MACROMOLECULES IN THE BIOLOGICAL SYSTEM

Elias Narciso Matos, Ph.D.
Foreword

The African Virtual University (AVU) is proud to participate in increasing access to education in African countries through the production of quality learning materials. We are also proud to contribute to global knowledge as our Open Educational Resources (OERs) are mostly accessed from outside the African continent. This module was prepared in collaboration with twenty one (21) African partner institutions which participated in the AVU Multinational Project I and II.

From 2005 to 2011, an ICT-integrated Teacher Education Program, funded by the African Development Bank, was developed and offered by 12 universities drawn from 10 countries which worked collaboratively to design, develop, and deliver their own Open Distance and e-Learning (ODeL) programs for teachers in Biology, Chemistry, Physics, Math, ICTs for teachers, and Teacher Education Professional Development. Four Bachelors of Education in mathematics and sciences were developed and peer-reviewed by African Subject Matter Experts (SMEs) from the participating institutions. A total of 73 modules were developed and translated to ensure availability in English, French and Portuguese making it a total of 219 modules. These modules have also been made available as Open Educational Resources (OER) on oer.avu.org, and have since then been accessed over 2 million times.

In 2012 a second phase of this project was launched to build on the existing teacher education modules, learning from the lessons of the existing teacher education program, reviewing the existing modules and creating new ones. This exercise was completed in 2017.

On behalf of the African Virtual University and our patron, our partner institutions, the African Development Bank, I invite you to use this module in your institution, for your own education, to share it as widely as possible, and to participate actively in the AVU communities of practice of your interest. We are committed to be on the frontline of developing and sharing open educational resources.

The African Virtual University (AVU) is a Pan African Intergovernmental Organization established by charter with the mandate of significantly increasing access to quality higher education and training through the innovative use of information communication technologies. A Charter, establishing the AVU as an Intergovernmental Organization, has been signed so far by nineteen (19) African Governments - Kenya, Senegal, Mauritania, Mali, Cote d’Ivoire, Tanzania, Mozambique, Democratic Republic of Congo, Benin, Ghana, Republic of Guinea, Burkina Faso, Niger, South Sudan, Sudan, The Gambia, Guinea-Bissau, Ethiopia and Cape Verde.

The following institutions participated in the teacher education program of the Multinational Project I: University of Nairobi – Kenya, Kyambogo University – Uganda, Open University of Tanzania, University of Zambia, University of Zimbabwe – Zimbabwe, Jimma University – Ethiopia, Amoud University - Somalia; Université Cheikh Anta Diop (UCAD)-Senegal, Université d’ Antananarivo – Madagascar, Universidade Pedagogica – Mozambique, East African University - Somalia, and University of Hargeisa - Somalia.
The following institutions participated in the teacher education program of the Multinational Project II: University of Juba (UOJ) - South Sudan, University of The Gambia (UTG), University of Port Harcourt (UNIPORT) – Nigeria, Open University of Sudan (OUS) – Sudan, University of Education Winneba (UEW) – Ghana, University of Cape Verde (UniCV) – Cape Verde, Institut des Sciences (IDS) – Burkina Faso, Ecole Normale Supérieure (ENSUP) - Mali, Université Abdou Moumouni (UAM) - Niger, Institut Supérieur Pédagogique de la Gombe (ISPG) – Democratic Republic of Congo and Escola Normal Superieur Tchicote – Guinea Bissau

Bakary Diallo

The Rector

African Virtual University
Production Credits

This second edition is the result of the revision of the first edition of this module. The informations provided below, at the exception of the name of the author of the first edition, refer to the second edition.

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1. INTRODUCTION

1. Title of Module

Module Developer Writing Tip. The title of the module is provided by AVU.

2. Prerequisite Courses or Knowledge

Module Developer Writing Tip. Module Developers should specify the prerequisite courses or knowledge required in order for learners (preservice teachers) to start the module.

The student must possess knowledge of the basic contents covered in chemistry curriculum and, in particular topics concerning modules 5, 6, 7, mainly.

- Notion of isomerism and of stoichiometry
- Structure and reactivity of Aldehydes and Ketones
- Structure and reactivity of Amino acids
- Concept of Aromatics and heterocyclic

3. Time

Module Developer Writing Tip. In this section, Module Developers should approximate how much time (total in hours) is required to complete the module.

120 hours, PLEASE DIVIDE THIS INTO TIME REQUIRED FOR EACH UNIT OR LEARNING ACTIVITY

<table>
<thead>
<tr>
<th>Unit</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>GLUCIDS</td>
<td>40</td>
</tr>
<tr>
<td>PROTEINS</td>
<td>40</td>
</tr>
<tr>
<td>LIPIDS</td>
<td>30</td>
</tr>
<tr>
<td>Practical Activity</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>120</td>
</tr>
</tbody>
</table>

4. Material

Module Developer Writing Tip. In this section, Module Developers should specify the materials required to complete the module.

Module 8 (macromolecules in the biological system) is based on the following learning material: chemistry school books, chemistry educational software, virtual computerised experiments, simple experiments, textbooks and manuals.
Module Developer Writing Tip. In this section, Module Developers should specify the main rationale for the module. A good rationale will clearly present why learners (preservice teachers) will better teach the subject matter having completed the module (maximum length: 50-75 words).

This module introduces the study of some representative compounds of macromolecular nature which are vital for the balance, development, maintenance, and supplement of living organisms.

The module solidifies and extends knowledge obtained from previous modules mainly on Aldehydes, Ketones and amino acids, linking them to the organism’s vital functions. The study on the contents of this module will give knowledge about properties and the activity of some of the main macromolecules for the survival of organisms.

II. CONTENT

6. Overview

Module Developer Writing Tip. In this section, Module Developers should first write an overview of the module. An overview briefly presents the content of a module in paragraph form (maximum length: 100-150 words). The Module Developers will also be briefly interviewed (videotaped) to present the overview of the module. This video file (Quicktime, .mov) will be included with this section of the module.

Second, the overview must also be accompanied by a clear outline of the content. Contrary to an overview, an outline is not a continuous text, it presents the content of the module in point form, and includes the approximate time required to complete each unit, element or theme (the total time must be equal to the time indicated in section 3 above. An outline could take the form of a table of contents for the module. The OUTLINE must also include UNITS (with the appropriate time). Each module should be divided into 4 to 6 UNITS. UNITS help the instructor or the learner break down the content of a module into sections.

Third, Module Developers should draw a graphic organizer - a graphical way of organizing information so it can be better understood and retained. They are powerful tools in open and distance education that can be used to enhance learning. For more information on graphic organizers, see Annex 1 or consult eduplace (http://www.eduplace.com/graphicorganizer/) for examples of graphic organizers (Annex 2).

Overview

WHAT DOES THE MODULE LOOK LIKE IN THE BIG PICTURE (IN PROSE)?

The present module 8 (macromolecules in the biological system) is made up of four units they are: Carbohydrates, Proteins, Lipids, and finally practical activities.

Each unit states and analyses the basic knowledge about the structure, nomenclature and synthesis, as well as the chemical and physical macromolecular properties with biological significance.
In the practical components, the module offers training on how to handle basic laboratory equipment and/or computer simulated exercises about techniques for synthesizing, separating, purifying and determination of physical constants of the compound.

The module has the duration of a total of 120 hours.

Graphic Organizer (can be drawn manually)

WHAT IS THE FLOW OF THE MODULE, MAP OUT A LEARNER’S PROGRESSION THROUGH THE UNITS.

![Flowchart Diagram]

WHAT IS THE FLOW OF THE MODULE, MAP OUT A LEARNER’S PROGRESSION THROUGH THE UNITS.

<table>
<thead>
<tr>
<th>Unit #</th>
<th>Name</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit I :</td>
<td>Glucids</td>
<td>40</td>
</tr>
<tr>
<td>Unit II:</td>
<td>Proteins</td>
<td>40</td>
</tr>
<tr>
<td>Unit III:</td>
<td>Lipids</td>
<td>30</td>
</tr>
<tr>
<td>Unit IV:</td>
<td>Experimental activity</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>120</td>
</tr>
</tbody>
</table>

7-General Objective(s)

Module Developer Writing Tip. In this section, Module Developers should outline the general objective(s) of the module, as specified in the curriculum. Writing clear, informative, concise and understandable objectives is extremely important in an Open and Distance Learning Module.

Module 8 (macromolecules in the biological system) offers the basic fundamentals about the main theoretical and practical aspects of macromolecule chemistry.
This module systematically discusses some of the main classes of organic macromolecular compounds of vital importance for the living organisms, they are: Carbohydrates (Glucids), Proteins and Lipids.

This module also analyzes the relation between the structures, properties, reactivity, and the physical-chemical behavior of the organic compounds of great molecular weight.

Studying the module will deepen the knowledge about organic compounds and help establish a correlation between structure of matter and its properties.

Develops the ability to make critical observation, and reasoning permitting thus the best application and/or usage of these compounds.

