a depth of about 660 km, pressure becomes so great that the mantle can no longer flow freely; this rigid portion is called the mesosphere. The lithospheric mantle, asthenosphere, and mesosphere share the same chemical composition, primarily peridotite.

Conclusion

The study of the Earth's structure is essential because it strongly influences the planet's geological past, present, and future. The mantle and crust are directly involved in plate tectonics, explaining the movement of continents and ocean basins. Mantle convection generates and recycles the Earth's crust at plate boundaries, while the inner and outer cores play a fundamental role in generating the Earth's magnetic field.

(Voice and reading here: https://luvvoice.com/it)

KEYWORDS

1) Which of the following rocks are associated with the Earth's crust and mantle?

basalt – conglomerate – sandstone – granite – peridotite – evaporite – gneiss – gabbro

Solutions:

Basalt – Granite – Peridotite – Gabbro

2) Select the three layers based on their mechanical behaviour.

lithosphere – upper mantle – outer core – oceanic crust – asthenosphere – continental crust – mesosphere – inner core

Solutions:

Lithosphere – Asthenosphere – Mesosphere

EARTH-AFTER

DRILLS

Multiple Choice

Select the single correct choice to make natural and scientifically correct sentences.

1) The Moho is the boundary between:
a. the lithosphere and the asthenosphere
b. the inner core and the outer core
c. the crust and the mantle
d. the mantle and the core

2) Earthquakes are useful for studying the Earth's interior because:
a. each earthquake produces an array of seismic waves
b. earthquakes are extremely destructive
c. they happen below the surface of the Earth
d. they release stress that has been stored

3) Although we do not have any samples of the core, most scientists agree that the main constituents of the core are:
a. basalt
b. granite
c. iron and nickel
d. peridotite

4) The lithosphere and asthenosphere are defined on the basis of differences in:
a. chemical composition
b. mechanical properties
c. the way they are formed
d. where they are formed

5) What does the P-wave shadow zone indicate about the Earth's interior?
a. the core is made of iron
b. the mantle is denser than the crust
c. the mantle is liquid
d. the outer core is liquid

Matching

Match the words on the left with the correct definition on the right.

1) Gutenberg discontinuity	a) it is located at the base of the lithosphere
2) Geothermal gradient	b) separates the outer core from the inner core
3) Earthquake	c) variation of the Earth's temperature with depth
4) Asthenosphere	d) separates the mantle from the core
5) Lehmann discontinuity	e) vibrations of the Earth's surface caused by the release of energy

True or False

State whether the following sentences are true (T) or false (F).
1) Seismic waves increase velocity when density increases.
2) The mantle is made up of low-density material.
3) The inner core is situated between the Lehmann discontinuity and the centre of the Earth.

Cloze Test

Complete the text using the correct words from the box.

granite – crust – outer core – mantle – solid – lower – density – oceanic – basalt

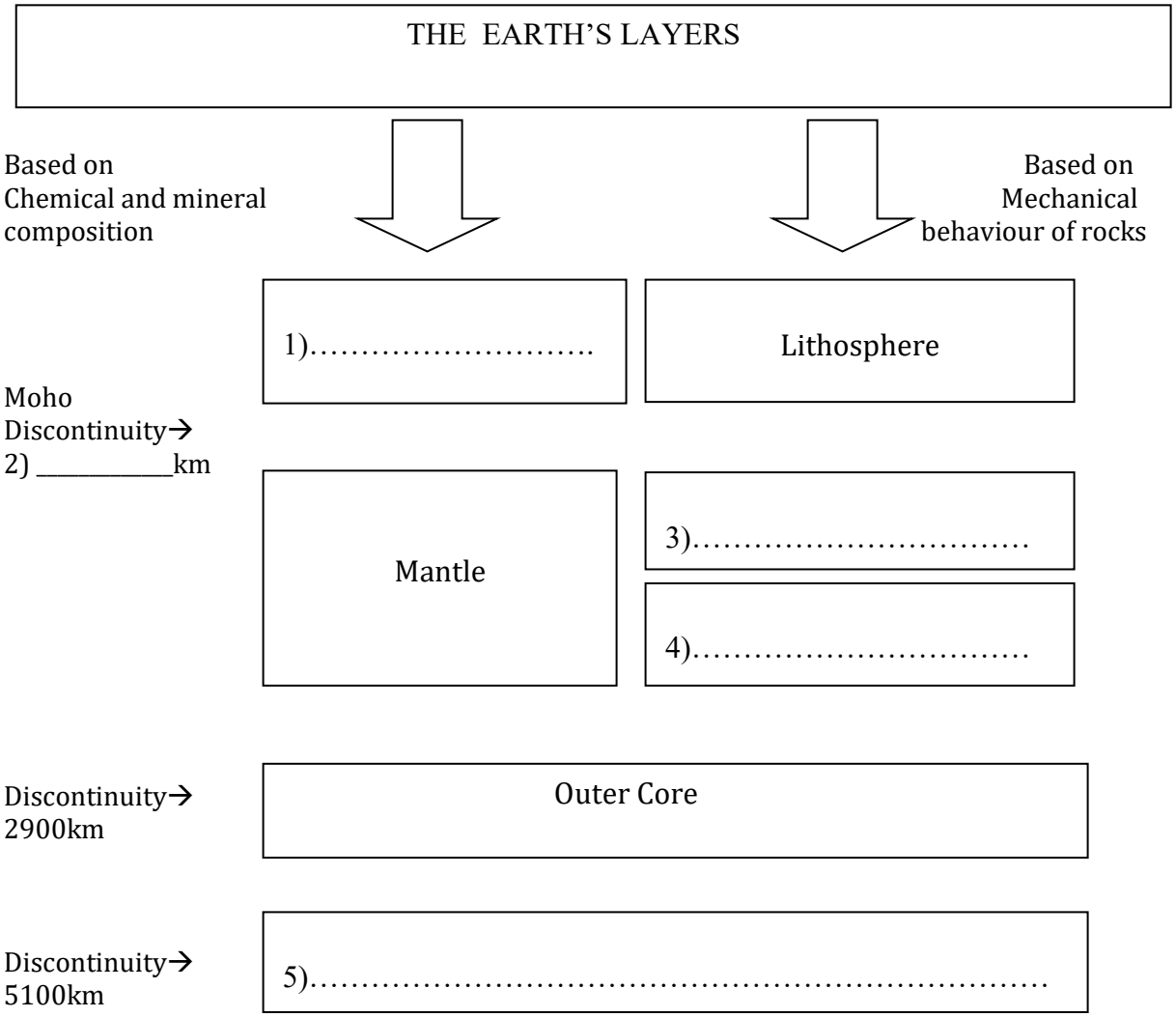
The structure of the Earth is layered and commonly divided into four parts: the silicate crust, the viscous _____[1] mantle, the liquid iron-nickel _____[2] outer core, and the

_____[3] solid iron-nickel inner core. The mantle is subdivided into the _____[4] lower and upper mantle, based on differences in rock types, temperature, _____[5] density and viscosity. The _____[6] crust, which is the only part of the Earth that is both relatively cool and completely solid, makes up less than 1% of its total volume. The thickness of the crust varies, mainly depending on whether it is _____[7] oceanic (6 to 8 km thick) or continental (30 to 70 km thick). The oceanic crust is composed of dense rocks such as gabbro and _____[8] basalt, while the continental crust is made up of somewhat lighter rocks such as _____[9] granite.

Solutions:
Multiple Choice:1c, 2a, 3c, 4b, 5d
Matching:1d, 2c, 3e, 4a, 5b
True / False: T, F, T
Cloze:1. mantle; 2. outer core; 3. solid; 4. lower; 5. density; 6. crust; 7. oceanic; 8. basalt; 9. granite

SOFT SKILLS

Flow Chart
Complete the following flow charts:



Solutions:
1) Crust; 2) 30 Km; 3) Asthenosphere; 4) Lower mantle; 5) Inner core

Think and Discuss

The following activities can be carried out in written or oral form. The teacher will choose the method depending on the skill (writing, speaking, interacting) to be developed.
The task will be presented to the students within the following contexts:
A) the student writes an article about the Earth's interior structure
B) the student prepares an interview for a local TV programme about the Earth's interior structure
The student should:

1. Choose one of the following topics:
   - Describe the direct and indirect methods used to study the Earth's interior.
   - The study of seismic waves.
   - The Earth's layers based on chemical and mineral composition.
   - The Earth's layers based on the mechanical behaviour of rocks.
2. Prepare an article or a debate, outlining the main points of the chosen topic, on the basis of what has been studied.
3. For the written activity, the student should provide an article, indicating the target readers and the type of magazine, newspaper, or school magazine where the article would be published.
4. For the oral activity, the student should present the point of view on the chosen topic to the whole class. A debate may start at the end of the presentation.

Compendium

The study of the Earth's surface and interior is the domain of geology. We have little direct knowledge of the Earth's interior, and most of our information comes from the study of seismic waves, which are vibrations that travel through the Earth.
There are two main categories of seismic waves. P-waves are longitudinal pressure waves that can propagate through both solids and liquids, whereas S-waves are transverse waves that can propagate only through solids and not through liquids. These seismic waves are generated naturally by earthquakes, volcanic activity, and meteorite impacts, and they can also be produced artificially by explosions and mechanical devices.
Seismic waves provide information about the Earth's interior in several ways. First, their velocity and direction of motion change (refraction) when they pass through materials with different densities. By studying how seismic waves propagate through the Earth, scientists can infer variations in density within the interior. Second, because P-waves can travel through liquids while S-waves cannot, scientists can determine whether certain regions of the Earth's interior are solid or liquid.
Detailed seismic studies, together with theoretical models, indicate that the Earth's interior includes a solid inner core, composed mainly of iron and nickel, surrounded by a liquid outer core, also made largely of iron and nickel. The Lehmann discontinuity, located at a depth of approximately 5,170 km, separates the liquid outer core from the solid inner core. The radius of the core is estimated to be about 3,470 km, compared with an average Earth radius of approximately 6,370 km.
The crust is the outermost and thinnest layer of the Earth. Its thickness varies from about 6–8 km beneath the oceans to an average of about 35 km beneath the continents. The boundary between the crust and the underlying mantle is known as the Mohorovičić discontinuity (Moho).
The Gutenberg discontinuity, located at a depth of approximately 2,900 km, separates the mantle from the core. The mantle lies between the crust and the core and can be described in terms of its mechanical behaviour. The crust and the uppermost part of the mantle together form the lithosphere, a rigid layer. Beneath the lithosphere lies the asthenosphere, a region with plastic behaviour that allows slow flow of material. Below the asthenosphere, the mesosphere is more rigid, and its density increases progressively with depth toward the core.

1) *Answer the following questions.*

The answers can be given in written or oral form, depending on the teacher's objectives.

A) Describe the two main categories of seismic waves.
A1) Explain where seismic waves are generated.
A2) Describe how seismic waves propagate through rock layers with different density and aggregation states.
B) Describe the Earth's interior structure.
C) Discuss the three mantle layers based on their mechanical behaviour.
D) Explain what seismic discontinuities are.
E) Describe the three main discontinuities of the Earth.

2) *Write a short abstract of the Compendium (maximum 150 words) highlighting the main points about the Earth's interior structure.*

Problem Solving
The following activities can be carried out at school, if a computer room is available, or at home. Students are invited to use the web references listed above.

***1**) Individual activity*
Choose one of the following characters to play and write your report.
a) You are a geologist writing an article titled: "What is there inside the Earth?".
b) You are a geologist working for a petroleum company. Write an article on the study of seismic waves used to investigate the Earth's interior.
c) You are a geologist writing an article on the layers of the Earth based on the chemical and mineral composition and the mechanical behaviour of rocks.

***2**) Small group activity.*
Choose one of the following topics, use the web references listed above, create a power point presentation and present it to your classmates.
Topics:
a. Choose an Earth's interior structure and explain the indirect methods that can be used to analyse it.
b. Choose a compositional layer of the Earth and explain its chemical and mineral composition.
c. Explain the importance of the mechanical behaviour of the interior layers of the Earth.

***3**) Class project*.
Prepare a poster and a brochure describing the Earth's interior using chemical and mineral composition of rocks as well as their mechanical behaviour. You can pin up the poster in your school and distribute copies of the brochure to your schoolmates and friends.

GMO

GMO-BEFORE

Prerequisites

Biology
- Cells as basic units of life
- DNA as genetic material
- Basic structure of DNA (double helix)
- Genes determine characteristics
- Simple inheritance concepts
- Microorganisms (bacteria and viruses)

Chemistry
- Atoms and molecules
- Simple chemical bonds
- Basic organic molecules

Linking to Previous Knowledge and Predicting

- What is DNA?
- Why are organisms similar but not identical?
- What does it mean to modify something?
- Can humans change plants?
- Can genes move from one organism to another?
- Why might scientists want to change an organism?

What are GMOs
Genetically Modified Organisms are organisms whose genetic material has been artificially altered using genetic engineering techniques to obtain specific characteristics.

Scientific Areas Involved:
- Biology
- Genetics
- Biotechnology
- Agriculture
- Environmental science
- Medicine

GLOSSARY

Allevamento	Husbandry
Ambiente	Environment
Azzurro, Ciano	Cyan
Battersi, Darsi da fare	To strive
Bovini	Cattle
Cacciatore	Hunter
Cieco	Blind
Criminologia	Forensics
Diffondersi, Filtrare	To seep

Discutere, Argomentare	To argue
Dividere	To split
Enzima di restrizione	Restriction enzyme
Erbaccia, Infestante	Weed
Evidenziare, Segnalare	To point out
Fabbrica	Factory
Foraggio	Fodder
Forzatamente	Forcibly
Frumento	Wheat
Gene reporter	Reporter gene
Granoturco	Corn
Granoturco	Maize
Incrocio	Cross
Ingegneria	Engineering
Innestare	To graft
Innocuo	Harmless
Inondazione	Flood
Inquinamento	Pollution
Inquinare	To pollute
Larva	Maggot
Manioca	Cassava
Mansueto	Tame
Maturare	To ripen
Messaggero	Harbinger
Mortale	Deadly
Nano	Dwarf
Nonostante	Notwithstanding
Pericoloso	Hazardous
Pianta da coltivazione/Raccolto	Crop
Plasmide	Plasmid
Presumibilmente	Arguably
Produrre, dar vita	To bring forth
Promotore	Promoter
Prole	Offspring
Prosperare	To thrive
Raccoglitore	Gatherer
Rafforzare	To enhance
Rapporto (Mat.)	Ratio
Recupero	Recovery
Resistere	To withstand
Ricevente	Recipient
Ricombinante	Recombinant
Ripido, Repentino	Steep
Riprodursi	To interbreed
Riso	Rice
Rivestire	To coat
Scopo	Purpose
Segale	Rye
Semplice, Lineare	Straightforward
Soia	Soy

Sorgere	To arise
Subire	To undergo
Superare, Vincere	To overcome
Terreno	Soil
Tono (di colore)	Hue
Tossina	Toxin
Transgenico	Transgenic
Trasportare, Comunicare	To convey
Vaccinare	To inoculate
Vettore	Vector

GMO-DURING

GMO Video

Definition

A Genetically Modified Organism (GMO) is an organism whose genetic material has been artificially altered using genetic engineering techniques.
A GMO can acquire one or more genes from another species or from a different variety of the same species; in these cases the organism is referred to as transgenic.
Viruses, bacteria, fungi, plants, and animals can become GMOs after the insertion of one or more genes taken from other organisms, which can be phylogenetically very different. This allows new genetic combinations that would be extremely unlikely to occur naturally.
The modified organism is called the recipient (or receiver), while the organism from which the DNA is taken is called the donor. The DNA introduced into the recipient organism is called exogenous DNA.
A classification scheme proposed by Kaare Nielsen divides GMOs into five levels according to the genetic distance (phylogenetic difference) between donor and recipient:

Source of genetic modification	**Genetic variability via conventional breeding**	**Genetic distance**
Intragenic (within the same genome)	Possible	Low
Famigenic (species in the same family)	Possible	
Linegenic (species in the same phylogenetic lineage)	Impossible	
Transgenic (unrelated species)	Impossible	
Xenogenic (laboratory-designed genes)	Impossible	High

Main Techniques

Recombinant DNA technology comprises a set of procedures that allow the transfer of genes from one organism to another. These techniques include the extraction, isolation, modification, and transfer of DNA fragments, even between different species.
Although complex in practice, the theoretical process involves a few fundamental steps:
I. Identification of the gene
II. Extraction of the gene using specific enzymes
III. Attachment of the gene to a DNA vector
IV. Transfer of the gene into a recipient cell
One of the key tools in recombinant DNA production is the group of enzymes that cut DNA molecules at specific sites.
These enzymes are called restriction endonucleases (or restriction enzymes) and were discovered in the 1960s when researchers studying bacteria observed that these proteins could limit the infective power of bacteriophages.

Restriction enzymes

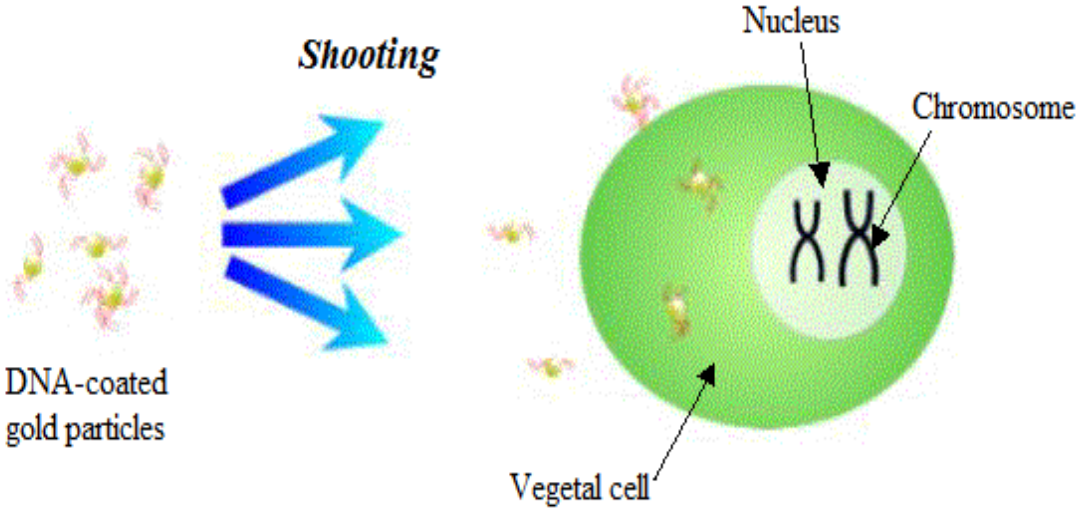
Scores of restriction endonucleases have been identified and isolated; each of these molecules can recognize a DNA sequence, called a restriction site, with very high specificity. For example, the enzyme EcoRI splices DNA only when it encounters the following base sequences, paired in the DNA double helix:
5'…GAATTC…3'
3'…CTTAAG…5'
The two sequences are called palindromic, as the complementary strands carry exactly the same bases, but in reverse order.
Most restriction enzymes work by recognizing palindromic sequences that can occur several times in a DNA molecule. When they come under the action of the same restriction enzyme, copies of a particular DNA molecule are cut in a consistent way, thus forming a homogeneous set of fragments.
The most commonly used restriction enzymes splice DNA in different places, leaving a single-strand end, called a sticky end, which can attach to other complementary sticky ends, in a process called annealing. Such couplings are unstable, but they can be stabilized by particular enzymes called DNA ligases: it is easy to see that annealing DNA fragments originating from different sources produces recombinant DNA.

Promoters, reporter genes, and the Ti plasmid

It is important to point out that the gene to be transferred must include a DNA sequence called a promoter, which regulates gene expression, as well as a terminating sequence. It is also essential to mark the sequence to be grafted in order to identify the genetic transformation; this is usually done with reporter genes, which are used as marker genes, since their phenotype is easily observable.
The most widely used vectors, which introduce the genetic material into the recipient cell, are bacterial cells, mainly because they host tiny circular chromosomes, called plasmids, which are easily altered for the purpose of carrying recombinant DNA. One example is the Ti plasmid from Agrobacterium tumefaciens, a bacterium which normally lives in the soil and is harmless to human beings. Its main use is to transfer genes into plant cells.

Biolistics

Some plants, though, are not easily infected by Agrobacterium, and among the available techniques a very effective one is biolistics (from biology and ballistics), which makes use of delivery systems commonly called gene guns. This technique uses gold or tungsten particles coated with recombinant DNA, which are injected (or "shot") into the recipient cell culture.



Other important vectors

Other vectors are also used, which have the fundamental characteristics of plasmids but, unlike them, are also capable of carrying large DNA fragments, thus solving the differences in the process of gene expression in different organisms, such as the presence, in eukaryotic cells, of introns (non-coding DNA segments), which cannot be processed in bacterial cells as they lack the machinery required for splicing. Viruses are also feasible vectors, as their very nature is to infect cells, so they do not need special mechanisms to penetrate them.
Another widely used vector is the yeast artificial chromosome (YAC). Yeasts are unicellular fungi which have several favorable traits: besides being eukaryotic organisms, they are easy to grow, and they contain plasmids. YACs combine the essential components of eukaryotic chromosomes: telomeres, centromeres, and one or more origins of replication. They also contain restriction sites and artificially synthesized reporter genes, and can carry DNA fragments from 50,000 to 1.5 million bases long. During mitosis, these fragments behave like normal chromosomes, replicating foreign DNA when cells divide.
Researchers have developed another method for the introduction of recombinant DNA into eukaryotic cells, mostly in mammals but also in bacteria: electroporation, which, thanks to the application of a short electric pulse, creates temporary pores in cell membranes, through which DNA fragments can be introduced. It is also possible to use microscopic needles for direct mechanical injection.
Clearly, whatever vector is used, the DNA grafted into a recipient cell, once incorporated into the cellular genome, will be expressed by the cell itself.

Bt corn

The technology for the production of transgenic plants has found great application in the fight against insect parasites; specifically, some varieties of corn have undergone genetic modifications for the main purpose of acquiring resistance to one of the most damaging insects, the European corn borer (Ostrinia nubilalis). The larva of this butterfly is considered one of the main phytophagous pests of maize, causing significant damage and leading to the extensive use of chemical insecticides, which are harmful both to the environment and to farmers exposed to them.
This corn variety has been genetically engineered using genes extracted from Bacillus thuringiensis, a common soil prokaryote. This bacterium produces a protein that is toxic to many insect pests, among them the European corn borer: the modified gene produces a protoxin which becomes active only in the digestive system of insects, under specific alkaline conditions, unlike the high acidity present in mammals, for whom the protoxin is totally harmless.
Bacillus thuringiensis produces various toxins which can be deadly to several insect species: this makes it possible to selectively use these proteins, generated as crystals, hence the prefix Cry in their names. These genes have been introduced into many plants, such as corn and potato: it can be argued that huge progress has been made in producing insect-resistant crops, requiring much less pesticide use.
Research is also pointing towards the development of genetically engineered plants more resistant to diseases, especially viral ones, using a technique similar to vaccination.

Transgenic papaya

A vaccine is a preparation containing material derived from pathogenic agents, or parts of them; it works by inducing the development of active immunity in the inoculated subject. Similarly, plants can be modified to withstand the attack of several viruses.
One of the most important examples is the engineering of the papaya plant, commonly attacked by PRSV (Papaya Ringspot Virus), which is carried by aphids and is lethal to both young and adult plants. Researchers from the University of Hawaii and Cornell University decided to genetically engineer papaya plants, making them resistant to the virus by

transferring a gene sequence that encodes one of the proteins forming the viral coat: this acts like a vaccination, with the advantage of transferring the new functionality to the offspring.
After a long trial, which lasted from 1995 to 1998, transgenic papaya was widely cultivated, allowing a sharp recovery in production; moreover, by restricting the viral epidemic, it allowed the survival of traditional crops in Hawaii.
Transgenic plants can also be made resistant to herbicides and floods – the latter being very common in Asian monsoon regions.

Intelligent plants

Researchers are now trying to create so-called intelligent plants, able to "signal" specific deficiencies before they cause damage. These plants could produce unusually colored pigmentations in leaves, indicating the lack of specific elements: for example, a cyan hue could signal a deficiency of phosphorus.

"Factory" animals

Transgenic animals can acquire characteristics normally obtainable only through a long selection process, such as leaner meat in pigs, stronger muscles in cattle, or faster growth. Contrary to what happens with transgenic plants, genetically engineered animals are currently used mainly for the production of useful proteins, not least because animals with foreign genes often have problems such as reduced fertility or a weakened immune system.
Proteins can be produced by either prokaryotes or eukaryotes. Bacteria are normally very suitable for producing proteins, as they can be grown quickly and are easily modified. Nevertheless, eukaryotic cells are sometimes preferable, such as the yeast Saccharomyces cerevisiae, which is able to produce several recombinant proteins, or recombinant cell cultures used in the synthesis of the hormone erythropoietin (EPO), which stimulates the production of red blood cells.
It is very difficult to obtain whole organisms, animal or plant, able to code for human proteins, as this requires cloning the GMO individual, which is then used as a living pharmaceutical laboratory: one example is the goat that produces the human blood protein antithrombin (AT).
We must consider that the proteins produced by these "factory" animals could be slightly different from the original ones, due to differences in molecular structure; therefore they require accurate control to avoid possible allergic reactions in patients.

"Factory" plants

Nowadays, pharmaceutical research is concentrating on the production of "factory" plants, able to produce human proteins (for therapeutic use) and viral proteins (for vaccination).
The FDA has recently approved, in Kansas, the cultivation of a variety of rice genetically engineered with the insertion of genes producing milk proteins, which can be used in the treatment of children affected by diarrhea in developing countries.
Another very important application makes use of genetically engineered microorganisms in environmental decontamination, such as the degradation of chlorinated hydrocarbons and other hazardous chemicals before their release into the environment, or the conversion of heavy metals into simpler, easier-to-handle substances.
There is also a well-established production of biofuel from corn, cassava, and soy through the action of non-transgenic microorganisms.