8. Specific Learning Objectives (Instructional Objectives)

Module Developers Writing Tip. In this section, Module Developers should identify the specific learning objectives for each unit, element or theme of the module. Each specific objective will be at the heart of a teaching and learning activity. Writing clear, informative, concise and understandable objectives is extremely important in an Open and Distance Learning Module.

Clear, concise, informative and well-written objectives help learners organize their efforts. Objectives provide some basis and guidance for the selection of instructional content and procedures. Finally, they also help the instructor (or evaluator) assess the extent to which a learner masters an objective.

Many researchers present four characteristics essential to writing learning objectives:

- A good learning objective is clear and concise, leaving little room for interpretation.
- A good learning objective always states what a learner is expected to achieve.
- A good learning objective describes, when possible, the conditions under which a learner must perform a task.
- A good learning objective, when possible, clarifies how well the student must perform a task, in order for the performance to be acceptable.

Attached, is Bloom’s taxonomy (Annex 3). It provides useful verbs that can be used to write learning objectives which relate either to cognitive, affective, or psychomotor domains.

Module Developers must also complete the table below in which all units are clearly linked to one specific learning objective.

SPECIFIC, MEASURABLE, ATTAINABLE/REALISTIC, TIME-BOUND OBJECTIVES FOR EACH UNIT (IN POINT AND TABLE FORM)

Provide the student with theoretical knowledge about Carbon compounds of great molecular weight with biological importance, revealing its coherence, obtain its physical properties and its reactivity, mainly of the Glucids, the proteins and the lipids.

Be able to handle basic laboratory equipment for a laboratorial research, and know the techniques to synthesize, separate, purify and determine physical constants of organic compounds. Offer macromolecular compounds simulations.
<table>
<thead>
<tr>
<th>Unit</th>
<th>Learning objective(s)</th>
</tr>
</thead>
</table>
| 1. Glucids (Carbohydrates) | At the end of the unit the student should be able to:  
- Describe the structure of Carbohydrates  
- Classify the carbohydrates  
- Attribute names to carbohydrates using the nomenclature of IUPAC  
- Know the chemical and physical properties of carbohydrates and its correlations  
- Know the method of production and identification  
- Know the stereochemistry in Glucids, as well as phenomenon involved in the spatial disposition of these molecules  
- Discuss the relation between structure and properties based on simple examples |
| 2. Proteins | At the end of the unit the student should be able to:  
- Know the structure and properties of the essential amino acids  
- Know the structure of the peptides  
- Describe the peptide bond  
- Know the structure of proteins  
- Differentiate the protein structures and their functions (primary, secondary, tertiary)  
- Describe the structure and function of some Proteins e Nucleotides (DNA, RNA)  
- Know the methods of production |
3. Lipids

At the end of the unit the student should be able to:
- Know the general structure of lipids
- Classify lipids (saturated and non-saturated)
- Interrelate the structure and properties of the fatty acids
- Know the physical and chemical structure of lipids
- Know the sources of production and identification

4. Practical Activity

At the end of the unit the student should be able to:
- Identify the carbons in the carbohydrates
- Exercise carbohydrates’ properties
- Identify the Proteins
- Identify the Properties of Lipids

III. TEACHING AND LEARNING ACTIVITIES

9. Pre-assessment

Module Developer Writing Tip. It is generally agreed that there are three important types of assessments in Open and Distance Learning:

- pre-assessment;
- formative assessment;
- summative assessment.

In this Module Developer Writing Tip, we will discuss pre-assessments.

Pre-assessments are required to highlight the learner’s mastery level of the learning objectives. A pre-assessment always has more to do with helping students learn than with underlining their mistakes. Pre-assessments allow both the learner and the instructor to determine what is already known by the learner in a specific domain. Pre-assessment is also critical to recognize prior knowledge so learners can engage fully in the learning activity in order to construct new knowledge appropriate to their level.
Here are some of the benefits of pre-assessing as identified by Kingore (2004):

1. Pre-assessment can motivate students to be more involved in, and attentive to, instruction and learning experiences as the pre-assessment helps more clearly identify what they know and what they need to know.

2. Pre-assessment appropriately raises the learners’ level of concern by signaling what they need to learn.

3. Pre-assessment helps avoid boredom; students are more mentally engaged when the learning is directly relevant to their needs and interesting to them.

4. Pre-assessment saves instruction time when teachers do not re-teach what students already know.

5. Pre-assessment enables teachers to form appropriate flexible groups—a key principle of a differentiated classroom.

6. Pre-assessment supports the use of compacting and tiered instruction to match students’ readiness.

7. Pre-assessment allows students to demonstrate and get credit for the concepts and skills previously mastered.

To make sure that all modules have the same structure, Module Developers should use a 20-question, multiple-choice, pre-assessment that briefly skims the most important content of the module. The answer key also needs to be provided, as well as pedagogical comments for learners.

**Title of pre-assessment-** Macromolecules in the biological system

**Rationale:** The worksheet evaluates the basic knowledge on organic chemistry, as well as solid knowledge of the contents of modules 5, 6, 7 indispensable to the success of the work in the present module.

**Questions**

1. Glucids or Carbohydrates are:
   a. Compounds made up of only carbon and hydrogen
   b. Compounds that contain water
   c. Aldehydes and Ketones containing Polyhydroxyl group
   d. Compounds of the family of fats
2. Chemically fats are:
   a. Esters of glycerol with fatty acids
   b. Esters of superior alcohols with fatty acids
   c. Aldehydes of great molecular weight
   d. Acids of great molecular weight

3. Proteins are compounds made up of:
   a. Units of glucose linked by glycosidic linkage
   b. Units of amino acids linked by peptide bond
   c. Units of monosaccharide linked by glycosidic linkage
   d. Products of the decomposition of polysaccharides

4. Fatty acids are:
   a. Acids with many ramifications
   b. Acids of fat people
   c. Acids of great molecular weight
   d. Carboxylic acids

5. Glycosidic linkage occurs between
   a. Fats
   b. Units of Amino acids
   c. Units of monosaccharide
   d. Proteins

6. The bonds between organic compounds are mainly:
   a. Ionic
   b. Covalent
   c. Metallic
   d. Dipole-dipole

7. Peptide bond occurs between:
   a. Fats
   b. Units of amino acids
   c. Units of monosaccharide
   d. Proteins
8. Polysaccharides are made up of:
   a) Thousands of units of acids linked by Glycosidic linkage
   b) Thousands of units of amino acids linked by peptide bonds
   c) Thousands of units of monosaccharide linked by Glycosidic linkage
   d) Thousands on units of amino acids linked by peptide bonds

9. Isomerism is the phenomenon of:
   a. Existence of molecules with the same molecular mass
   b. Molecules absorbing all light
   c. Molecules with the same composition but different structures
   d. Molecules differing in one segment constituted by one atom of carbon and two atoms of hydrogen.

10. Asymmetrical carbon is:
    a. Central Carbon
    b. Carbon with four different bonds
    c. Carbon with two double bonds
    d. Carbon in heterocyclics

11. Glucose is:
    a. Aldose
    b. Ketose
    c. Pentose
    d. Hexoketose

12. Fructose is:
    a) Aldose  b) Ketose
    c) Pentose
    d) Hexoaldose

13. In sugars the carbon atom that determines the series is:
    a. The closest to the main functional group
    b. The farthest from the main functional group
    c. The central atom
    d. None of the above
14. Reducing sugars are:
   a) The easily soluble
   b) The ones with a free functional group
   c) The sweetest
   d) The ones that do not have a free functional group

15. Oils are:
   a. Esters of glycerol and saturated fat acids
   b. Esters de glycerol and unsaturated fat acids
   c. Esters de superior alcohols and saturated fat acids
   d. Esters de superior alcohols and saturated fat acids

16. Waxes are:
   a) Esters of glycerol and saturated fat acids
   b) Esters of glycerol and unsaturated fat acids
   c) Esters of superior alcohols and saturated fat acids
   d) Esters of superior alcohols and saturated fat acids

17. Enantiomers are isomers:
   a) – Which differ on the position of the central atom
   b) – Which rotates the light in the same magnitude but in opposite direction
   c) – Which differ on the position of one hydrogen central atom
   d) – Which rotates the light in different magnitude but the same direction

18. Glycosidic linkage:
   a) Bond between Amino and carboxyl groups
   b) Between two Amino groups
   c) Between carboxyl and hydroxyl groups
   d) Between two monosaccharides

19. 19. A typical bond in proteins is:
   a) Glycoside
   b) Peptide
   c) Acetalic
   d) None of the above
20. Cellubiose is:
   a) Monosaccharide
   b) Disaccharide
   c) Polysaccharide
   d) None of the above

Title of pre-assessment: Macromolecules in the biological system

Answer key

1. Glucids or carbohydrates are:
   c) – Polyhydroxyl Ketones and Aldehydes
2. Fats chemically are:
   a) – Esters of glycerol and fat acids
3. Proteins are compounds made up of:
   b) Units of Amino acids bonded by peptide bond
4. Fatty acids are:
   c) – Acids of great molecular weight
5. Glycosidic linkage occurs between:
   c) – Units of monosaccharide
6. Bonds in organic compounds are mainly:
   b) – Covalent
7. Peptide bonds happen between:
   b) Units of amino acids
8. Polysaccharides are made up of:
   c) Thousands of monosaccharide units bonded by glycosidic linkage.
9. Isomerism is the occurrence of:
   c) – Existence of molecules with the same composition but different structures
10. Asymmetrical carbon is:
    b) – Carbon with four different bonds
11. Glucose is:
    a) – Aldose
12. Fructose is:
   b) – Ketose

13. In sugars the carbon atom that determines the series is:
   b) – The farthest from the main functional group

14. Reducing sugars are:
   b) – The ones that have a free functional group

15. Oils are:
   b) – Esters of glycerol and unsaturated fat acids

16. Waxes are:
   c) – Esters of superior alcohols and saturated fat acids

17. Enantiomers are isomers:
   b) – Which rotates the light in the same magnitude but in opposite directions

18. Glycosidic linkage in Proteins is:
   d) – Between two monosaccharide

19. The typical bond in a protein is:
   b) – Peptide

20. Cellubiose is:
   b) – Disaccharide

Title of pre-assessment: Macromolecules in the biological system

PEDAGOGICAL COMMENT FOR LEARNERS

(100-200 words)

The above exercise is constructed in order to; allow the student to grade his levels of basic knowledge and pre requisites he possesses for the comprehension of this module.