History

About 10,000 years ago, the lifestyle of hunter-gatherers was permanently replaced by an agricultural system: mankind entered a phase of deliberate control and modification of the environment, starting the alteration of primitive food sources, both animal and plant. As the ice sheets retreated, many human groups had already begun to cultivate plants known in

their wild varieties and to breed the tamest animals they used to hunt.
Though we tend to consider agriculture and animal husbandry as natural activities, with them mankind began to permanently transform its environment, selecting plants and animals, modifying them over time by crossings and hybridizations, even without a clear understanding of the scientific basis of biology.
In a relatively short period of time, between 12,000 and 7,000 years ago, mankind managed to domesticate almost all the crops still in use. Genetic variations soon followed: the species of grain on which human consumption is based are the result of hybridization between different plants, a technique long used by farmers to introduce genetic variations, with the ultimate purpose of enhancing crop production and quality.
In agriculture, it is very important to identify favorable traits between wild and cultivated plants that can arise spontaneously; however, due to the long time required for these natural processes, farmers have experimented with continuous hybridizations and cross-pollinations between species of the same genus: the Cavendish banana, commonly eaten all over the world, is the result of a crossing between two species of the Musa genus.
In 1888, the German agronomist Wilson Rimpau obtained the first fertile cross between common wheat and rye, thus creating a totally new species, dubbed Triticale, from Triticum aestivum (wheat) and Secale cereale (rye).
After countless attempts, which took many decades to stabilize the growth of fertile hybrids, only in 1968 was Triticale successfully sown over 40,000 hectares in Hungary. Nowadays, this cereal is grown for fodder all over the world, after overcoming several problems, such as slow ripening and low yield, through continuous artificial selection. Triticale, besides becoming more nutritious than rye, also became hardy enough to be cultivated on poor soil, as in the sandy and acidic fields of Poland, where it is widely cultivated.
Some authors define Triticale as a “harbinger GMO”, as its genome comprises copies of all the chromosomes from both its originating species, thus emphasizing one of the possible contributions of biotechnologies in agriculture, namely growing crops in environmentally disadvantaged lands.
Only in the 1970s, however, was science able to develop a set of techniques for the study and manipulation of DNA: in 1973, the Americans Stanley Cohen and Herbert Boyer obtained the first modern GMO by cloning a frog gene into an E. coli bacterium. This was a huge step forward, paving the way for the production of recombinant DNA, that is, DNA molecules taken from different species and brought together in vitro.
The impact on public opinion was very strong, so much so that 1974 saw the drafting of genetic engineering guidelines that GMO laboratories still follow today. Soon, an ongoing debate arose about biotechnologies, the ethical aspects regarding the manipulation of organisms or their parts, and the business opportunities that these techniques created.
1978 saw the birth of the most famous biotech drug, insulin (marketed from 1981), which marked the shift of biotechnologies from the laboratory to the pharmaceutical industry. Insulin, and later HGH (Human Growth Hormone), were the first medicines produced by the new technologies, and estimates report that, in the USA alone, about two million diabetes patients control their illness through insulin, while HGH is successfully used to treat children affected by dwarfism.
From the 1970s onward, genetic engineering has revolutionized the applications of biotechnologies, now available in a wide variety of fields, previously unthinkable, such as agriculture, forensics, medical research, oncology, industry, and food production.

(Voice and reading here: https://luvvoice.com/it)

KEYWORDS

1) Which of the following terms are associated with genetic engineering techniques?
plasmid – vector – promoter – sediment – restriction enzyme – reporter gene – fossil – ligase

Solutions:
Plasmid – Vector – Promoter – Restriction enzyme – Reporter gene – Ligase

2) Select the three elements involved in gene transfer into a recipient cell.
donor – recipient – pesticide – vector – climate – mutation – soil

Solutions:
Donor – Recipient – Vector

GMO-AFTER
DRILLS

Multiple Choice
Select the single correct choice to make natural and scientifically correct sentences.
1) A genetically modified organism (GMO) is an organism whose:
a. cells reproduce faster than normal
b. DNA has been artificially altered
c. chromosomes are naturally mutated
d. proteins are chemically modified

2) Restriction enzymes are used in genetic engineering to:
a. replicate DNA molecules
b. transport DNA into cells
c. cut DNA at specific sequences
d. activate gene expression

3) The Ti plasmid is commonly used to:
a. clone animal cells
b. transfer genes into plant cells
c. synthesize proteins in fungi
d. destroy viral DNA

4) Bt corn is resistant to insects because it:
a. produces chemical pesticides
b. has thicker cell walls
c. expresses a toxin lethal to specific insects
d. prevents insect reproduction

5) Reporter genes are mainly used to:
a. increase crop productivity
b. identify transformed cells
c. regulate DNA replication
d. protect organisms from viruses

Matching

Match the words on the left with the correct definition on the right.

1) Restriction enzyme	a) organism that receives foreign DNA
2) Vector	b) DNA molecule used to carry genes
3) Donor	c) enzyme that cuts DNA at specific sites
4) Recipient	d) organism from which DNA is taken
5) Promoter	e) DNA sequence controlling gene expression

True or False

State whether the following sentences are true (T) or false (F).

1) GMOs can be obtained using recombinant DNA techniques.
2) Restriction enzymes recognize random DNA sequences.
3) Transgenic animals are widely used for food production.

Cloze Test

Complete the text using the correct words from the box.

vector – donor – recipient – plasmid – restriction enzyme – promoter – toxin – insects – recombinant

Genetic engineering allows the creation of _____[1] recombinant DNA by transferring genes from a _____[2] donor organism to a _____[3] recipient organism. The gene of interest is cut using a _____[4] restriction enzyme and inserted into a _____[5] plasmid, which acts as a _____[6] vector. To ensure gene expression, the transferred gene must include a _____[7] promoter. In Bt corn, the inserted gene produces a _____[8] toxin that is lethal to specific _____[9] insects.

Solutions:

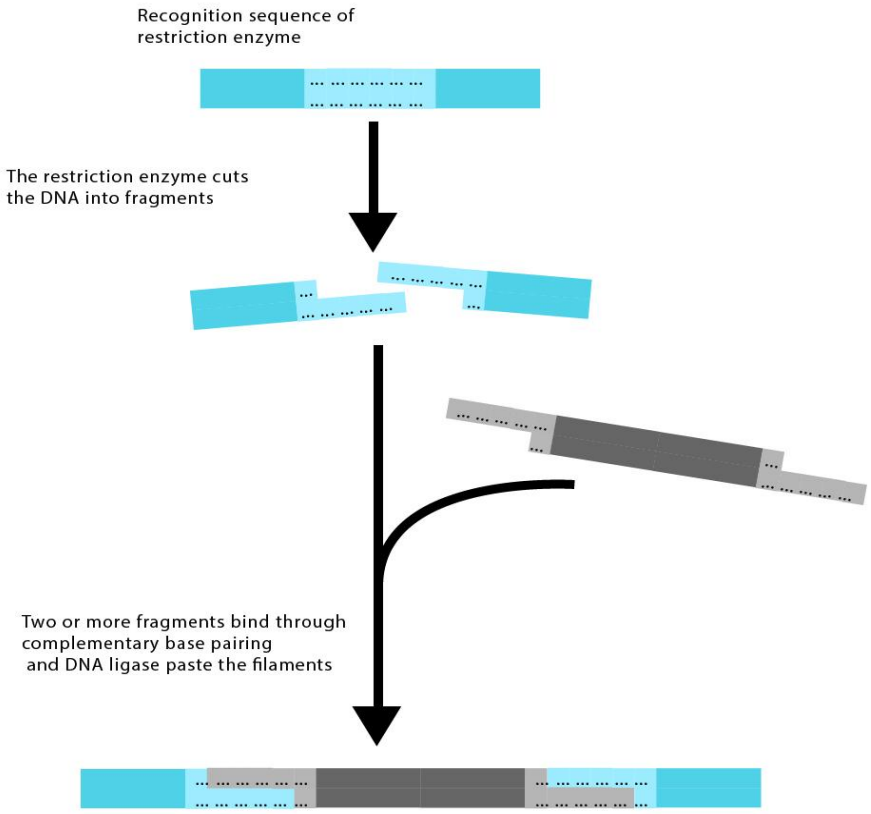
Multiple Choice: 1b, 2c, 3b, 4c, 5b
Matching: 1c, 2b, 3d, 4a, 5e
True / False: T, F, F
Cloze: 1 recombinant; 2 donor; 3 recipient; 4 restriction enzyme; 5 plasmid; 6 vector; 7 promoter; 8 toxin; 9 insects

SOFT SKILLS

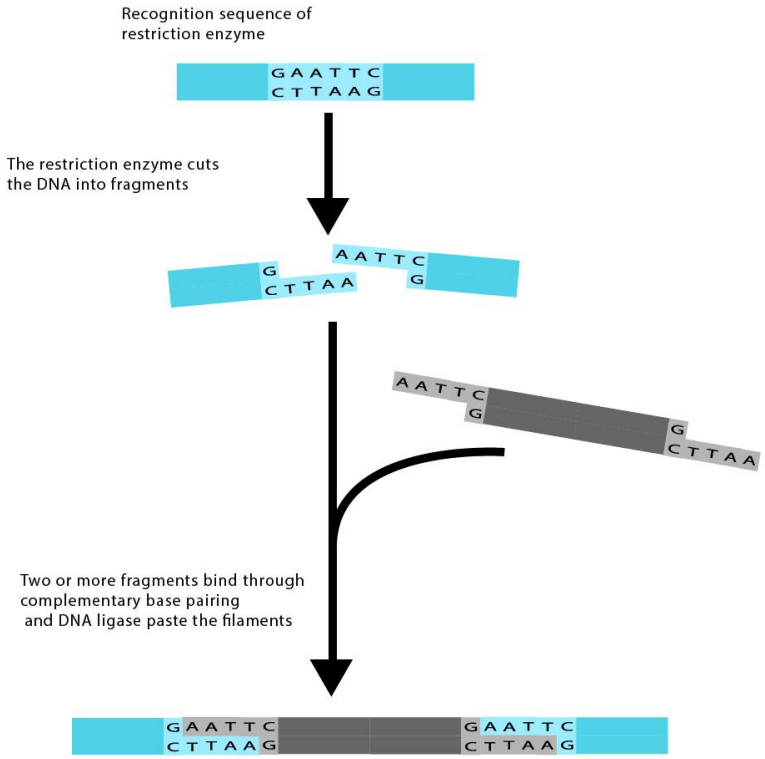
Flow Chart

Complete the following flow chart:

Considering the usage of a restriction enzyme, sketch the double-threaded sequences before and after the enzyme split.


Recognition sequence of
restriction enzyme
The restriction enzyme cuts
the DNA into fragments
Two or more fragments bind through
complementary base pairing
and DNA ligase paste the filaments

Solutions:


Recognition sequence of
restriction enzyme
GAATTC
CTTAAG
The restriction enzyme cuts
the DNA into fragments
AATTC
G
G
CTTAA
AATTC
G
G
CTTAA
Two or more fragments bind through
complementary base pairing
and DNA ligase paste the filaments
GAATTC
CTTAAG
GAATTC
CTTAAG

Think and Discuss

The following activities can be performed in written or oral form. The teacher will choose the method depending on the skill (writing, speaking, interacting) to be developed.
The task will be presented to the students within the following contexts:
A) the student writes an article about GMOs
B) the student prepares for an interview on local TV about GMOs
The student should:

1. Choose one of the following topics:
- Explain the importance of GMOs in agriculture.
- Explain the possible problems that the use of GMOs could bring about.
- Explain the main techniques for gene transfer.
2. Prepare an article or a debate, outlining the main points of the chosen topic, on the basis of what has been studied.
3. For the written activity, the student should provide an article, indicating the target readers and the type of magazine, newspaper, or school magazine where the article would be published.
4. For the oral activity, the student should present the point of view on the chosen topic to the whole class. A debate may start at the end of the presentation.

Compendium

In 1996, only six countries grew GMO crops: the USA, China, Canada, Argentina, Australia, and Mexico. By 2008, that number had increased to 25, including several European countries such as France, Spain, Portugal, Germany, the Czech Republic, Slovakia, Romania, and Poland. About 99% of GMO crops are concentrated in a few countries: the USA, Canada, Argentina, Brazil, Paraguay, India, China, and South Africa.
In Europe, some countries (such as Austria and Greece) have banned GMO crop cultivation. In other countries (including Italy, the United Kingdom, Denmark, Sweden, Finland, Hungary, and Slovenia), cultivation is restricted, while the import of GMO products is allowed. The main GMO crops are soybean, maize, cotton, and rapeseed.
Biotechnology companies invest in the development of GMOs and patent their products. In many cases, patented seeds must be purchased every year, generating significant profits. In most countries, GMO production is regulated to ensure biosafety, meaning the protection of the environment and human and animal health. International legal principles are contained in the Cartagena Protocol.
In Europe, legislation on GMOs, based on the Precautionary Principle, includes Directive 2001/18/EC, Regulations 1829 and 1830/2003/EC, and Recommendation 556/2003 on the coexistence of traditional and GMO crops. Italy implemented Directive 2001/18/EC with Legislative Decree 224/2004. In 2013, a decree temporarily banned the cultivation of the MON810 maize variety.
GMOs have generated intense debate. Every technological innovation produces both benefits and risks, which should be carefully evaluated. GMOs may have important applications, such as improving crop productivity, increasing nutritional value (as in the case of Golden Rice), and enabling cultivation in poor soils. Decisions should therefore be based on sound scientific evidence and on a careful evaluation of the risk–benefit ratio.

1) Answer the following questions.

The answers can be given in written or oral form, depending on the teacher's objectives.

A. Which nations use GMO crops on a large scale?
B. On what is the Precautionary Principle based?
C. Which could be the most important applications of GMOs?

2) Write a short abstract of the Compendium (max. 150 words) highlighting the main points regarding the unit and focusing mainly on the legislation on GMOs.

Problem Solving

The following activities can be carried out at school, if a computer room is available, or at home. Students are invited to use the web references listed above.

***1**) Individual activity*

Choose one of the following roles and write and present your report.

a) You are a supporter of GMOs: study resistance to water and climatic stress, enhanced nutritional value, and higher yields, which make GMOs one of the possible solutions to world hunger.
b) You are an opponent of GMOs: study the extra cost of GMO seeds and their possible economic impact on developing countries.
c) Study the problem of possible unexpected allergic reactions in consumers of GMOs.