Scores between 30% and 60% show the existence of fundamentals, although with gaps in the basic knowledge required to successfully undertake this module. Such gaps can be filled through the study of pre-university books of modules 5, 6, and 7.

Scores below 30% show the need of some thorough work for preparation, which should be done through the study of secondary school books.

Results above 90% show the existence of basic principals required to successfully undertake the course.
10. Learning activities

Module Developer Writing Tip. The learning activities are at the heart of each module. They represent the tasks or activities learners must accomplish in order to meet the module’s objectives.

Module Developers should write at least four learning activities per module. Three of these activities are compulsory. The fourth one, focusing on teaching skills, would be optional. For each learning activity, clear learner guidance needs to be provided (a section called “INSTRUCTIONS”), including the resources required in order to accomplish the learning tasks.

Module Developers should write a summary (maximum length: 100 words) for each learning activity. Each summary should be followed by a series of 5 key words.

Module Developers are also required to provide a detailed description for each learning activity (maximum length: 250 words).

As students learn best when they are actively involved in the process, the learning activities developed should focus on active learner involvement. Also, as many studies report that, regardless of the subject matter, students working collaboratively in small groups tend to be more motivated, satisfied and to learn more than when the same content is presented in other instructional formats, one of the four learning activities must include a collaborative learning component. Module Developers who need more information on collaborative learning can consult Annex 4 (What is collaborative learning).

The optional learning activity must focus on the teaching skills inherent to the content of the module (remember: this module is for preservice or inservice teachers).

Module Developers should find a variety of learning activities (practice activities, exercises, assignments, projects, reports, presentations, problem solving activities, etc.) which will suit a variety of learning styles, within the African context.

Module Developers are required to make sure that information and communication technologies (ITC) are integrated in most learning activities. When specific tools are used in one activity, these need to be mentioned. These also have to be open source tools (such as Open Office tools: www.openoffice.org).

Module Developers should assure that the readings, the resources and the useful links mentioned in the sections above are all integrated in the learning activities. Because of the reality of the African context, some learning activities and learner support must be provided for students who have limited access to technology.

Also, Module Developers have to make sure that staff feedback loops are integrated into the Module.

Each learning activity must include at least one formative evaluation component. A formative evaluation is an ongoing assessment throughout the learning process. It is essential to help the instructor understand the learners’ mastery of the learning objectives of the module. Module Developers should understand that formative evaluation must also offer guidance on how the learner’s work or performance can be improved.
For each of the compulsory learning activities, Module Developers must include an optional self-reflection (formative assessment) that would help learners reflect on the challenges inherent to teaching a similar topic in a classroom, with either elementary or secondary school students.

Module Developers must also address the type of feedback required by the instructor of the course. This feedback must go beyond managerial functions and focus on the learning process. In fact, it should be recommended to instructors that feedback focus on the performance, with advice on what could be done to further improve that performance. Research clearly shows that feedback improves learning when it gives students specific guidance both on the strengths and weaknesses of the students.

Formative assessments should take many different forms in the module. For example, some learning activities could integrate on-line small-group discussions among students (these need to be highly structured), whole class discussions on the module electronic discussion forum (again, this needs to be highly structured), journal entries, portfolios entries, surveys, analytical observations, problem solving activities, reading activities (followed by questions), etc. The Module Developer needs to indicate if this formative evaluation counts for the final mark of the module, as well as its value. An answer key also needs to be provided for each formative evaluation. Also, Module Developers must indicate how learners will submit their answers to the instructor. Will the summary evaluation be emailed to the instructor? Will it be submitted online? Will there be an online test? Will there be an on-site evaluation? Finally, formative evaluations should include opportunities for students to respond to the module to provide feedback to the instructor.
Learning activity 1

Title of learning activity: Glucids (carbohydrates)

Summary of the learning activity (ALSO REFERENCE SPECIFIC LEARNING OBJECTIVES TO WHICH THIS ACTIVITY RELATES):

Learning activity 1 allows gathering of basic knowledge about Glucids (carbohydrates), its classifications and its derivatives, main physical and chemical properties, stereo symmetry, as well as phenomenon involved in the molecules space disposition.

To this group of substances belong the sugars, vital compounds for life on earth. They are found in a large spectrum of natural substances and serve above all as the main source of energy for the organisms.

They are generally classified by their size and main functional group.

The study of theme 1 (Glucids) requires around 40 hours of work. During which the references should be closely studied, take notes and make small resumes and answer orientation quizzes found along the course.

List of REQUIRED readings Carbohydrates origin: Wikipedia, free encyclopedia

6. http://www.google.co.ke/search?hl=en&q=a%C3%A7ucar+redutor&btn=Seas (Properties of sugars /discussion on inverted sugar
(Carbon Hydrates/nucleic acids/lipids /functions
(Carbohydrate’s analysis) practical activities
10. Sweet like sugar http://www.qmc.ufsc.br/qmcweb/artigos/sugar.html (Concept/Functions/ basic needs of organism
Detailed description of the activity

Carefully read the references and take notes about the following topic:

i. Definition of carbohydrates and the historical development of the concept
ii. Classification and nomenclature of carbohydrates
iii. Characterization of carbohydrates (monosaccharide, disaccharides, and the most common polysaccharides)
iv. Structure, properties, and reactivity of the monosaccharide
v. Structure and properties of disaccharides
vi. Structure, properties and reactivity of polysaccharides

The acquirement of the capacity and abilities offered by this module is aided by carrying out the following tasks:

Task 1: Carbohydrates introduction

- Carbohydrate’s concept
- Occurrence, composition and importance
- Classification and nomenclature of the carbohydrates
- Physical properties

Task 2: Monosaccharide

2.1- Structure of monosaccharide
2.2- Formation of rings (lactone)
2.3- Stereoisomerism
2.4- oxocyclotautomerism
2.5- Monosaccharide reactions

Task 3: Oligosaccharides

3.1- Disaccharides
3.2- Reducing disaccharides (type 1)
3.3- non reductor disaccharides (type 2)

Task 4: Polysaccharides

4.1- Polysaccharides composition
4.2- Properties
4.3- Starch
4.4- Glycogen
4.5- Cellulose
Formative evaluation

Along with the contents there are questions that help in the orientation of your studies.

Learning activities

Task 1: Carbohydrates

This task consists on the reading and resume of the compulsory references above listed, in which are found and deepened the knowledge on the historic concept of CARBOHYDRATES and its occurrence, classification, most common carbohydrate’s nomenclature, offers information about the relation, structure of physical and chemical properties.

Concept carbohydrates

The concept of carbohydrates of carbon hydrates is generally used to appoint natural compounds that other than carbon have a hydrogen structure and oxygen in a 2:1 ratio just like water.

\[ C_n(H_2O)_n = C_{nH_{2n}O_n} \]

It is worth pointing out that there are compounds with this composition that do not belong in the group of carbon hydrates, the same way that there are compounds classified as carbohydrates without strictly obeying with this composition.

Ex.        Acetic acid                Lactic acid        
          C₂H₄O₂                    C₃H₆O₃

Apart from that the hydrogen and oxygen present in this natural compound are not found in the form of a molecule in water. These facts make some group of actors to prefer to refer to them as Glucids.

Carbohydrates or Glucids are chemically Aldehydes or Ketones containing polyhydroxyl group or compounds which by hydrolysis can be transformed into Aldehydes or Ketones

Formative Assessment 1:

Why is it preferred to use the name Glucids instead of carbohydrates?

- Chemically define carbohydrates or Glucids!
- Occurrence, composition and importance.

Most of these substances are found in nature in its vegetal form where they are synthesized from the Carbon Dioxide (CO2) and water (H2O) present in the atmosphere from the process of photosynthesis.

Belonging to this group are the sugars, which we already know about its vital importance for life on earth. One of the most important Glucids formed that way is glucose (+) C₆H₁₂O₆ which by condensation forms substances of great molecular weight like cellulose (C₆H₁₀O₅) n, which constitute the supporting structure of plants (forms the walls of vegetal cells), or the amino acid that by storing mainly seeds serves as the plant’s food reserve during its growth.
Ingested by animals, starch and in the case of herbivores animals Cellulose, are broken down in its original units of Glucose. These are taken to the liver by the blood stream and there they are recombined with the formation of glycogen or animal starch (substance of animal reserve).

Starts from glucose, transforms into amino acids, which also combine to form proteins that make up most of the animal's body. The nucleic acids (DNA, RNA) carriers of the hereditary genetic characters in the living cells partially contain in their structures Glucids.

Practical applications of Glucids are found in the paper of textile industries, natural (cotton), or artificial (rayon, viscose), cellophane, plastic materials (celluloid), explosives, adhesives, etc.

**Formative Assessment 2**

Give three examples of practical applications of Glucids!

1.3- Classification and nomenclature of carbohydrates.

The carbohydrates are classified under different points of views.

The most usual ways of classifying are:

By size (number of basic units) Taking into account the make up and enormous size of molecules as well as its properties they are divided in three groups:

- **Monosaccharide**
  
  Simple sugars formed by basic non hydrolysable with generally 5-6 carbon atoms.
  
  Examples: Glucose, fructose, mannose.

- **Oligosaccharides**
  
  Sugars made up of 2 to 10 basic units of monosaccharide. The oligosaccharides are hydrolysable into simpler compounds (monosaccharide)
  
  Examples: Sucrose, lactose, maltose.

  The carbohydrates that can be hydrolyzed in two monosaccharide molecules are called disaccharides.

- **Polysaccharides**
  
  The carbon hydrates that can be hydrolyzed in many units of monosaccharide (they can reach 10000 approximately units).
  
  Examples: Cellulose, amylase, glycogen, starch.

  By main function (functional group)

  In carbohydrates we mainly find hydroxyl and carbonyl with the main function taken up by the carbonyl group. So, in the particular case of monosaccharide we have:

  - **Aldoses**
Sugars that have the Aldehydes group as the main group

Ex. Aldose
   CHO
   \(H - C - OH\)
   CH2OH

D- Glyceraldehydes
   (Aldotriose)

-Ketoses

Sugars that have the Ketones group as the main group

Ex. Ketose
   CH2OH
   C = O
   CH2OH

Dihydroxyl ketone
   (Cetoetriose)

Ex.

<table>
<thead>
<tr>
<th>Aldose</th>
<th>Aldose</th>
<th>Ketose</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHO</td>
<td>CHO</td>
<td>CH2OH</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H - C - OH</td>
<td>H - C - OH</td>
<td>C = O</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H - C - OH</td>
<td>HO - C - H</td>
<td>HO - C - H</td>
</tr>
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<td></td>
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<td></td>
</tr>
<tr>
<td>H - C - OH</td>
<td>H - C - OH</td>
<td>H - C - OH</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CH2OH                  H – C – OH               H – C – OH
      I                        I
D- Ribose                  CH2OH                 CH2OH
\text{(Aldopentose)}

D- Glucose                  D- Fructose
\text{(Aldo hexose)}            \text{(Ceto hexose)}

By the number of carbon atoms

- Triose (contain 3 carbon atoms)
- Tetrose (contain 4 carbon atoms)
- Pentose (contain 5 carbon atoms)
- Hexose (contain 6 carbon atoms)
- Heptose (contain 7 carbon atoms)

By the absolute configuration of the molecule

This system has as its compound of reference the Glyceric aldehydes

\[ \text{CHO} \]
\[ \text{I} \]
\[ \text{H – C – OH} \]
\[ \text{I} \]
\[ \text{CH2OH} \]

D- Glyceraldehyde

- D configuration (destro)

When the similarity of the Glyceric aldehyde of the hydroxyl group of the asymmetric carbon atom farthest from the functional group is to the right.

(lat: Dexter=right)

- L configuration
Learning activity 1

When the hydroxyl group of the asymmetric carbon atom farthest from the functional group is found at the left.

(lat: Laevus=left)

By specific rotation of light

(+): Rotation: Clockwise
When the compound rotates light in the direction of clock pointers.

Ex. (+)-D - Glucose (< +52.70)

(-): Rotation: Anticlockwise
When the compound rotates light in the reverse direction of clock pointers.

Ex: (-) (D)- Fructose (< -92.40)

Nomenclature

The majority of carbohydrates have trivial names originated from the substances from which they were firstly isolated and added with the terminations –ose or –uloses for the Aldoses and Ketoses respectively.

Ex. Ribose, Glucose, Fructose, Mannose.

<table>
<thead>
<tr>
<th>CHO</th>
<th>CHO</th>
<th>CH2OH</th>
<th>CHO</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>H – C – OH</td>
<td>H – C – OH</td>
<td>C = O</td>
<td>HO - C – H</td>
</tr>
<tr>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>H – C – OH</td>
<td>HO - C – H</td>
<td>HO - C – H</td>
<td>HO - C – H</td>
</tr>
<tr>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>H – C – OH</td>
<td>H – C – OH</td>
<td>H - C – OH</td>
<td>H - C - OH</td>
</tr>
<tr>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
<tr>
<td>CH2OH</td>
<td>H – C – OH</td>
<td>H – C – OH</td>
<td>H - C - OH</td>
</tr>
<tr>
<td>I</td>
<td>I</td>
<td>I</td>
<td>I</td>
</tr>
</tbody>
</table>

Ribose CH2OH CH2OH CH2OH
Glucose Fructose Mannose
Formative Assessment 3

Illustrate the structure of fructose!

Make a complete classification of fructose!

Define the concepts of monosaccharide, disaccharides, and polysaccharides

1.4 Physical properties

The mono- and disaccharides are crystalline, colorless, tasteless, and sweet.

Carbohydrates are substances easily soluble in water (this is because of the presence of many hydroxyl groups) and in some solvent organics.

They are not very soluble in nonpolar solvents. (Ex. Benzene, ether, etc.)

In water they form oversaturated solutions (melasses).

Under heat, they are stable until reaching around 150c. Decompose at temperatures up to 200c and form caramel. Form charcoal at temperatures above 200c.

In general they deviate the plan of polarized light.

Task 2: monosaccharide

The aim of this task is to familiarize with the basic structures of Glucids as well as the properties resulting from the structure. These compounds being Aldehydes and Ketones containing polyhydroxyl group present in its reactivity the properties of common compounds.

2.1- Structure of monosaccharide

- Monosaccharide are compounds of carbon containing polyhydroxyl group
- Are part of chiral compounds i.e., molecules not congruent with their reflex on a mirror.
- Present optic activity (optic isomers rotate polarized light plan)
- Are stereoisomers (isomers that differ on spatial orientation of the substituents).
- Have at least one asymmetric carbon atom.

Ex:

\[
\text{CHO} \\
\text{I} \\
\text{HO – C* - H} \quad * \text{Asymmetric carbon} \\
\text{I} \\
\text{H – C*- OH} \\
\text{I}
\]
For a molecule with \( n \) asymmetric atoms there can be formed \( 2n \) stereoisomers.

For example, a D-glucose with 4 asymmetric centers form 24, so sixteen (16) stereoisomers which makes eight (8) pairs of Enantiomers (antipodes optics).

The constituents of a pair of Enantiomers have the same physical and chemical properties and have the same magnitude of deviation of plane polarized light, but in opposite directions.

Of the sixteen (16) isomers only one (1) is (+) Glucose, and the most abundant monosaccharide. The second isomer corresponds to a (-) Glucose which is enantiomer found in nature. The other fourteen (14) isomers are diasteriomers of (+) Glucose.

All these aldo-hexoses have the same the of reactions as glucose only differing by its velocity.

Glyceraldehydes are used as the compound of reference to attribute a name.

According to Wohl and Freundenberg the Glyceraldehydes has the D configuration when it rotates light to the right (+).

When a compound has various asymmetric compounds we choose the one farthest away from the functional group as point of reference.

Enantiomers are isomers that are different in all asymmetric centers, i.e., nonsuperimposable mirror images of each other.

Carbohydrates that differ in the asymmetric center vicinal to the carboxylic group are called epimer sugars.

**Formative Assessment 4:**

Explain the solubility of glucose!

Explain why ribose contains optic activity!

### 2.2 Formation of rings (Lactones)

Monosaccharides have side by side structural elements of Aldehydes or Ketones and alcohols respective to the carbonyl groups Aldehydes and Ketones. About the chemistry of this group we know that they can react between them forming Acetals.

As the number of C-atoms increase in the chain of the sugars, it becomes possible for the OH group to react with the Carbonyl group.
These structural elements in monosaccharide react between them forming intermolecular semiacetals named Lactone.
Learning activity 1

It is worth emphasizing that due to the esteric conditions mainly occurs the formation of rings with six (6) atoms (without internal tensions) in some rings with five (5) atoms relative to the less stable.

The cyclic forms can be derived from the tetrahidropirane and tetrahidrofurane, so they are also called piranose and furanose respectively.