***2)** Small group activity*

Choose one of the following topics, create a PowerPoint presentation, and present it to your classmates.
Topics:
a) Explain, using a PowerPoint presentation, the use of the Ti plasmid to produce transgenic plants.
b) Explain, using graphs, the activity of restriction enzymes.
c) Explain the importance of hybridization in the history of agriculture.

3) *Class project*

Let us imagine being a multinational corporation about to launch a new substance produced using recombinant DNA. The substance must be submitted to, and approved by, specific authorities such as the Food and Drug Administration. The class should outline the procedure to be followed for commercializing a new medicine in Italy, subdividing the various tasks among the students.
Let us also imagine being an environmental protection authority tasked with evaluating the liberalization of GMO crop cultivation in a given country. Students should evaluate all aspects of the topic, both positive and negative, using the most scientific method possible and carefully discussing risks and potential actions.

HYDROCARBONS

SATURED HYDROCARBONS-BEFORE

Prerequisites

Chemistry
- Atoms and molecules
- Chemical bonds
- Carbon atom and its bonding ability
- Simple molecular formulas
- Saturated vs unsaturated hydrocarbons

General Science
- Difference between organic and inorganic substances
- Everyday materials derived from oil

Linking to Previous Knowledge and Predicting

- What is an atom?
- What elements are most common in living organisms?
- What do you know about carbon?
- Where does petrol come from?
- Why is carbon so important in chemistry?
- What is the difference between single and double bonds?

What are Hydrocarbons?
Hydrocarbons are organic compounds made only of carbon and hydrogen.
Gli idrocarburi sono composti organici formati solo da carbonio e idrogeno.

Scientific Areas Involved
- Organic chemistry
- Environmental science (basic level)
- Energy and fuels
- Industrial chemistry

GLOSSARY

Alcano	Alkane
Alogenazione	Halogenation
Alogeno	Halogen
Anello	Ring
Angolo	Angle
Barca (conformazione a)	Boat conformation
Bromo	Bromine
Calore	Heat
Carbonio	Carbon
Catena	Chain
Catena principale	Main chain
Cicloalcano	Cycloalkane

Cloro	Chlorine
Combustione	Combustion
Composto	Compound
Condividere	Share
Conformazione	Conformation
Covalente	Covalent
Eclissato	Eclipsed
Elemento	Element
Elettrone	Electron
Elettronegatività	Electronegativity
Energia di attivazione	Activation energy
Fluoro	Fluorine
Forma	Shape
Formula	Formula
Forza	Force
Gas	Gas
Gruppo	Group
Ibridazione	Hybridization
Idrocarburo	Hydrocarbon
Idrogeno	Hydrogen
Inerzia	Inertness
Insolubile	Insoluble
Interazione	Interaction
Iodio	Iodine
Isomero	Isomer
Legame	Bond
Liquido	Liquid
Meccanismo	Mechanism
Molecola	Molecule
Nomenclatura	Nomenclature
Organico	Organic
Prefisso	Prefix
Prodotto	Product
Proprietà	Property
Punto di ebollizione	Boiling point
Ramificato	Branched
Reagente	Reactant
Saturo	Saturated
Sedia (conformazione)	Chair conformation
Sfalsato	Staggered
Solido	Solid
Solubile	Soluble
Sostituzione	Substitution
Stabile	Stable
Stechiometria	Stoichiometry
Struttura	Structure
Suffisso	Suffix
Tensione	Strain
Tetraedrico	Tetrahedral

SATURED HYDROCARBONS-DURING

Satured Hydrocarbons Video

General features

Saturated hydrocarbons are organic compounds composed only of carbon and hydrogen, with the maximum ratio of hydrogen to carbon atoms. Their molecules contain no double or triple bonds. Saturated hydrocarbons include alkanes and cycloalkanes.
Alkanes – whose molecular formula is CnH2n+2 – are arranged in chains.
Cycloalkanes – whose molecular formula is CnH2n – are arranged in rings.

Methane: structure and three-dimensional model

Methane, whose molecular formula is CH4, is the simplest alkane. Its molecule has a tetrahedral structure, with angles between C–H bonds measuring about 109°28', according to both the sp3 hybridization of carbon and VSEPR theory. The shape of the molecule is well represented by three-dimensional models such as the Dreiding and ball-and-stick models.

Two-dimensional representations

The molecular structures of alkanes and cycloalkanes can be represented by means of the following two-dimensional formulas:

- Kekulé formulas, which display all the bonds
- Condensed formulas, in which the bonds to each carbon are omitted
- Shorthand formulas, in which the symbols for carbon and hydrogen are omitted, the segments of polygonal chain represent covalent bonds, the ends and intersections of the segments represent carbon atoms and the correct number of hydrogens is calculated considering the tetravalency of carbon

Cycloalkanes such as cyclopropane, cyclobutane, and cyclopentane are represented by regular polygons.

Structural isomerism

Alkanes with four or more carbon atoms have structural isomers, which are different compounds having the same molecular formula but different sequences of carbon atoms. For instance, there are three isomers with the formula C5H12: one linear and two branched.

Conformational isomerism in alkanes

Alkane molecules undergo continuous rotation around carbon–carbon bonds; therefore, the chain takes different shapes. Different spatial orientations resulting from these rotations are called conformations. Ethane is a good example of conformational isomerism because it has only one carbon–carbon bond, and all the conformations lie between two extremes: staggered and eclipsed. The eclipsed conformer is less stable than the staggered one due to the repulsion between the carbon–hydrogen bond electrons. Newman projections illustrate different conformers. Conformers interconvert rapidly at room temperature and therefore cannot be isolated.

Conformational isomerism in cycloalkanes

Cyclopropane and cyclobutane have bond angles measuring 60° and 90° respectively, very different from the typical 109° of sp3 hybridization; consequently, they are less stable due to angle strain. Cyclopentane is quite stable and shows very little angle strain because the angles

of a pentagon measure 108°, very close to 109°. Cyclohexane would exhibit angle strain if it were planar; it shows three important conformations: one boat conformation and two chair conformations with six axial and six equatorial hydrogens alternating. The chair conformation is predominant because it is more stable.

IUPAC denomination of unbranched alkanes

IUPAC nomenclature of alkanes is very important because it is the basis for naming many other organic compounds. The suffix –ane identifies alkanes. Below is the list of the first ten unbranched alkanes:

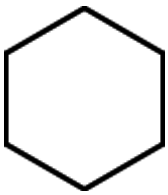
CH_4	Methane	C_6H_{14}	Hexane
C_2H_6	Ethane	C_7H_{16}	Heptane
C_3H_8	Propane	C_8H_{18}	Octane
C_4H_{10}	Butane	C_9H_{20}	Nonane
C_5H_{12}	Pentane	$C_{10}H_{22}$	Decane

Below is an example illustrating important IUPAC rules for branched alkanes.

```
                    C
                    |
C – C – C – C – C – C – C – C        5–ethyl–2,2-dimethyloctane
            |       |
            C       C
            |
            C
```

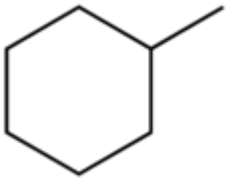
1. Choose and name the longest continuous carbon chain (main chain).
2. Identify the substituent groups attached to the main chain.
3. Number the chain starting from the end closest to the first substituent group, thus determining the position of each group.
4. The names of alkyl groups derive from the corresponding alkanes by replacing the suffix –ane with –yl.
5. List alkyl groups alphabetically, indicating their positions with numbers.
6. The prefixes di-, tri-, and tetra- are not considered in alphabetical order.
7. Use dashes to separate numbers from letters and commas to separate numbers.

Cycloalkane nomenclature is similar to alkane nomenclature because it uses the cyclo- prefix together with the –ane suffix.



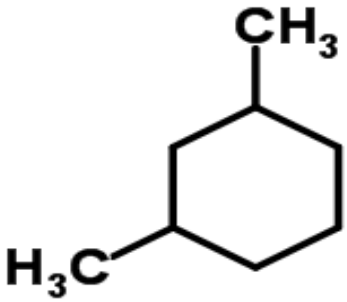
Cyclohexane

If a cycloalkane is monosubstituted, it is not necessary to number the carbons of the ring.

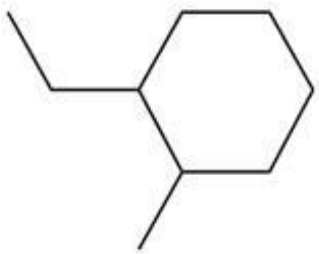


Methylcyclohexane

If there are two or more substituents on the ring, it is necessary to number the carbon atoms. IUPAC rules are similar to those for alkanes: if the substituents are the same, they are grouped together; if they are different, they are listed in alphabetical order, with carbon 1 assigned to the substituent that gives the lowest set of locants. The numbering of ring carbons may proceed either clockwise or counterclockwise, so as to give the substituents the lowest possible numbers.



1,3-dimethylcyclohexane



1-ethyl-2-methylcyclohexane

Reactivity of alkanes

Alkanes are chemically quite inert. The main reason for their inertness is the lack of a functional group, which is the reactive part of a molecule. In their structure there are only non-polar or slightly polar covalent bonds. Nevertheless, alkanes undergo important reactions such as combustion and halogenation. Both reactions initially require some activation energy to raise the reactants to a transition state that later turns into products.

Combustion of alkanes

Below are the equations for the combustion of butane:

a) $2\ C_4H_{10} + 13\ O_2 \rightarrow 8\ CO_2 + 10\ H_2O$ + heat

b) $2\ C_4H_{10} + 9\ O_2 \rightarrow 8\ CO + 10\ H_2O$ + heat

The equations are balanced. The reactions are exothermic and produce heat; the latter reaction, which produces carbon monoxide, occurs when oxygen is insufficient to achieve complete combustion and form carbon dioxide. The combustion of hydrocarbons, for example those derived from oil, has fostered the development of our civilization.

Halogenation of alkanes

Alkanes also undergo substitution reactions such as halogenation. Consider the following reaction:

$$C{-}C{-}C + Cl_2 + \text{energy (light or high temperature)} \rightarrow \underset{\displaystyle Cl}{\underset{|}{C}}{-}C{-}C + \underset{\displaystyle Cl}{\underset{|}{C}}{-}C{-}C + HCl$$

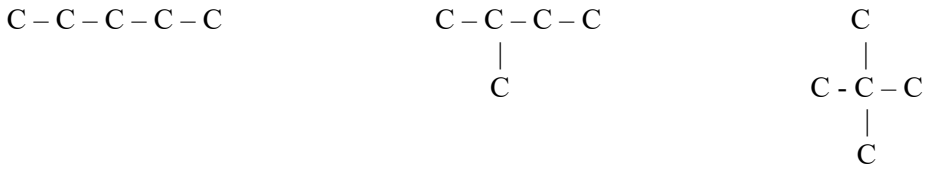
This reaction represents propane chlorination. As you can see, the reaction requires either light or high temperature and produces a mixture of two isomers: 2-chloropropane and 1-chloropropane. The percentage of the first isomer is higher. Halogenation is a substitution reaction in which a carbon–hydrogen bond is broken and a halogen—chlorine in this case—replaces hydrogen.

In propane, the eight hydrogen atoms are not equally reactive: the two bonded to the secondary carbon are more reactive than those bonded to the primary carbons. This is the reason why 2-chloropropane is more abundant.

Physical properties

In conclusion, we can highlight some physical properties of alkanes. The unbranched alkanes methane, ethane, propane, and butane are gases at room temperature. Pentane through hexadecane are liquids, whereas unbranched alkanes heavier than hexadecane are solids (heptadecane is liquid above 22 °C).

Branched alkanes usually show lower boiling points than unbranched alkanes with the same number of carbon atoms. For instance, consider the three structural isomers with the molecular formula C_5H_{12}:



Pentane	2-methylbutane	2,2- dimethylpropane
b.p. = 36°C	b.p. = 28°C	b.p. = 10° C

As we can see, pentane, 2-methylbutane, and 2,2-dimethylpropane have different boiling points even though their molecular masses are the same. In fact, the more branched the carbon chain, the weaker the van der Waals interactions and therefore the lower the boiling point. Pentane exhibits stronger van der Waals forces due to the larger contact surface between its molecules.

Finally, it should be observed that alkanes do not dissolve in water: they are completely insoluble because water is a polar liquid, whereas alkanes—as discussed previously—are non-polar compounds.

(Voice and reading here: https://luvvoice.com/it)

KEYWORDS

1) Which of the following features are associated with saturated hydrocarbons?

combustion – oxidation – reduction – polar molecule – halogenation – activation energy – ring – chain – boat conformation – staggered conformer

Solutions:

Associated with saturated hydrocarbons:
- combustion
- oxidation
- halogenation
- activation energy
- ring
- chain
- boat conformation
- staggered conformer

Not associated:
- reduction
- polar molecule

2) Select branched alkanes and unsubstituted cycloalkanes.

hexane – cyclohexane – 2-methylhexane – methylcyclobutane – 3,3,4-trimethyldecane – nonane – cyclopentane – pentane

Solutions:
Branched alkanes:
- 2-methylhexane
- 3,3,4-trimethyldecane

Unsubstituted cycloalkanes:
- cyclohexane
- cyclopentane

SATURED HYDROCARBONS-AFTER
DRILLS

Multiple Choice
Select the single correct choice to make natural sentences.
1. The correct molecular formula of an alkane is:
a. C6H6
b. C6H12
c. C6H14

2. In propane, the hybridization of carbon atoms is:
a. sp
b. sp3
c. sp2

3. The molecule of methane has bond angles measuring about:
a. 109.5°
b. 107°
c. 104°

4. The alkane whose molecular formula is C7H16 has:
a. 7 structural isomers
b. 8 structural isomers
c. 9 structural isomers

5. The complete combustion of two molecules of C8H18 to produce 16 molecules of CO2 requires:
a. 25 molecules of oxygen
b. 25 atoms of oxygen
c. 20 molecules of oxygen

6. Halogenation of pentane produces a mixture of isomers. The least abundant is:
a. 1-chloropentane
b. 2-chloropentane
c. 3-chloropentane

Matching
Match the numbered IUPAC names with the lettered molecular formulas.