Formative Assessment 5:

- Explain the major stability of the piranose and furanose in relation to other rings!

2.3- Stereoisomerism

With the cyclization there is always one more asymmetric center formed. This conditions the existence of two more diasteriomers lactones called Monomers α and β.

\[
\begin{align*}
\text{CHO} & \quad \text{HO - C - H} \\
\| & \quad \| \\
H - C - OH & \quad H - C - OH & \quad H - C - OH \\
\| & \quad \| \\
\text{HO - C - H} & \quad \text{O} & \quad \text{HO - C - H} & \quad \text{O} \\
\| & \quad \| \\
H - C - OH & \quad H - C - OH & \quad H - C - OH \\
\| & \quad \| \\
H - C & \quad H - C - OH & \quad H - C \\
\| & \quad \| \\
\text{CH2OH} & \quad \text{CH2OH} & \quad \text{CH2OH}
\end{align*}
\]

α - D -(+) - Glucopiranose   D-(+)-Glucose   β - D -(+) - Glucopiranose

(Lactol)   (Aldehyde)   (Lactol)
In Fisher’s projection of series D sugars, the new hydroxyl group is written on the right when related to monomer (α) and on the left to represent the monomer in the form of (β). For the L series we use the naturally opposite process.

2.4- Oxocyclotautomerism

-In solution there are formed a balance of three tautomeric forms. This balance is known as oxocyclo-tautomerism is generally moved to the cyclic form.

Let us use glucose as an example:

Through the changing conditions of crystallization (mainly the temperature and solvent variations) is possible to isolate from glucose solution a series of monomers α- or β- piranoses.

The glucopiranose of the pure α- series rotates polarized light at a specific angle of 1120. The β rotates polarized light at a specific angle of 190.

However dissolving one of these in pure water we observe a gradual change in the polarized light rotation caused by the conformation at a rotation angle equal to 52.70.

A fresh aqueous solution (that has just been made) of α- Glucopiranose rotates polarized light at a specific angle of 1120. However with time these angles decrease until 52.70. Meanwhile dissolving a β- glucopiranose with a specific angle of deviation of 190 it is observed that with time the angle increases to the same size of 52.70.

Pure B-D-glucose has an optical relation of $[\alpha]_D = +18.7^0$, the α - anomer has $[\alpha]_D = +112^0$. If either pure anomer is dissolved in water, the optical rotation of the solution gradually changes until it reaches an equilibrium value of $+52.7^0$. This phenomenon results from interconversion of the two anomers in solution. At equilibrium the solution contains 63.6% of β - (more stable) and 36.4% of α - anomer.

This phenomenon of change in the rotation of monomers α or β to reach the value of balance is known as mutarotation

Example. Mutarotation of glucose

Hawort projection
Formative Assessment 6

What are monomers?

What do is mutarotation?

2.5- Monosaccharide reactions

In the presence of halides of Lithium and Aluminum or amalgams (NaBH4) the carbohydrates let themselves reduce to alcoholics sugars (alditol) whose name is characterized by the termination –itol.

While in aldose’s hydrogenation we always get one alcohol in Ketone’s hydrogenation there are two diastereomers, since the reduction happens while a new asymmetric center is formed.

Ex.

CHO  CH2OH  CH2OH  CH2OH  CH2OH  CHO
   I     |     |     |     |     |
H – C – OH    H – C – OH    C = O     HO – C – H    HO – C – H
   I     +2H     I     +2H     I     +2H     I
   I     |     |     |     |
   I     |     |     |     |
   I     |     |     |     |
CH2OH  CH2OH  CH2OH  CH2OH  CH2OH
D-(+)-Glucose  D-(+)-glucitol  D-(−)-Fructose  D-(+)-Manitol  D-(+)-Mannose

Alcoholic sugars are colorless substances that crystallize well and have a sweet flavor.
The D-glucitol or D-sorbitol (sorbite) is used in place of sugars for diabetics.

Many hexitol are usual components of plants. For example red algae, fruit like pears, apples, strawberry and peaches. Manitol is found in algae, grass, fruit and fungus.

### 2.5.2 Monosaccharide oxidation

#### 2.5.2.1 Aldoolic acid

Using mild oxidants like bromine water (Br₂aq) or diluted nitric acid (HNO₃dil) is possible to oxidise the Aldehyde group of Aldoses, there is a carboxylic group that is only stable in an alkaline environment. In an acidic environment we have condensation between the carboxylic group and the hydroxyl group of α or β forming lactones.

Ex1                                                        Ex2

\[
\begin{array}{cccc}
\text{CHO} & \text{COOH} & \text{CHO} & \text{COOH} \\
\text{I} & \text{I} & \text{I} & \text{I} \\
\text{H} - \text{C} - \text{OH} & \text{H} - \text{C} - \text{OH} & \text{HO} - \text{C} - \text{H} & \text{HO} - \text{C} - \text{H} \\
\text{I} & \text{+Br}_2 & \text{I} & \text{+Br}_2 & \text{I} \\
\text{HO} - \text{C} - \text{H} & \rightarrow & \text{HO} - \text{C} - \text{H} & \text{HO} - \text{C} - \text{H} & \rightarrow & \text{HO} - \text{C} - \text{H} \\
\text{I} & \text{I} & \text{I} & \text{I} \\
\text{H} - \text{C} - \text{OH} & \text{H} - \text{C} - \text{OH} & \text{H} - \text{C} - \text{OH} & \text{H} - \text{C} - \text{OH} \\
\text{I} & \text{I} & \text{I} & \text{I} \\
\text{H} - \text{C} - \text{OH} & \text{H} - \text{C} - \text{OH} & \text{H} - \text{C} - \text{OH} & \text{H} - \text{C} - \text{OH} \\
\text{I} & \text{I} & \text{I} & \text{I} \\
\text{CH}_2\text{OH} & \text{CH}_2\text{OH} & \text{CH}_2\text{OH} & \text{CH}_2\text{OH}
\end{array}
\]

D-(+)-Glucose            Ác.-D-(+)-glucónico     D-(+)-Mannose           Ác. D-(+)-Manonic

#### 2.5.2.2 Aldaric acids

Strong oxidizing environments attack not only the Aldehyde group, but also the hydroxyl group primary of the Aldoses forming dicarboxyl acids (aldaric acids) known as acid sugars.

Aldaric acids can also easily form lactones.
Learning activity 1

Ex1

CHO       COOH       CHO       COOH
I          I          I          I

H – C – OH       H – C – OH       H – C – OH       H – C – O H
I          +HNO3       I          I          +HNO3       I

HO – C – H       →       HO – C – H
HO – C – H       →       HO – C – H
I          I          I          I

H – C – OH       H – C – OH       HO – C – H       HO – C – H
I          I          I          I

H – C – OH       H – C – OH       H – C – OH       H – C – OH
I          I          I          I

CH2OH       COOH       CH2OH       COOH

D-(+)-Glucose         Ác.-D-(+)-glucáric         D-(+)-galactose         Ác.-D-(+)-galactáric

(Ác. mucíc)

Ex.3 Resume

COOH       CHO       COOH
I          I          I

H – C – OH       H – C – OH       H – C – OH
I          +Br2(H2O)       I          +HNO3       I

HO – C – H       ←       HO – C – H       →       HO – C – H
I          I          I

H – C – OH       H – C – OH       H – C – OH
I          I          I

H – C – OH       H – C – OH       H – C – OH
I          I          I

CH2OH       CH2OH       COOH

Ác. D-glucónic         D – Glucose         Ác. D- glucácíc
2.5.2.3 Acidos urinics (glycoside oxidation)

Medium oxidizing agent (Ex. Dinitrogen peroxide in water solution) oxide the hydroxyl group primary to glycosides up to the carboxylic group. The compounds formed are called Uronides.

Uronides can be transformed into Uronic acid through hydrolysis of the acetal bond.

Ex.

\[
\begin{align*}
\beta-D-Glucopyranoside & \quad \beta-D-glucorónide & \quad \text{Ac.-}\beta-D- \text{glucorónic} \\
\text{CH}_2\text{OH} & \quad \text{OR} & \quad +\text{N}_2\text{O}_4 & \quad \rightarrow & \quad \text{COOH} & \quad \text{OR} & \quad +\text{H}_2\text{O(H}^+) & \quad \rightarrow & \quad \text{ROH} \\
\end{align*}
\]

Uronic acids are important to the organism, because with their help substances that contain hydroxyl groups are linked like glycosides and eliminated from the body in the form of urine (disentoxication). Free sugars represent low gain in this process.

O Ascorbic and glucoronic acids are products of the oxidization of monosaccharide and have particular importance. Ascorbic acid makes up Vitamin C, widely found in nature especially in green plants. They have as function, reactant of oxidation-reduction transporting hydrogen in biochemical reactions.

As for glucorónic ácid, in which the primary glucose hydroxyl was oxidized to carboxylic group, while the aldehyde group remains intact have special importance in the biosynthesis of natural polysaccharides.