1. Methylcyclopentane	a. C5H12
2. 3,3-dimethylhexane	b. C6H12
3. Cyclopentane	c. C5H10
4. 2-chloropentane	d. C8H18
5. 2,2-dimethylpropane	e. C5H11Cl

True or False

State if the following sentences are True or False.

1. In alkanes, bond angles measure 90°.
2. In alkanes, carbon atoms are sp^2 hybridized.
3. C_8H_{16} is the molecular formula of an alkane.
4. C_6H_{14} is the molecular formula of 2-methylpentane.
5. Kekulé formulas show the shape of molecules.
6. In cyclohexane, the chair conformation is more stable than the boat conformation.
7. The combustion of an alkane requires the same amount of oxygen to produce both CO and CO_2.
8. The chlorination of 2-methylpentane produces a mixture of products. The most abundant product is 2-methyl-2-chloropentane.

Cloze

To complete the text, use the correct words from the list:

lack – chains – combustion – ratio – C-H

Alkanes and cycloalkanes are saturated hydrocarbons with the maximum hydrogen-to-carbon _____. Alkanes are arranged in _____ and their molecular formula is C_nH_{2n+2}.
Despite their inertness, due to the _____ of a functional group, they undergo important reactions such as _____ and halogenation. Halogenation is a substitution reaction in which a_____ bond is broken and hydrogen is replaced by halogens such as chlorine and bromine.

Solutions:

Multiple Choice: 1. c; 2. b; 3. a; 4. c; 5. a; 6. A
Matching: 1.b; 2.d; 3.c; 4.e; 5.a
True or False: 1.F; 2.F; 3.F; 4.T; 5.F; 6.T; 7.F; 8.T
Cloze: 1. ratio; 2. chains; 3. lack; 4. combustion; 5. C-H

SOFT SKILLS

Flow Chart

Complete the following flow chart:

Consider the combustion of 3-ethyloctane to produce carbon dioxide and water and write the equation of the reaction.
After the balanced reaction, fill in the gaps. Remember that the molecular formula of an alkane is C_nH_{2n+2} and that the number of atoms of the reactants is the same as the number of atoms of the products. Bear in mind that stoichiometric coefficients are integer numbers.

Molecular formula of 3-ethyloctane [ ]

Combustion reaction

[ ] [ ] + [ ] [ ] → [ ] [ ] + [ ] [ ]

Solutions:

Molecular formula of 3-ethyloctane $C_{10}H_{22}$

Combustion reaction

$$2\ C_{10}H_{22} + 31\ O_2 \rightarrow 20\ CO_2 + 22\ H_2O$$

Think and Discuss

The following activity can be carried out in written or oral form. The teacher will choose the modality depending on the skill (writing, speaking, or interacting) that needs to be developed.
The task will be presented to the students within the following contexts:
A) the student writes an article about saturated hydrocarbons
B) the student prepares for an interview on local TV about saturated hydrocarbons
The student should:

1. Choose one of the following topics:
   - Explain the importance of alkanes for our civilization, also focusing on the effects of increasing carbon dioxide in the troposphere.
   - Explain why alkanes require some activation energy to react.
   - Discuss the representation of alkane molecules, focusing mainly on two-dimensional formulas.
2. Prepare the article or the interview, outlining the main points of the subect on the basis of what has been studied.
3. For the written activity, the student should write an article indicating the target readers and the type of magazine, newspaper, or school magazine in which the article would be published.
4. For the oral activity, the student should present the point of view on one topic to the whole class, and a debate could start at the end of the presentation.

Compendium

Saturated hydrocarbons are alkanes and cycloalkanes whose molecular formulas are $C_nH_{2n}+2$ and C_nH_{2n} respectively. We can use both three-dimensional models, such as the Dreiding and ball-and-stick models, and two-dimensional formulas, such as Kekulé, condensed, or shorthand formulas, to represent alkanes; cycloalkanes are represented by regular polygons.
Isomerism is a very important feature of alkanes and cycloalkanes. There are important rules for assigning IUPAC names to alkanes and cycloalkanes. It is quite easy to name both unbranched alkanes and unsubstituted cycloalkanes. Some essential steps in naming branched alkanes or substituted cycloalkanes are: choosing the longest continuous carbon chain (alkanes), identifying the substituent groups (alkanes and cycloalkanes), and numbering the carbons of the chain (alkanes) or of the ring (cycloalkanes). The –ane suffix identifies alkanes, the cyclo- prefix together with the –ane suffix identifies cycloalkanes, and the –yl suffix identifies alkyl groups.
In alkane molecules there are only non-polar covalent bonds, so they lack functional groups; nevertheless, they undergo important reactions such as combustion and halogenation, which require some activation energy. Because their molecules are non-polar, alkanes are insoluble in water. Their aggregation state and other physical properties, such as boiling point and melting point, depend on their molecular mass and on whether the carbon chain is branched or unbranched, according to van der Waals interactions.

1) Answer the following questions.

The answers can be given in written or oral form, depending on the teacher's objectives.

A) How can you represent molecules of alkanes?
B) Explain what a halogenation reaction consists of.
C) Why is hexane insoluble in water?

2) *Write a short abstract of the Compendium (maximum 150 words) highlighting the main points about the reactivity and physical properties of alkanes.*

Problem Solving
The following activities can be carried out at school, if a computer room is available, or at home. Students are invited to use the web references listed above.

***1**) Individual activity*
Choose to impersonate one of the following characters and write a report.
a) You are a chemist writing an article titled: "Structural and conformational isomerism in alkanes."
b) You are a chemist working for a chemical company. Write an article on the reactions of alkanes.
c) You are a chemist writing an article on the physical properties of alkanes.

2) *Small group activity*
Choose one of the following topics, use the web references listed above, create a PowerPoint presentation, and present it to your classmates.
Topics:
a. Choose a branched alkane and explain how to name it.
b. Choose some reactions to explain the combustion of alkanes.
c. Explain how saturated hydrocarbons have fostered the development of our civilization.

3) *Class project*
Prepare a poster and a brochure explaining both how to assign IUPAC names to alkanes and cycloalkanes and how alkanes react with oxygen and halogens. You can display the poster at school and distribute the brochures to your schoolmates and friends.

POLYMERS

POLYMERS-BEFORE

Prerequisites

Chemistry
- Atoms and molecules
- Chemical bonds
- Simple molecular formulas
- Difference between organic and inorganic compounds

General Science
- Everyday materials
- Natural and artificial materials

Linking to Previous Knowledge and Predicting

- What materials are objects made of?
- What is plastic?
- Are all materials made of small units?
- Can small molecules join together?
- Why are some materials flexible or rigid?

What are Polymers?
Polymers are substances made of many small units joined together to form long chains.

Scientific Areas Involved
- Organic chemistry
- Materials science
- Industrial chemistry
- Environmental science (basic level)

GLOSSARY

Acido nucleico	Nucleic acid
Addizione (polimerizzazione per)	Addition (polymerization)
Alcol polivinilico (PVA)	Polyvinyl alcohol (PVA)
Amido	Starch
Amilopectina	Amylopectin
Amilosio	Amylose
Amminoacido	Amino acid
Borace	Borax
Borato (ione)	Borate (ion)
Cellulosa	Cellulose
Chitina	Chitin
Cloruro di vinile	Vinyl chloride
Condensazione (polimerizzazione per)	Condensation (polymerization)
Copolimeri	Copolymers
Deformazione	Deformation

Elastomero	Elastomer
Emoglobina	Hemoglobin
Enzima	Enzyme
Eteropolimero	Heteropolymer
Etilene	Ethylene
Fluido dilatante	Dilatant fluid
Glucosio	Glucose
Ione	Ion
Ispessimento al taglio	Shear thickening
Legame covalente	Covalent bond
Legame glicosidico	Glycosidic bond
Legame incrociato	Cross-link
Lineare	Linear
Macromolecola	Macromolecule
Metil metacrilato	Methyl methacrylate
Monomero	Monomer
Nylon	Nylon
Oligomero	Oligomer
Omopolimero	Homopolymer
Peso molecolare	Molecular weight
Plastica	Plastic
Plastificante	Plasticizer
Poliammide	Polyamide
Polibutadiene	Polybutadiene
Policarbonato	Polycarbonate
Poliestere	Polyester
Polietilene (PE)	Polyethylene (PE)
Polietilentereftalato (PET)	Polyethylene terephthalate (PET)
Polimero	Polymer
Polimetil metacrilato	Polymethyl methacrylate
Polipropilene	Polypropylene
Polisaccaride	Polysaccharide
Polistirene	Polystyrene
Polistirolo (PS)	Polystyrene (PS)
Politetrafluoroetilene	Polytetrafluoroethylene
Poliuretano	Polyurethane
Polivinilcloruro	Polyvinyl chloride
Propilene	Propylene
Proteina	Protein
Pseudoplastico	Pseudoplastic
Ramificato	Branched
Reologia	Rheology
Resina epossidica	Epoxy resin
Reticolato	Cross-linked
Sforzo di taglio	Shear stress
Solvente	Solvent
Stirene	Styrene
Termoindurente	Thermosetting
Termoplastico	Thermoplastic
Tetrafluoroetilene	Tetrafluoroethylene

POLYMERS-DURING

Polymers Video

A polymer is formed by monomers

Polymers are natural and synthetic substances formed by molecules containing an enormous number of atoms. Hence, a polymer is a macromolecule, a molecule with a high molecular weight, formed by the periodic repetition of a large number of units called monomers.

Covalent bonds for long chains

The single monomeric units (which can be all of the same type or of different types) are kept together by covalent bonds. These form long chains, more or less branched, having a molar mass of the order of several thousand g/mol.

Polymer chains of infinite size

We can picture a polymer molecule as a pearl necklace in which each pearl represents a monomer unit. In some cases the chains are formed by the repetition of a single monomer unit, while in other cases the chains can contain different monomer units. Theoretically, polymer chains can reach infinite sizes.

Polymers are everywhere

Polymers can be found everywhere inside or outside our bodies. They represent a very large category of substances: from biological polymers such as proteins and nucleic acids (DNA) to polymer solutions such as blood, vitreous humour and synovial fluid, and to plastics and natural fabrics such as cotton and silk.

Natural and synthetic

Examples of natural polymers include DNA, proteins, and polysaccharides such as starch and cellulose. Examples of common synthetic polymers are nylon, polystyrene (PS), polyethylene (PE) and polyethylene terephthalate (PET).

Polymer classification

Polymers can be classified according to origin (natural, synthetic, semi-synthetic), structure (homopolymers, copolymers, heteropolymers), polymerization method (condensation or addition), and thermal properties (thermoplastic or thermoset).

- Common natural polymers

Proteins (enzymes, silk, muscle fibers),
Polynucleotides (nucleic acids)
Polysaccharides (cellulose, starch, chitin)
Rubbers (caoutchouc or natural rubber), resins (ambers)

- Common synthetic polymers

Plastics (PET, PS)
Elastomers (polybuatadiene or silicon rubber)
Fibers (nylon, polyester)

- Common semi-synthetic polymers

Rayon: regenerated cellulose fiber through chemical reactions
Nitrocellulose: explosive
Celluloids: plastic material formed using nitrocellulose and camphor

From homopolymers to heteropolymers

When the polymer chain is formed by the repetition of a single monomer unit, it is defined as a homopolymer. If the repeating units are of two different types, we use the word copolymer; three different repeating units give terpolymers, and so on.

When the repeating units are of many different kinds, we use the word heteropolymers.
Copolymers are further divided into:
- Statistical copolymers (with a random distribution of the two monomers)
- Alternating copolymers (the two monomers alternate regularly along the chain)
- Block copolymers (the chain is formed by distinct homopolymer blocks for each of the monomers)
- Graft copolymers (the backbone is formed by one of the monomers while the other forms branches on the sides)

Cellulose

An example of a homopolymer is cellulose; here the monomeric unit is a derivative of the β-glucose molecule which has lost a water molecule ($C_6H_{10}O_5$).

Starch is a homopolymer

Another homopolymer of the monosaccharide group is starch. This is also formed by glucose molecules. More precisely, it is a blend of two polymers: amylose (constituting approximately 20%) and amylopectin (the remaining 80%). Amylose is a linear polymer, while amylopectin is branched. The branching points are due to 1–6 glycosidic bonds (bonds between carbon 1 of a glucose and carbon 6 of the adjacent glucose) and are so numerous that the complete structure of amylopectin resembles the veins of a leaf. Amylopectin can contain up to a hundred thousand glucose units and is one of the largest biological macromolecules known.

Oligomers and polymers

There is no clear boundary in the number of monomeric units above which a molecule can be defined as a polymer; generally speaking, we can distinguish **oligomers** from real polymers:

1. The word oligomer (from the Greek *oligon* = little) is generally used for molecules that contain few repeating monomer units and are therefore not defined as polymers (the chain length is less than 50 Å and the molecular weights are less than 1500 a.m.u.). These oligomers do not display the properties typical of polymers.
   Sugar polymers, for example, are classified according to the number of monosaccharides that form them: oligosaccharides (2 to 10 monomer units) or polysaccharides (more than 10 monomers); among the oligosaccharides, disaccharides are very common, being formed by two sugar units.
2. Real polymers can be further divided into:
   - Low molecular weight polymers: molecular weight between 1500 and 5000 a.m.u., formed by 20 to 100 units and with a total chain length between 50 and 500 Å;
   - Mesopolymers: molecular weight between 5000 and 10000 a.m.u., formed by 100–200 units and with a total length between 500 and 2500 Å;
   - High molecular weight polymers: weighing at least 10000 a.m.u. and reaching masses of the order of a million, with more than 100 units in their chain and total length above 2500 Å.

High and low molecular weight polymers

An extreme example of a high molecular weight polymer is polyethylene (a polymer of ethylene). This macromolecule develops its physical properties, which are very useful for the fabrication of plastic water bottles, only if the molecular weight exceeds one million a.m.u. The opposite example is nylon; its typical physical properties are visible already above a molecular weight of about 50,000 a.m.u. These different behaviors depend on intermolecular forces: in the first case they are mainly van der Waals forces (very weak), while in the second case stronger hydrogen bonds are present.

Polymerization

The chemical process through which monomers are joined together in order to form a polymer is called **polymerization**.

The main polymerization methods are:
• Addition
• Condensation
Both of these processes occur in the presence of specific catalysts.

Addition polymerization

Addition polymers are macromolecules in which the chemical formula of the repeating unit is identical to that of the monomer used. For example, polypropylene $(C_3H_6)_n$, a widely used substance, is an addition polymer formed from propylene (C_3H_6).
Addition of monomers is triggered by the presence of an active molecule which binds to the monomers and always moves to the end of the growing chain; this active molecule is the reactive center of the polymer and can be a carbocation, a carbanion, or a radical.

Polyaddition polymerization

Polyaddition polymers include polyethylene, polypropylene, and polybutadiene.
Polyethylene (PE) is used in common plastic bags, water bottles, and cable housing.
Polypropylene (PP) is used for the production of plastic materials (food containers and rigid bottles) but also for fibers (carpets).
Polyvinyl chloride (PVC) is used for hoses, panels, gutters, discs, toys, credit cards, exterior furniture, and much more.
Finally, polystyrene (PS) is used for packaging and insulation.

Condensation polymerization

The polymer chain is obtained by the condensation of single monomer units, which occurs together with the loss of small molecules such as water or alcohol.
The difference from addition polymers is that, in this case, polymerization is a series of reactions that are independent of the previous ones.
The chemical formula of the repeating unit of a condensation polymer has a smaller number of atoms than that of the starting monomers due, for example, to the loss of water.

Condensation polymers

Notable condensation polymers are polyamides (nylon), proteins (enzymes, hemoglobin), polysaccharides (starch, cellulose), and polyesters.
With this type of polymerization it is more difficult to reach very high molecular weights, and the mechanical properties of condensation polymers are generally worse than those obtained by addition polymerization.
An exception is nylon, which can form very long chains and obtain its well-known mechanical properties.

Polymer structures

Molecular weight is not the only factor that contributes to the mechanical properties of a polymer; an important contribution is also given by the different structural conformations of the chain.
According to polymer structure we can distinguish between:

1. Linear polymers, in which the monomer units form a single chain.
   Common linear polymers are polyethylene, polyvinyl chloride, polystyrene, polymethyl methacrylate, nylon, and fluorocarbons.
2. Branched polymers, polymers in which lateral secondary chains are grafted along the backbone.
   The same linear polymers can also form branched chains.
3. Cross-linked polymers: in these cases the adjacent linear chains are bound together at different points by covalent bonds.

The formation of these cross-linking points can be performed during synthesis (giving a more controlled and ordered structure) or by irreversible chemical reactions at high temperature.
These reactions require the addition of atoms and molecules that bind to the chain by covalent bonds; this is similar to the process by which rubber is vulcanized: in this case the formation of crosslinks is achieved by the addition of sulfur to the carbon–carbon double bonds.

4. Network polymers are materials in which the monomer units bind together to form three-dimensional scaffolds. These materials have very peculiar mechanical and thermal characteristics. A famous class of network polymers is epoxy resins.

Thermoplastics

The physico-chemical properties of polymers are a direct consequence of their three-dimensional structure. Linear polymers are called thermoplastics or, more generally, plastics. By heating the material it is possible to melt them by separating the individual chains. Moreover, using plasticizers or suitable solvents, these substances can be softened or dissolved.

Thermoset resins

Network polymers form thermoset resins.
These materials, during preparation, initially melt and then undergo a second phase transition, becoming irreversibly hard. They cannot be melted and molded again without damaging the polymer by breaking the covalent bonds between monomer units.
In conclusion, while a thermoplastic material can be melted many times without altering its nature, a thermoset polymer is molded in an irreversible and permanent way.
The most famous thermoset polymers are Bakelite, one of the first synthetic plastics (commercially available since 1910), and melamine-formaldehyde, a component of Formica® plastics.

Most common synthetic addition polymers

Polymer	Repeating unit	Monomer	Applications
Low-density polyethylene (LDPE)	[–CH2–CH2–]n	Ethylene CH2=CH2	Films, bags
High-density polyethylene (HDPE)	[–CH2–CH2–]n	Ethylene CH2=CH2	Bottles, toys, cable housing
Polypropylene (PP)	[–CH2–CH(CH3)–]n	Propylene CH2=CHCH3	Various objects
Polyvinyl chloride (PVC)	[–CH2–CHCl–]n	Vinyl chloride CH2=CHCl	Tubes, flooring, discs
Polystyrene (PS)	[–CH2–CH(C6H5)–]n	Styrene CH2=CHC6H5	Toys, boxes, packaging
Polytetrafluoroethylene (PTFE, Teflon®)	[–CF2–CF2–]n	Tetrafluoroethylene CF2=CF2	Insulators, low-friction applications
Polymethyl methacrylate (PMMA, Plexiglas®)	[–CH2–C(CH3)(CO2CH3)–]n	Methyl methacrylate CH2=C(CH3)CO2CH3	Plastic glass

Most common synthetic condensation polymers

Polyesters
a. Polyethylene terephthalate (PET):
i. DACRON, a more resistant and stiff polyester fiber
ii. MYLAR film, used for balloons

Polyamides
a. Nylon 66: two monomers with 6 carbon atoms each
b. Nylon 610
c. Nylon 6
d. Kevlar: very light and highly resistant fiber used for bulletproof vests
Polycarbonates
a. LEXAN: hard and resistant, used for lenses and safety glasses
Polyurethanes
a. LYCRA fibers for underwear and clothing
Epoxy resins
a. Generally thermosets, used as adhesives, coatings and insulators

(Voice and reading here: https://luvvoice.com/it)

KEYWORDS

1. ***Which of these terms defines a polymer formed by the sequence of many monomer units different from each other:***

homopolymer, graft copolymer, terpolymer, heteropolymer, statistical copolymer

Solutions:
heteropolymer

2. Select from the following list the synthetic polymer categories

elastomers, silk, fibers, nucleic acids, rubber, resins, plastics

Solutions: elastomers, fibers, plastics

3. Identify among the following definitions the one that corresponds to alternating copolymers
polymers in which:
- the distribution of the two monomers is random
- the two monomers alternate regularly along the chain
- the chain is formed by sequences of blocks of the two monomeric units
- the units of one monomer form branching chains starting from the backbone composed of the second monomer

Solutions: the two monomers alternate regularly along the chain

BIOMOLECULES-AFTER
DRILLS

Multiple Choice
Select the single correct choice to make natural sentences.
1. Polymers are substances formed by the repetition of:
a. macromolecules
b. monomers
c. identical molecules
d. atoms

2. Polymerization is:
a. the process by which a polymer is molded
b. a reaction between two or more polymers
c. a reaction that forms polymers
d. the melting of a polymer

3. Which is the difference between a thermoplastic polymer and a thermoset one?
a. the thermoplastic polymer has a higher viscosity
b. the thermoset has a higher melting point
c. the thermoplastic can be melted many times without its molecules undergoing chemical changes
d. the thermoset is always softer

4. Homopolymers are polymers formed by:
a. many different monomer units
b. alternating monomer units
c. a single repeating monomer unit
d. cross-linked chains

5. Condensation polymerization is characterized by:
a. the loss of small molecules such as water or alcohol
b. the absence of chemical reactions
c. the formation of only branched polymers
d. the breaking of polymer chains

6. Cross-linked polymers are characterized by:
a. independent polymer chains with no connections
b. covalent bonds linking different polymer chains
c. very low molecular weight
d. the absence of intermolecular forces

Matching

Match the words on the left with the correct definition on the right.

1. Monomers	a) Addition polymerization
2. Condensation polymerization	b) Polymers formed with the loss of small molecules
3. Thermoplastics	c) Repeating units that form macromolecules
4. Addition polymerization	d) Polymers that can be melted and reshaped
5. Polymers	e) Macromolecules formed by many repeating units

True or False

State if the following sentences are True or False.
1. Cellulose is a copolymer
2. Starch is a tripolymer
3. Polyesters are produced by condensation
4. Rubber is a synthetic polymer
5. Nylon is polymerized by addition
6. Thermoset resins are linear polymers
7. Rayon is a yarn produced from cellulose
8. Epoxy resins are cross-linked polymers

Cloze

To complete the text, use the correct words from the list:

thousands – covalent – melt – temperature – thermoplastics – water – β-glucose – viscosity – addition – stands for – vinyl – ethylene terephthalate

In polymers the single monomer units are kept together by _____ [1] bonds and form long chains, more or less branched, in which the molar mass is of the order of _____ [2] of g/mol.
Thermoset resins, during their preparation, initially _____ [3] but with a further increase in _____ [4] they harden permanently.
In cellulose, the monomer unit derives from a _____ [5] molecule that has lost a _____ [6] molecule.
Linear polymers are generally called _____ [7] or, more simply, plastics; by heating it is possible to _____ [8] them by separating the single linear chains from each other.
During rubber vulcanization, cross-linking between the chains occurs thanks to the _____ [9] process of elementary sulfur.
Non-Newtonian fluids are those in which the _____ [10] varies according to the rate of shear strain applied.
LLDPE _____ [11] low-density polyethylene.
PVC poly _____ [12] chloride.
PET poly _____ [13]

Solutions:
Multiple Choice: 1b – 2c – 3c – 4c – 5a – 6b
Matching: 1c – 2b – 3d – 4a – 5e
True or False: 1F – 2F – 3T – 4F – 5F – 6F – 7T – 8T
Cloze: 1. covalent – 2. thousands – 3. melt – 4. temperature – 5. β-glucose – 6. water – 7. thermoplastics – 8. melt – 9. addition – 10. viscosity – 11. stands for – 12. vinyl – 13. ethylene terephthalate

SOFT SKILLS

Flow Chart
Complete the following flow chart that describes the polymerization reaction of PET:

Place the following sentences in the correct order:

Because of this, the total number of atoms in the repeating unit
one molecule of water is released during the reaction.
For each molecule of terephthalic acid and ethylene glycol,
is smaller than that of the sum of the monomers.
and as such, its repeating unit differs from those of the building monomers.
Polyethylene terephthalate (PET) is a condensation polymer,

Solutions:

Polyethylene terephthalate (PET) is a condensation polymer,

and as such, its repeating unit differs from those of the building monomers.

For each molecule of terephthalic acid and ethylene glycol,

one molecule of water is released during the reaction.

Because of this, the total number of atoms in the repeating unit

is smaller than that of the sum of the monomers.

Think and Discuss

The following activities can be performed in written or oral form. The teacher will choose the method, depending on the skill (writing, speaking, interacting) to be developed.
The task will be presented to the students within the following contexts:
A) the student writes an article about polymers
B) the student prepares for an interview on a local TV programme about polymers
The student should:

1. Choose one of the following topics:
   - Describe a class of polymers
   - Describe the typical characteristics of polymers
   - Different polymerization processes
2. Prepare an article or a debate outlining the main points of one topic, on the basis of what has been studied.
3. For the written activity, the student should provide an article, indicating the target readership and the type of magazine, newspaper or school magazine in which the article would be published.
4. For the oral activity, the student should present the point of view on one topic to the whole class, and a debate may start at the end of the presentation.

Compendium

Polymers are macromolecules with a molecular weight of several thousand grams per mole. A polymer is formed by a series of repeating units called monomers. Notable examples of polymers are DNA, a macromolecule about two meters long contained in each cell of our body, and polyethylene terephthalate (PET), the material from which plastic beverage bottles are made. Polymers can be classified in different ways. One important classification is based on the polymerization process. There are addition polymers, in which the chemical formula of the repeating unit is an exact repetition of the monomer formula, and condensation polymers, in which the chemical formula of the polymer differs from that of the monomers. This difference arises from the release of small molecules, such as water, during polymerization. Alternatively, polymers can be classified according to their thermal properties (thermoplastics or thermosets), their origin (natural, synthetic, or semi-synthetic), and their structure (homopolymers, copolymers, or heteropolymers).
Polymers can also have different structural arrangements. They may form linear chains, in which the monomers join to create a long one-dimensional sequence; branched polymers, in which side chains are attached to the main backbone forming a two-dimensional structure; and network or cross-linked polymers, in which multiple chains are chemically or physically connected to form a three-dimensional network. These different configurations strongly influence the physical properties of the final material.

1) *Answer the following questions*

The answers can be given in written or oral form, depending on the teacher's objectives.