2.5.3 Reaction of identification

Sugars being Aldehydes/Ketones containing polyhydroxyl group, present similarities in reactivity with Aldehyde, Ketones semiacetals, having the same reducing properties as these in which they base their main methods of identification.

Thus, sugars can reduce solutions of Fehling, Haine, Tollens, Nyland, Trommer oxidizing to acids.

- Fehling’s solution: Cu2+, KNa-Tartrate (OH)

\[
\begin{align*}
\text{Cu}^2+ & \quad +\text{KNa-Tartrate(OH)} & \quad \rightarrow & \quad \text{Cu}_2\text{O} & \quad +\text{CH}_2\text{OH}-(\text{CHOH})_4-\text{COOH} \\
\end{align*}
\]

\[
\text{Color: Blue } \rightarrow \text{ Red stone komplex}
\]
Tollen’s solution: Ag⁺, OH⁻ in ammoniacal solution.

\[
\begin{array}{c}
\text{Ag}^+ +\text{OH}^-\\
0
\end{array}
\]

\[
2 \text{[Ag(NH}_3\text{)]}_2\text{NO}_3 + \text{CH}_2\text{OH}-(\text{CHOH})_4-\text{CHO} + \text{H}_2\text{O} \rightarrow 2 \text{Ag} + \text{CH}_2\text{OH}-(\text{CHOH})_4-\text{COONH}_4 + 2 \text{NH}_4\text{NO}_3 + \text{NH}_3
\]

Production of silver mirror

+1 -

- Haine’s solution: Cu, OH⁻, Glycerol

Production of de Cu₂O (Red)

+3+

- Nyland’s solution: Bi⁺, K, tartrate

Reduction of Bismuth ion to element bismuth (oxidation state zero)

+ -

- Tollén’s solution: Ag⁺, OH⁻

\[
\begin{align*}
\text{CHO} & \quad \text{COOH} \\
\text{H} - \text{C} - \text{OH} & + - \quad \text{H} - \text{C} - \text{OH} \\
\text{I} & \quad +2 \text{Ag} + \text{OH} \quad \text{I} \\
\text{HO} - \text{C} - \text{H} & \rightarrow \quad \text{HO} - \text{C} - \text{H} \\
\text{I} & \quad \text{I} \\
\text{H} - \text{C} - \text{OH} & \quad \text{H} - \text{C} - \text{OH} \\
\text{I} & \quad \text{I} \\
\text{H} - \text{C} - \text{OH} & \quad \text{H} - \text{C} - \text{OH} \\
\text{I} & \quad \text{I} \\
\text{CH}_2\text{OH} & \quad \text{CH}_2\text{OH}
\end{align*}
\]

D-(+)-Glucose \quad Ác.-D-(+)

- glucónic
2.5.4 Hydroxyl groups reactions.

Monosaccharide being compounds containing polyhydroxyl group behave like polyalcohol.

Like with nucleophilic substitution reactions (SN) with halides of alkyl, they esterify with anhydride and form cyclic acetals with Carbonyl compounds.


With carbonyl compounds in the presence of ZnCl₂ form cyclic acetals.

In most cases we can obtain typical products of carbonyl compounds in nucleophylic agents.

For example, the reaction with cianidric acid forms a mixture of epimers cyanonides whose hydrolysis produce Aldoolic acids. These naturally can be reduced with amalgam of sodium until the monomers aldoses whose chain was increased by one carbon atom in relation to the agents.

\[
\begin{align*}
\text{CN} & \quad +2\text{H}_2\text{O} & \quad \text{COOH} \\
\text{I} & \quad \rightarrow & \quad \text{I} \\
\text{H} - \text{C} - \text{OH} & \quad \rightarrow & \quad \text{H} - \text{C} - \text{OH} \\
\text{I} & \quad - \text{NH}_3 & \quad \text{I} \\
\text{I} & \quad + \text{HCN} & \quad \text{R} \\
\text{CHO} & \quad \rightarrow & \quad \text{R} \\
\end{align*}
\]
Learning activity 1

\[ \text{R} \quad \square + \text{HCN} \]

\[ \text{CN} \quad \text{COOH} \]

\[ \square + 2\text{H}_2\text{O} \quad \square \]

\[ \text{HO} - \text{C} - \text{H} \rightarrow \text{HO} - \text{C} - \text{H} \]

\[ \square - \text{NH}_3 \quad \square \]

\[ \text{R} \quad \text{R} \]

On the other side the cyanohydrin in the presence of Ammoniac turns into aminonitriles that hydrogenates through acids catalytically to produce Amino sugars.

\[ \text{CN} \quad \text{CN} \quad \text{CHO} \]

\[ + \text{HCN} \quad I \quad +\text{NH}_3 \quad I \quad \square \quad I \]

\[ \text{CHO} \rightarrow \text{H} - \text{C} - \text{OH} \rightarrow \text{H} - \text{C} - \text{NH}_2 \rightarrow \text{H} - \text{C} - \text{NH}_2 \]

\[ \square \quad I \quad - \text{H}_2\text{O} \quad I \quad - \text{NH}_3 \quad I \]

\[ \text{R} \quad \text{R} \quad \text{R} \quad \text{R} \]

2.5.6 Formation of Osazones

Exposing Monosaccharide to heat in acetic acid with Phenylhydrazine forms osazones, which are yellow crystals not very soluble in water.

First the carbonyl group reacts with a mole of Phenylhydrazin forming Phenylhydrazone.

Next the adjacent carbonyl group is oxidized forming an osazone eliminating aniline and ammonia.

\[ \text{CHO} \quad \text{CH} = \text{N} - \text{NH} - \text{R}_2 \quad \text{CH} = \text{N} - \text{NH} - \text{R}_2 \]

\[ \square \quad + \text{R}_2\text{-NH-NH}_2 \quad I \quad + 2 \text{R}_2\text{-NH-NH}_2 \quad I \]

\[ \text{H} - \text{C} - \text{OH} \rightarrow \text{H} - \text{C} - \text{OH} \rightarrow \text{C} = \text{N} - \text{NH} - \text{R}_2 \]

\[ \square \quad I \quad - \text{R}_2\text{-NH}_2 \quad I \]

\[ \text{R}_1 \quad \text{R}_1 \quad - \text{NH}_3 , -\text{H}_2\text{O} \quad \text{R}_1 \]

Aldose \hspace{1cm} Phenylhydrazone \hspace{1cm} Osazone

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Mechanism:

\[ \text{Osonhydrazin} \quad \text{Osazone} \]

Osazones are Bis(phenylhydrazines) of compounds 1, 2-dicarbonyls.

The epimer sugars D-Glucose and D-Mannose as well as D-Fructose form identical osazones.

2.5.7 Formation of Oximes

Reactions of Aldoses (ex. Glucose) with hydroxylamina form an Oxime of Aldehyde function, whose dehydration forms a cyanohydrin.

In the presence of silver oxide, it decomposes in Hydrocyanic acid and an Aldose (Arabinose). This sequence of reaction constitutes Wohl’s method of degradation.

Macromolecules in Biological Systems

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Learning activity 1

H – C – OH    H – C – OH    H – C – OH    H – C – OH
   I       I       I       I
CH2OH     CH2OH     CH2OH     CH2OH

Aldose     Oxime (Aldoxime)     Cyanohydrin     D – Arabinose

D – Glucose     D-Glucosoxime     Nitrile D-glucónico     Aldose

2.5.7 Hydrocyanic acid action

Aldoses react with hydrocyanic acid forming cyanohydrins. These can be hydrolyzed to acids and these can also be reduced to Aldoses of the homolog superior series in carbon atoms. (Fischer Kaliani’s method of construction)

C≡N    COOH    C = O
       I       I       I

CH = O    H - C - OH    H - C - OH    H - C - OH
       I       I       I       I

H - C - OH    H - C - OH    H - C - OH    H - C - OH
       I       I       I       I

HO – C - H    HO – C - H    HO – C - H    HO – C – H
       I       HCN = N       I       H2O       I       I

H – C – OH    H – C – OH    H – C – OH    H – C
       I       I       I       I

H – C – OH    H – C – OH    H – C – OH    H – C – OH
       I       I       I       I

CH2OH     CH2OH     CH2OH     CH2OH

Aldose     δ-Lactam

Formative assessment 7

Write an equation of the reaction of the identification of glucose with Fehling’s reagent!

Explain why it is possible to identify the glucose with Fehling’s reagent!
Task 3: Oligosaccharides

In this activity you will get familiar with the theoretic and practical precepts of some compounds we deal with on a daily basis.

Oligosaccharides are compounds formed in two (2) to ten (10) units of monosaccharide bonded by glycosidic linkage.

Within the oligosaccharides the disaccharides are the ones that have the most importance.

In nature there are only found a few free disaccharides like sugar cane, milk and malt.

3.1 Disaccharides

Disaccharides are carbon hydrates made up of two units of monosaccharide. A molecule of a disaccharide produces two molecules of monosaccharide by hydrolysis.

From the analysis of the structure of disaccharide molecules it can be concluded that they are the result of condensation, with the elimination of water, of two monosaccharide molecules that can be identical or different in order for the disaccharides to be differentiated by:

- By nature of monosaccharide that constitute it
- By size of rings (Piranose or Furanose)
- By the configuration (α or β) of the glycosidic linkage
- By the position of the glycosidic linkage (whether it happens between the hydroxyl monomers of the two rings or not).