A) A chemist analyzes samples of polyethylene, nylon, and natural rubber. On the basis of your knowledge, answer the following questions:
a.1) Which of these polymers are produced by addition polymerization?
a.2) Which polymer is produced by condensation polymerization?
a.3) Which of these polymers can be classified as natural?
a.4) Which of these materials can be repeatedly melted and reshaped?

B) Describe the typical structures of linear, branched, and cross-linked polymers.

C) State the main applications of synthetic polymers in everyday life.

D) Describe addition and condensation polymerization, providing one example of each.

E) Outline the differences between thermoplastic and thermoset polymers.

2) *Write a short abstract of the Compendium (maximum 150 words) highlighting the main points about polymers.*

Problem Solving

The following activities can be carried out at school, if a computer room is available, or at home. Students are invited to use the web references listed above.

1) *Individual activity*
Choose one of the following roles and write your report:
a) You are a materials scientist writing an article titled "What Are Polymers?"
b) You are a chemist working for a plastics company. Write an article on the most important industrial polymers.
c) You are a researcher writing an article on polymerization reactions.

2) *Small group activity*
Choose one of the following topics, create a PowerPoint presentation and present it to your classmates.
Topics:
a) Compare the structures and properties of thermoplastic and thermoset polymers.
b) Explain the differences between addition and condensation polymers.
c) Describe the importance of synthetic polymers in everyday materials.

3) *Class project*
Prepare a poster and a brochure describing the main classes of polymers and their applications. Display the poster in your school and distribute copies of the brochure to your classmates.

STARS

STARS-BEFORE

Prerequisites

Physics
- Basic concepts of energy and forms of energy
- Nature of light as electromagnetic radiation
- Gravity as a force and its role in large-scale systems
- Basic concepts of heat and temperature
- Simple ideas about energy transfer (radiation and convection)

General Science / Astronomy
- Observation of the night sky
- The Earth–Sun system (rotation and revolution)
- Basic idea of scale in the Universe (distances in space)
- Use of scientific models to explain natural phenomena

Linking to Previous Knowledge and Predicting

- What can you observe in the night sky?
- What is the Sun and how is it different from other stars?
- Why do stars shine?
- Are all stars the same in size and temperature?
- How far do you think stars are from Earth?
- What do you think determines the life cycle of a star?

What Are Stars?
Stars are extremely large, hot spheres of gas that produce light and energy through nuclear fusion in their cores.
Le stelle sono enormi sfere di gas molto calde che producono luce ed energia attraverso la fusione nucleare nel loro nucleo.

Scientific Areas Involved
- Astronomy
- Physics
- Astrophysics (introductory level)
- Space Science

GLOSSARY

Astronomia	Astronomy
Atomo	Atom
Attività	Activity
Buco nero	Black hole
Ciclo protone-protone	Proton-proton chain
Classe spettrale	Spectral class
Corona	Corona
Cromosfera	Chromosphere

Densità	Density
Diagramma di Hertzsprung-Russell	Hertzsprung-Russell diagram
Diagramma H-R	H-R diagram
Elettrone	Electron
Ferro	Iron
Fotosfera	Photosphere
Fusione nucleare	Nuclear fusion
Gigante blu	Blue giant
Gigante rossa	Red giant
Gravità	Gravity
Ione	Ion
Luce	Light
Luminosità	Brightness / Luminosity
Magnitudine	Magnitude
Massa	Mass
Massa solare	Solar mass
Metallo	Metal
Nana bianca	White dwarf
Nana bruna	Brown dwarf
Nebulosa	Nebula
Nucleo stellare	Stellar core
Parallasse	Parallax
Protostella	Protostar
Sequenza principale	Main sequence
Spettro	Spectrum
Spettroscopia	Spectroscopy
Stella	Star
Stella di neutroni	Neutron star
Supergigante	Supergiant
Supernova	Supernova
Temperatura	Temperature
Zona convettiva	Convective zone
Zona radiativa	Radiative zone

STARS-DURING

Stars Video

Intro

"Here you will study some important aspects of the stars: what they are, how they are formed, their life cycle, their classification and the importance of spectroscopy in this field. We'll show you how to build a spectroscope in the laboratory with inexpensive, easy-to-find materials: a necessary tool to study the chemical nature and the age of a star."

History of Observations

Astronomy — the study of the heavens — may be the most ancient of the sciences, present since the dawn of recorded civilization, with the stars often playing a key role in religion and proving vital to navigation. The invention of the telescope and the discovery of the laws of gravitational motion in the 17th century prompted the realization that stars were just like the Sun, all obeying the same laws of physics. In the 19th century, photography and spectroscopy (which studies the wavelengths of light that objects emit) made it possible to investigate the composition of stars from afar, leading to the development of astrophysics.

In 1937, the first radio telescope was built, enabling astronomers to detect otherwise invisible radiation from stars. In 1990, the first space-based optical telescope was launched, the Hubble Space Telescope, providing the deepest, most detailed visible-light view of the Universe.

Naming Designations

Ancient cultures saw patterns in the heavens that resembled people, animals or common objects — constellations that came to represent figures from myth, such as Orion the Hunter, a hero in Greek mythology. Astronomers now often use constellations in the naming of stars, with the International Astronomical Union, the world authority for assigning names to celestial objects, officially recognizing 88 constellations that cover the entire sky. Usually, the brightest star in a constellation has “alpha”, the first letter of the Greek alphabet, as part of its scientific name. The second brightest star in a constellation is typically designated “beta”, the third brightest “gamma”, and so on until all the Greek letters are used, after which numerical designations follow.

From Hipparchus to Hipparcos: Measuring the Universe, One Star at a Time

Hipparchus of Nicaea must have been an interesting fellow. He was a second-century B.C. mathematician, philosopher and astronomer. Using the only astronomical instrument available to him — his eyes — Hipparchus took on the daunting task of measuring the positions of the stars and planets as they passed overhead each night.

He came up with a catalogue of 1,080 stars, each of which he described simply as "bright" or "small." Hipparchus wasn't the first astronomer to pursue the science of astrometry, as the astronomical discipline of positional measurement is now called. However, his star catalogue was the first of many compiled over the centuries by astronomers using ever-better instruments and techniques. From those measurements — all made from the Earth's surface — astronomers have derived everything from basic stellar properties to estimates of the age of the Universe. On August 8, 1989, the science of astrometry took a long-awaited leap to the stars. Riding aboard an Ariane rocket was the High Precision Parallax Collecting Satellite, otherwise known as Hipparcos. For the next three and a half years, Hipparchus's 20th-century namesake measured the parallax and brightness of more than a million stars, despite a potentially crippling accident that sorely challenged the project's architects.

What Is a Star?

A star is a huge sphere of very hot, glowing gas. Stars produce their own light and energy by a process called nuclear fusion. Fusion happens when lighter elements are forced to become heavier elements. When this happens, a tremendous amount of energy is created, causing the star to heat up and shine. Stars come in a variety of sizes and colours. Our Sun is an average-sized yellowish star. Stars that are smaller than our Sun are reddish and larger stars are blue.

Stellar Structure

The structure of a star can often be thought of as a series of thin concentric shells, somewhat like an onion. A star during most of its life is a main-sequence star, which consists of a core, radiative and convective zones, a photosphere, a chromosphere and a corona. The core is where all the nuclear fusion takes place to power a star. In the radiative zone, energy from these reactions is transported outward by radiation, like heat from a light bulb, while in the convective zone energy is transported by the boiling hot gases, like hot air from a hairdryer. Massive stars that are more than several times the mass of the Sun are convective in their cores and radiative in their outer layers, while stars comparable to the Sun or less in mass are radiative in their cores and convective in their outer layers. Intermediate-mass stars of spectral type A may be radiative throughout. After those zones comes the part of the star that radiates visible light, the photosphere, which is often referred to as the surface of the star.

After that is the chromosphere, a layer that looks reddish because of all the hydrogen found there. Finally, the outermost part of a star's atmosphere is the corona, which, if super-hot, might be linked with convection in the outer layers.

Stars: Formation

The stellar nursery is a nebula consisting of collapsing clouds of interstellar gas and dust. A star develops from a giant, slowly rotating cloud that is made up entirely or almost entirely of hydrogen and helium. Due to its own gravitational pull, the cloud begins to collapse inward, and as it shrinks, it spins more and more quickly, with the outer parts becoming a disk while the innermost parts become a roughly spherical clump. This collapsed material is hot and dense, forming a ball-shaped protostar. When the heat and pressure in the protostar reach about 1 million °C, atomic nuclei that normally repel each other start fusing together, and the star ignites. Nuclear fusion converts a small amount of the mass of these atoms into extraordinary amounts of energy: for instance, 1 gram of mass converted entirely to energy would be equal to an explosion of roughly 22,000 tons of TNT.

The Evolution Path

The life cycles of stars follow patterns based mostly on their initial mass. These include intermediate-mass stars such as the Sun, with 0.5 to 8 times the mass of the Sun; high-mass stars that are more than 8 solar masses; and low-mass stars 0.1 to 0.5 solar masses in size. Generally, the greater a star's mass, the shorter its lifespan. Objects smaller than a tenth of a solar mass do not have enough gravitational pull to ignite nuclear fusion — some might become failed stars known as brown dwarfs.

Sun-Like Stars

An intermediate-mass star begins with a cloud that takes about 100,000 years to collapse into a protostar with a surface temperature of about 3,725 °C.
After hydrogen fusion starts, the result is a T Tauri star, a variable star that fluctuates in brightness.
This star continues to contract for roughly 10 million years until its expansion due to energy generated by nuclear fusion is balanced by its contraction due to gravity, after which point it becomes a main-sequence star that gets all its energy from hydrogen fusion in its core.

Red Giant

The greater the mass of such a star, the more quickly it will use its hydrogen fuel and the shorter it stays on the main sequence. After all the hydrogen in the core is fused into helium, the star changes rapidly — without nuclear pressure to resist it, gravity immediately crushes matter down into the star's core, quickly heating the star. This causes the star's outer layers to expand enormously and to cool and glow red as they do so, rendering the star a red giant. Helium starts fusing in the core, and once the helium is gone, the core contracts and becomes hotter, once more expanding the star but making it bluer and brighter than before, blowing away its outermost layers.

Planetary Nebula

Planetary nebulae are created when some stars, usually at the end of their lives, emit a large amount of gas, forming bubbles (or cones) of gas. The central star emits sufficient radiation to keep the ejected gas hot enough to reissue light. Despite its name, it has nothing to do with planets; such terminology was invented because, when viewed with a small telescope at low magnification, these objects appear like small planets. A typical planetary nebula has a diameter of less than one light-year.

White Dwarf

After the expanding shells of gas fade, the remaining core is left: a white dwarf that consists mostly of carbon and oxygen, with an initial temperature of roughly 180,000 °F (100,000 °C).

Black Dwarf

A black dwarf is the final stage in the life of a star with a mass comparable to that of the Sun. It follows the white dwarf stage, where the star has exhausted all its heat through radiation.
Since white dwarfs have no fuel left for fusion, they grow cooler and cooler.
In fact, it is estimated that to exhaust all the heat of a white dwarf, tens of billions of years are required. This time period is far greater than the age of the Universe, currently estimated to be about 13.8 billion years.
For this reason, the black dwarf stage remains theoretical, since no star has yet had the time to complete this evolutionary path.

High-Mass Stars

A high-mass star forms and dies quickly. These stars form from protostars in just 10,000 to 100,000 years. While on the main sequence, they are hot and blue, some 1,000 to 1 million times as luminous as the Sun and roughly 10 times wider.

Supergiant

When they leave the main sequence, they become bright red supergiants and eventually become hot enough to fuse carbon into heavier elements. After some 10,000 years of such fusion, the result is an iron core roughly 3,800 miles wide (6,000 km); since any further fusion would consume energy instead of releasing it, the star is doomed, as nuclear pressure can no longer resist the force of gravity.

Supernova

When the iron core of such a star reaches a mass of about 1.4 solar masses, the result is a supernova. Gravity causes the core to collapse, making the core temperature rise to nearly 10 billion °C, breaking the iron down into neutrons and neutrinos. In approximately one second, the core shrinks to about six miles (10 km) wide and rebounds like a compressed spring, sending a shock wave through the star that causes fusion to occur in the outer layers. The star then explodes in a so-called Type II supernova.

Neutron Star

If the remaining stellar core is less than roughly three solar masses, it becomes a neutron star made up nearly entirely of neutrons. Rotating neutron stars that emit detectable radio pulses are known as pulsars.

Black Hole

If the stellar core is larger than about three solar masses, no known force can support it against its own gravitational pull, and it collapses to form a black hole.

Modern Classification of Stars

Stars are typically classified by their spectrum in what is known as the Morgan–Keenan or MK system.
There are eight spectral classes, each corresponding to a range of surface temperatures — from the hottest to the coldest, these are O, B, A, F, G, K, M, and L.
Each spectral class also consists of 10 spectral types, ranging from the numeral 0 for the hottest to the numeral 9 for the coldest.
Stars are also classified by their luminosity under the Morgan–Keenan system.
The largest and brightest classes of stars have the lowest numbers, given in Roman numerals:

Ia is a bright supergiant; Ib, a supergiant; II, a bright giant; III, a giant; IV, a subgiant; and V, a main-sequence star or dwarf.
A complete MK designation includes both spectral type and luminosity class — for instance, the Sun is a G2V star. These designations, often followed by additional catalogue numbers, can be found in star catalogues that reproduce the constellations (see our constellation overview).

Physical Parameters

1. Brightness
   Astronomers describe star brightness in terms of magnitude and luminosity.
2. Colour
   Stars come in a range of colours, from reddish to yellowish to blue. The colour of a star depends on its surface temperature.
3. Surface Temperature
   Astronomers measure star temperatures in a unit known as the kelvin (K), with a temperature of 0 K equalling −273.15 °C. A dark red star has a surface temperature of about 2,500 K (2,225 °C); a bright red star, about 3,500 K (3,225 °C); the Sun and other yellow stars, about 5,500 K (5,225 °C); a blue star, about 10,000 K (9,725 °C) to 50,000 K (49,725 °C).
4. Mass
   Astronomers represent the mass of a star in terms of the solar mass, the mass of our Sun. For instance, Alpha Centauri A is 1.08 solar masses.

Stars with similar masses might not be similar in size because they have different densities. For instance, Sirius B is roughly the same mass as the Sun but is 90,000 times as dense and so is only a fiftieth of its diameter.
The mass of a star affects its surface temperature.

Modern Classification: The H-R Diagram

"*Oh, Be A Fine Girl/Guy, Kiss Me*" (classes from the hottest to the coolest stars: O, B, A, F, G, K, M).
The Hertzsprung-Russell, or simply H-R, diagram plots star colour along the horizontal axis and luminosity along the vertical axis. This allows us to see at a glance a star's surface temperature and brightness, as well as compare these two important properties with those of other stars on the chart.
Over a hundred years ago, astronomers started to classify stars according to their colour. Letters of the alphabet were assigned to each type, but as new information accumulated, this system took on a sequence that is not at all like the alphabet. Harvard astronomers put their collective foot down, and a colour assignment was agreed upon.
Very hot stars, like Rigel, were given the letter B. All B-type stars have a bluish-white colour.
White stars, like Sirius, were a little cooler and given the letter A.
Next came a group of yellowish stars with a hint of white. These were assigned the letter F.
These star types are rare and have some unusual qualities (often involving details of their "absorption spectra"). Each of these "colour classes" is split into ten subclasses, numbered 0 to 9. For example, our Sun is classified as G2, so it is slightly hotter and less yellow than Capella, which is a G8 star.

What Is Spectroscopy?

Spectroscopy is the study of the interaction between matter and radiated energy.
Historically, spectroscopy originated through the study of visible light dispersed according to its wavelength, for example by a prism.
Later, the concept was greatly expanded to include any interaction with radiative energy as a function of its wavelength or frequency.
Spectroscopic data are often represented by a spectrum, a plot of the response of interest as a function of wavelength or frequency.
(Voice and reading here: https://luvvoice.com/it)

KEYWORDS

1) Which of the following terms are associated with the life cycle of a Sun-like star:
brown dwarf – red dwarf – blue giant – red supergiant – yellow dwarf – red giant – neutron star – black hole – white dwarf

Solutions:
yellow dwarf – red giant – white dwarf

2) Select the elements involved in nucleosynthesis in the core of a low-mass star:
hydrogen – carbon – oxygen – helium – calcium – nitrogen – iron

Solutions:
hydrogen – helium – carbon – oxygen

STARS-AFTER
DRILLS

Multiple Choice
Select the single correct choice to make natural sentences.
1. Stars produce energy through a process called:
a. combustion
b. nuclear fission
c. nuclear fusion
d. radiation

2. The Sun is classified as a:
a. red giant
b. blue supergiant
c. yellow main-sequence star
d. white dwarf

3. The final stage of a Sun-like star is:
a. neutron star
b. black hole
c. supernova
d. white dwarf

4. In the H-R diagram, luminosity is plotted on the:
a. horizontal axis
b. vertical axis
c. diagonal axis
d. lower axis

5. Massive stars may end their lives as:
a. planetary nebulae
b. brown dwarfs
c. neutron stars or black holes
d. red dwarfs

Matching

Match the words on the left with the correct definition on the right.

Protostar	a) Final stage of a low-mass star
Red giant	b) Explosion of a massive star
White dwarf	c) Early stage of star formation
Supernova	d) Expanded phase of a Sun-like star
Main sequence	e) Stable phase with hydrogen fusion in the core

True or False

State if the following sentences are True or False.

1. Blue stars are hotter than red stars.
2. The Sun is a supergiant star.
3. A black dwarf is a theoretical final stage of a white dwarf.
4. Spectroscopy allows astronomers to study the composition of stars.

Cloze

To complete the text, use the correct words from the list:

helium – gravity – main sequence – hydrogen – supernova – white dwarf

Stars are formed from clouds of gas and dust called nebulae. Due to _____[1], the cloud collapses and forms a protostar. When nuclear fusion begins, _____[2] nuclei fuse together to form _____[3]. The star then enters the stable phase known as the _____[4]. A Sun-like star will eventually become a red giant and finally a _____[5], while a massive star may explode as a _____[6].

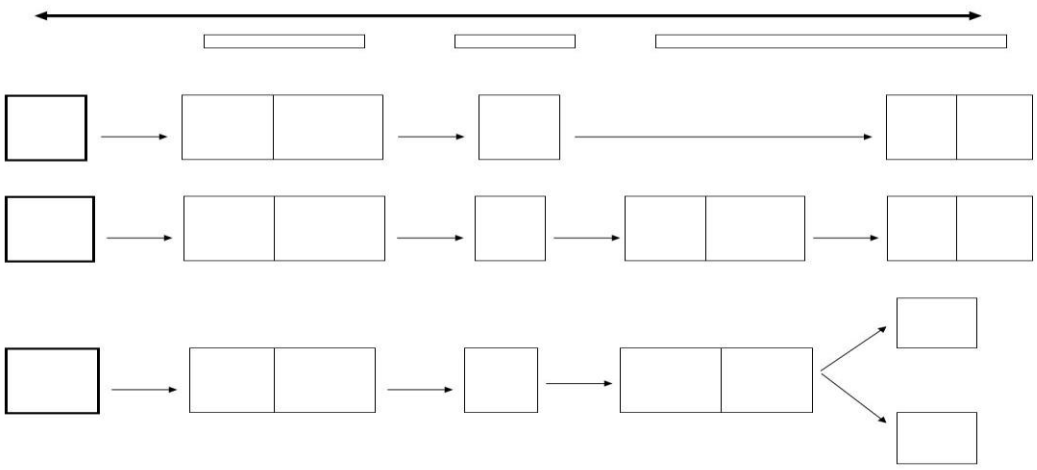
Solutions:

Multiple Choice: 1c, 2c, 3d, 4b, 5c
Matching: Protostar–c; Red giant–d; White dwarf–a; Supernova–b; Main sequence–e
True / False: 1T, 2F, 3T, 4T
Cloze: 1 gravity; 2 hydrogen; 3 helium; 4 main sequence; 5 white dwarf; 6 supernova

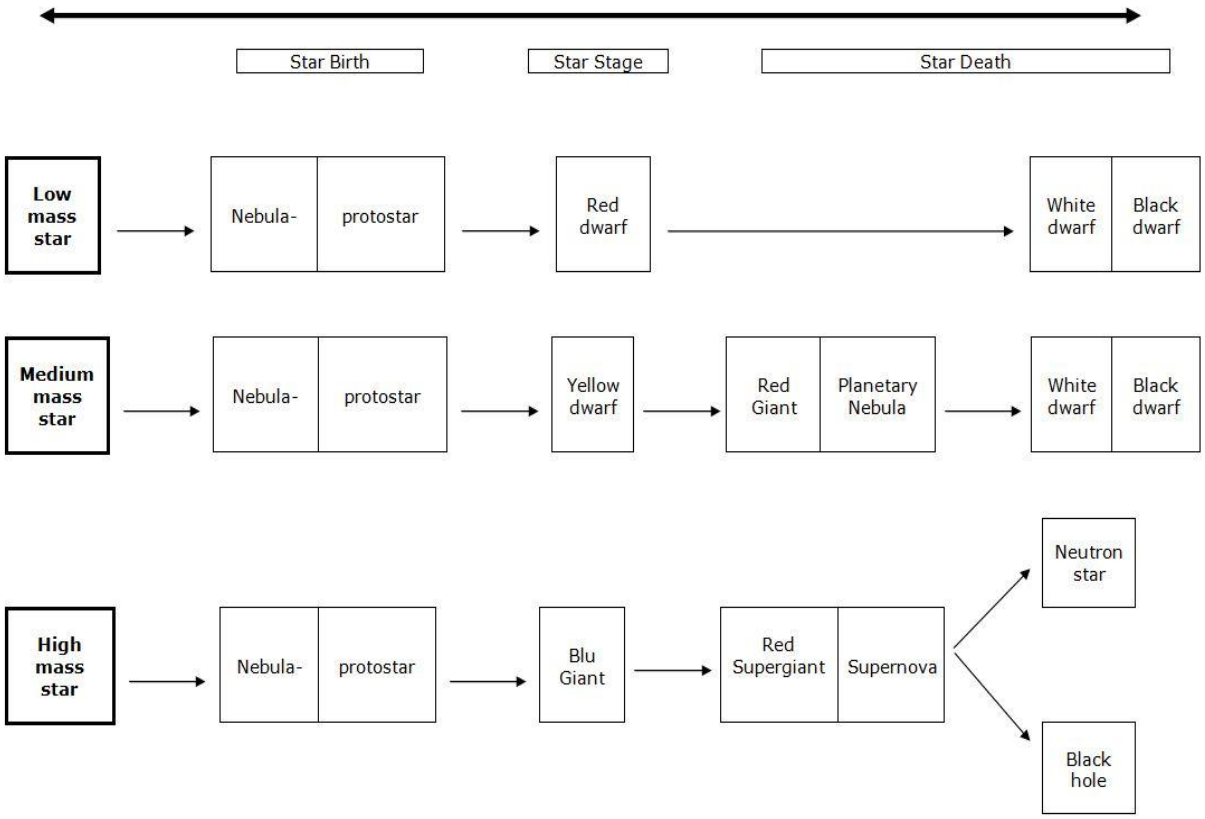
Flow Chart

Star Lyfe Cycle Flow Chart Directions:

1. Inside each box draw a simple illustration of each step in the life cycle for each star mass (low, medium, high).
2. Underneath each box label the name of each step in the life cycle.
3. Label the line across the top to indicate Star Birth, Star Stage and Death.



Solutions:



Think and Discuss

The following activities can be performed in written or oral form. The teacher will choose the method depending on the skills (writing, speaking, interacting) to be developed.
The task will be presented to the students in the following contexts:
A) The student writes an article about spectroscopy.
B) The student prepares for an interview on a local TV program about spectroscopy.
The student should:

1. Choose one of the following topics:

- Describe the properties of white light and its decomposition into component colours when passing through a prism or a diffraction grating.
- Relate the dark lines of a light spectrum to the presence of specific chemical elements.
- Explain the importance of spectroscopy for the study of the physical properties of stars.

2. Prepare an article or presentation outlining the main points of the chosen topic, based on what has been studied.
3. For the written activity, the student should produce an article, specifying the target audience and the type of magazine, newspaper or school publication in which the article would appear.
4. For the oral activity, the student should present their point of view on the chosen topic to the whole class. A debate may follow the presentation.

Compendium

Astrophysics is a branch of astronomy that deals with the physical nature of heavenly bodies, including their chemical composition, light and temperature. Astrophysicists use many of the principles and theories of physics.
Astrophysicists analyse the light collected by telescopes. One of the most important tools they use is the spectroscope, a device that produces a spectrum.
For example, the Sun's spectrum consists of a bright band of colours ranging from violet to red, crossed by dark lines. By analysing a spectrum, astrophysicists can determine the temperature and chemical composition of the surface of the Sun or a star.
When surface conditions are known, astrophysicists can calculate how temperature, pressure and density increase towards the centre by applying the principles of theoretical physics.
The main source of energy of all stars comes from nuclear reactions that convert hydrogen nuclei into helium nuclei. In red giants, helium is converted into carbon and oxygen. In the cores of red supergiants, iron may be produced before the stars explode as supernovae.
Another important theoretical investigation concerns the past history and future evolution of stars.

1) Answer the following questions.

The answers can be given in written or oral form, depending on the teacher's objectives.

A) In the core of a main-sequence star, hydrogen nuclei undergo nuclear fusion and are converted into helium nuclei.
A.1) What elements are involved in this process?

B) Describe the work carried out by astrophysicists.

C) What information can be obtained from the analysis of a spectrum?

D) What elements are produced in red giants and in red supergiants?

E) What is the main source of energy of stars?

2) Write a short abstract of the Compendium (maximum 150 words) highlighting the main points about astrophysics and the study of stars.

Problem Solving

The following activities can be carried out at school, if a computer room is available, or at home. Students are invited to use the web references listed above.

1) *Individual activity*
Choose one of the following roles and write your report.
a) You are an astronomer writing an article titled: "What Is the H-R Diagram?"
b) You are an astronomer working in an astrophysics laboratory. Write an article on the most widely accepted theory about the evolution of stars.
c) You are an astrophysicist writing an article on the nuclear reactions in the Sun's core.

2) *Small group activity*
Choose one of the following topics, create a PowerPoint presentation, and present it to your classmates.
Topics:

a) Choose a type of main-sequence star and explain its physical characteristics.
b) Explain why the fate of a star depends on its mass.
c) Explain the importance of spectroscopy in astronomy.

3) *Class project*
Prepare a poster and a brochure explaining how the life cycle of stars works. You can display the poster at school and distribute copies of the brochure to your schoolmates and friends.

Materiale sviluppato da eniscuola nell'ambito del protocollo d'intesa con il MIUR
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