In general two monosaccharide molecules link each other in the form glycoside.

In the glycoside union between two monosaccharide molecules can originate a disaccharide, a water molecule can separate itself from the hydroxyl glycoside groups (also known as hemiacetal), or between one hydroxyl group hemiacetal (glicosidic) and another alcoholic. In the act of formation of the link we find two variables:

1. The condensation happens between two (2) hydroxyl glycoside. In this case we are talking about a decarburation of a disaccharide (type 1).

2. On the other hand the transformation may happen between a hydroxyl glycoside of one of the units of monosaccharide and a hydroxyl non glycoside (alcoholic) of another monosaccharide unit. In this case we are talking about a monocarbonization (type 2).

3. In the first case (type 1) the two types of monosaccharide contain a acetyl group, on the second case (type 2) stays only a hemiacetal (semi-acetyl).

As consequence the type 2 disaccharides with the monocarbonilization show redacting properties and show maturation because as consequence of o xo-cyclo-tautomerism it is possible to have a transition of the cyclic semi-acetyl to the form of oxo (open) with one free aldehyde group.
In contrary, type 1 disaccharides do not show these properties because of the blockage of the two hydroxyl glycoside by the formation of the acetyl.

3.2 Reductor Disaccharides (type 1)

As an example of non-reductor disaccharides we have Saccharose (sugar from sugar cane) that we abundantly find in the vegetal kingdom and are technically obtained from sugar cane or beetroot.

Saccharose is structurally made up of one unit of -glucose and one unit of D-fructose. The two units of hexose link, each other, by a glycosidic linkage between Glucose’s C-1 and Fructose’s C-2, this causes the blockage of carbonyl functions (glycosidic linkage - 1, 2)
Saccharose's systematic name is o a-D-Frutofuranosil-b-D-Glucopiranoside or a-D-Glucopiranosil-b-D-Frutofuranoside.

Saccharose rotates polarized light to the right (+66.5°). Off its hydrolysis in an acidic environment we can get a mixture of Glucose and Fructose called inverted sugar because in it we can observe a strong light deviation to the left caused by the strong influence of fructose.

Saccharose's molecular formula is: C12H22O11

Saccharose does not have Osazones forms, there are not monomers and does not have mutarotation when dissolved, because they don’t make up the free Aldehyde and Ketone group.

3.3 Non-reductor Disaccharides (Type 2)

As an example of a reductor sugar we have Lactose and Maltose.

Lactose is mainly found in mammal’s milk. It is made up of a b-D-Galactose molecule that links glycosidically with a hydroxyl in the position 4 (alcoholic) of a b-D-Glucose molecule. It is a 4-O-b-D-Galactopiranosil-b-D-glucopiranose.

Lactose

Glycosidic linkage -1,4

β-D-Galactose   β-D-glucose

4-O-β-D-Galactopiranosil-β-D-glucopiranoside

Lactose is a reductor sugar, it exists in the forms a and b, which have mutarotation and forms Osazones because of the fact that it has a free hemiacetal hydroxyl in the glucose molecule.

It can be obtained commercially as a sub product in cheese making.

General formula: C12H22O11

Maltose

Maltose is formed by two (2) glucose molecules. These molecules are linked glycosidically by the hemiacetal hydroxyl group of a a-glucose (position 1) and a alcoholic hydroxyl group in position 4 of another glucose molecule.

By consequence it contains a free carbonyl group that fits in the reductor properties, mutarotation and other typical properties of Aldehydes.
Reduces solutions by Fehling, Tollens, Haine, and others.

When joined with Phenylhydrazin it forms an Osazone C12H20O9.

It is oxidized by bromine water forming a monocarboxylic acid (C11H21COOH) the malt biotic acid.

Maltose can be produced along with other substances through amide hydrolyze with acidic solutions. Exist in the form a and b where a = < +112o and b = < 168o which have mutarotation, and when dissolved at an angle < +136o. These facts show that Maltose has a free Carbonyl group.

By acidic hydrolyze or by Maltase enzyme action, turns totally into a D- Glucose (α-Glycoside).

Maltose

\[
\alpha-D-\text{Glucose} \quad \alpha-D-\text{Glucose} \\
4-O-(\alpha-D-\text{Glucopiranosil})-\alpha-D-\text{Glucopiranoside}
\]

Formative Assessment 8:

**Characterize Oligosaccharides**

Glucids are part of the composition of milk. Illustrate this compound’s structure and explain what type of sugars it belongs to.

**Task 4: Polysaccharides**

Exercise 4 deepens the fundamental knowledge about vital compounds for the existence and survival of Humanity.

In the study will be found information about the structures of natural macromolecules with biological importance and will discuss the correlation between the structures and properties.

They serve for protection, support and reserve for living organisms.

**4.1 Polysaccharides composition**

Polysaccharides are compounds made up of hundreds or even thousands of monosaccharide units per molecule. These units link each other by glycosidic links that can break by hydrolysis.

Polysaccharides are natural polymers considered derived off Aldoses and Ketoses by polymerization by condensation.
4.2 Physical properties

Most of the polysaccharides are not soluble in water, or form a colloidal solution. The colloidal state reflects a relatively high molecular mass that changes from ca. 1700 to couple of millions.

In nature the main polysaccharides are Cellulose, starch and glycogen.

All of them are made up of D-glucose units.

Starch and cellulose are produced in plants from carbon dioxide (CO2) and water (H2O) by the process of photosynthesis.

Cellulose makes up the basic supporting structure for plants giving them their shape and rigidity. It is the most abundant organic material on earth.

Starch forms the nutritive reserve of plants, while glycogen represents the carbohydrates reserve in animals.

4.3 Starch

Starch, being the energetic reserve of plants is found in great quantities in seeds and in the foods like potatoes, cassava, corn etc.

Starch is always in the form of granules. These are insoluble in cold water and partially soluble in hot water.

In general starch is made up of a fraction of 20%, soluble in water, amylase and about 80% of a fraction insoluble in water the Amylopectin.

Starch degenerates until D-glucose by heating with diluted mineral acids. If the hydrolysis is partial we get a mixture that is hard to separate the fragments of polysaccharides called dextrines.

In the presence of iodine starch incorporates iodine's molecules turning blue.

Amylose as well as amylopectin are made up of D-Glucose units; the difference between them is the size and form of the molecule.

Amylose form linear chains, of Glucose molecules that are joined in the form β-(1,4)-glycosidic.

Presents a mass that varies between 150 000 and 600 000 that corresponds to between 1000 and 4000 units of glucose.

Amylose

\[(1-4)-\alpha-D-\text{Glucopiranoside}\]
Learning activity 1

Amylose is the fraction of starch that forms that intense blue color with iodine.

The Amylose chain in solution adopts the elliptical form, because of the α configuration of all glycosidic links. Because these chains are whirled up in a helix (like a whirlwind staircase) create spaces (interstices) big enough to hold the molecules de iodine allowing that way the appearance of the color.

Amylopectin is a highly branched molecule. The links through the chain in the form α-(1-4)-glycosidic, and in the form α-(1-6) glycosidic in the branching points.

The short chains (branches) have about 20 to 25 units of glucose.

In structure Glycogen is similar to Amylopectin. Even though its chains are more branched, with 3 to 18 units of D-Glucose in each branch, and has a relatively higher molecular mass that goes from 105 to 107.

While starch is produced exclusively in plants, Glycogen represents “the reserve of Carbon hydrates” of animals’ organisms.

After the partial conversion of Carbon hydrates of food, Glycogen is stored in the liver and muscles. With iodine it becomes of dark red color.

4.5 Cellulose

Cellulose is the main supporting substance in plants. As a supporting substance it is the main component of plant’s cellular walls and is the most common Carbon hydrates on earth.

The vegetal fibers, such as cotton, linen, hemp are made up of pure Cellulose.

Cellulose is soluble in water, is insipid and is non reductor.

Cellulose is different to starch, this is due to the fact that the units of D-Glucose that makes them up are joined by β(1, 4)-glycosidic links, off which derives the different properties of these natural products.

Cellulose’s molecular mass is relative to its origin, it varies from 200 000 to millions. This equates to over 1 500 glucose units per molecule.

The long cellulose chains are placed next to each other forming bundles, are kept in position by Hydrogen links between the numerous adjacent Hydroxyl groups.
Formative Assessment 9:
Compare the structure and properties of Amylose and of Amylopectin!

What is the importance of Cellulose in the biological system?

Formative Assessment s

Formative Assessment 1:
Why is the designation Glucids proffered over the name Carbohydrates?

That is because in nature there are carbon compounds like acetic acid and lactic acid that have the exact same proportions of Oxygen and Hydrogen as water, even though they are not classified as Carbohydrates.

Chemically define Carbohydrates or Glucids!

Carbohydrates or Glucids are chemically Aldehydes and Ketones containing polyhydroxyl group or compounds by hydrolysis, can transform them.

Formative Assessment 2:
Give three examples of biological importance of Glucids!

Substance of animal reserve. Ex. Glycogen

Plant support substance. Ex. Cellulose

Energy source. Ex. Saccharose

Formative Assessment 3:
Write down the structure of Fructose!

See text

Make a complete classification of Fructose!

Fructose is a monosaccharide, a ketose, hexose, series D, levorotatory (counterclockwise).

Define the following concepts, disaccharide and polysaccharide.

Monosaccharide
Learning activity 1

Simple sugars formed by one basic non hydrolisable unit with generally five to six carbon atoms. Ex. Glucose, Fructose, Mannose.

Disaccharide

Sugars made up of two basic units of monosaccharide. Disaccharides are hydrolosable in simpler compounds (monosaccharide).

Ex. Saccharose, Lactose, Maltose.

-Polysaccharides

Carbon hydrates that can hydrolyze in many monosaccharide units (can reach about 10 000 units).

Formative Assessment 4:

Explain Glucose’s solubility!

Glucose is an easily soluble compound because it is an Aldehyde containing polyhydroxyl group and polar.

Explain why Ribose has an optic activity!

Ribose has three asymmetric carbon atoms.

Formative Assessment 5:

-Explain why piranoses and furanoses are relatively more stable when compared to other chains!

Piranoses and furanoses have relatively less tension when compared to other chains resulting in the deformation of the linking angles (Bayer’s tension).

Formative Assessment 6:

a) What are monomers?

Monomers are Diasteriomers Lactones resultant of the cyclisation and formation of a new asymmetric centre designed by monomers a and b.

b) What do you understand by mutarotation?

Mutarotation is the phenomenon of change in the angle of deviation of monomers a or b until the value of equilibrium.
Formative Assessment 7:

a) Write the equation of the reaction of identification of Glucose with Fehling's reagent!

Fehlings: Cu2+, KNa-Tartrate (OH)

\[
\begin{align*}
2 \text{Cu}^{2+} + \text{CH}_2\text{OH}-(\text{CHOH})_4 - \text{C} + 5 \text{OH} & \rightarrow \text{Cu}_2\text{O} + \text{CH}_2\text{OH}-(\text{CHOH})_4 - \text{COOH} \\
\end{align*}
\]

Color before the reaction (Blue) → After (Red stone komplex)

Explain why it is possible to identify glucose using Fehling’s reagent!

Glucose is an Aldehyde containing polyhydroxyl group. The free Aldehyde group of sugar is oxidized by copper ions of an acid group, causing simultaneously the reduction of these forming Cu2O that has a red color.

Formative Assessment 8:

Characterize Oligosaccharides!

Oligosaccharides are sugars formed between two (2) to ten (10) units of monosaccharide linked by glycosidic linkage.

Glucids are part of milk’s composition. Illustrate the structure of this compound and explain to what type of sugar it belongs to!

The Glucid mainly found in mammal’s milk is Lactose.

It is made up of a β-D-Galactose molecule that links by glycosidic linkage to a hydroxyl in position 4 (alcoholic) of a β-D-Glucose. This means that it is in fact a 4-O-β-D-Galactopiranosil-β-D-Glucopiranose.

Lactose

![Lactose structure](image)

Glycosidic linkage -1,4

β-D-Galactose  β-D-glucose

4-O-β-D-Galactopiranosil-β-D-glucopiranoside
Learning activity 1

Lactose is a reductor sugar, exists in the forms $\alpha$ and $\beta$, presents mutarotation and forms Osazon due to the fact that it has free hemiacetalic hydroxyl in the Glucose molecule.

**Formative Assessment 9:**

Compare the structure and properties of Amylose and Amylopectin!

Both Amylose and Amylopectin are made up of D-Glucose units, differing from each other by size and shape of the molecule.

Amylose form linear chains, of Glucose molecules that are linked in the form $\alpha$- (1, 4) - glycosidic.

Has a mass that varies from 150 000 to 600 000 and corresponds to between 1000 and 4000 glucose units. It is easily soluble in water.

The Amylose link in solution adopts an elliptical form, because of the $\alpha$ configuration of all glycosidic links. Because these chains are wrapped around they create spaces (interstices).

Amylopectin is a highly branched molecule. The links throughout the chain are made in the form of $\alpha$-(1-4)-Glycoside, and in the form $\alpha$-(1-6)-Glycoside on the branching points.

The short chains (branches) have around 20 to 25 units of Glucose.

Its relative mass varies from 200 000 to 1000 000.

Amylopectin makes up the main component in starch (ca. 80%).

Due to the degree of branching it is not very soluble in water.

What is the importance of Cellulose in the biological system?

Cellulose serves as the material for plant support.

It can also be in taken by herbivores for the production of essential units for their metabolism.

**Key terms**

<table>
<thead>
<tr>
<th>Carbohydrates or Glucids</th>
<th>Monosaccharide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oligosaccharide</td>
<td>Polysaccharide</td>
</tr>
<tr>
<td>Aldose</td>
<td></td>
</tr>
<tr>
<td>Ketose</td>
<td></td>
</tr>
<tr>
<td>Oxocyclo-tautomerism</td>
<td></td>
</tr>
<tr>
<td>Mutarotation</td>
<td></td>
</tr>
<tr>
<td>Reductor sugar</td>
<td></td>
</tr>
<tr>
<td>Asymmetric Carbon</td>
<td></td>
</tr>
</tbody>
</table>
Carbohydrates or Glucids: Chemically Carbohydrates and Glucids are Aldehydes or Ketones containing polyhydroxyl group or compounds that through hydrolysis, can be transformed in these.

Monosaccharide: Simple sugars formed by a basic non hydrolysable unit generally with five to six Carbon atoms.

Oligosaccharide: Sugars made up of two to ten basic units of monosaccharide. Oligosaccharides are hydrolysable in simpler compounds (monosaccharide).

Polysaccharide: The carbohydrates which can hydrolyze in many units of monosaccharides (may reach about 100000 units).

Aldose: Sugar which main functional group is aldehyde.

Ketose: Sugar which main functional group is aldehyde.

Oxocyclo-tautomerism: Equilibrium of three tautomeric forms, of monomers α, β and the cyclic form of sucarese denominated oxo-cyclo-tautomerism.

Mutarotation: The occurrence of changes in the angle of deviation of monomers α and β up to the value of equilibrium is denominated mutarotation.

Reducing Sugar: Sugar with at least one free functional group capable of oxidation reduction reactions.

Symmetric carbon: Carbon with four different substituents. Chiral Carbon
Learning activity 2

The learning activity 2 (two) offers essential knowledge about Proteins, its composition, structure, main physical and chemical properties, its biological activity, as well as issues correlated with stereoisomerism of these compounds.

Proteins are vital bio compounds for the life on Earth.

They are found in all organisms and as essential part of their structure and functioning.

The study of Unit 2 (Proteins) takes approximately 45 studying hours. Here attention should be paid to references, taking notes, making summaries and answering to formative questionnaires for orientation which can be found along the sheet work.

List of REQUIRED readings

2. http://pt.wikipedia.org/wiki/Liga%C3%A7%C3%A3o_pept%C3%ADdica(Peptide bond)

List of relevant useful links:

   http://www.google.com/search?hl=en&q=Estrutura+das+proteinas(protein structures)
   (Carbon hydrates/nucleic acids/lipids /functions

List of relevant MULTIMEDIA resources: (The Molecules of life) == Screm capture

http://biop.ox.ac.uk/www/mol_of_life/index.html

Read with attention the reference and take notes in regard the following matters:

- Proteins
- Composition of Proteins
- Essentials Amino acid
- Peptide linkage

Importance and structure of proteins

- Proteide (DNA and RNA)

The process of acquiring skills and abilities offered in this module are facilitated by solving the following tasks:
Task 1: Introduction to Proteins

– Concept of Proteins
– Occurrence, composition and importance

Task 2: Amino acids

2,1 - Structure of Amino acids
2,2 – Properties of Amino acids
2,3 – Reactions of Amino acids
2,4 – Essentials Amino acids

Task 3: Peptides

3,1 – Structure of peptide linkage
3,2 – Formation of peptide linkage

Task 4: Proteins

4,1 – Primary structure
4,2 – Secondary structure
4,3 – Tertiary structure
4,4 – Quaternary structure

Task 5: Proteins

5,1 – Proteide structure
5,2 – Nucleoproteins
5,3 – Ribonucleic acid (RNA)
5,4 – Deoxyribonucleic acid

Formative evaluation:
Along the text you will find questions for orientation which you should answer.

Learning activities

Task 1: Introduction to Proteins

The readings on Proteins will familiarize you with important biomolecules for organisms. The Chapter offers an overview of Proteins and its functions and basic structure.

Proteins are considered biopolymers of life.
1,1 – Concept Protein

Proteins (or albuminous substances) are especially important among natural products that constitute living cells. The name protein originated from Greek proteos, meaning ‘first’. This name was certainly chosen because among all chemicals, they are indeed the substance of life. Together with the Hydrates of carbon and fat, they are essential components of animal food.

Proteins are natural polymers constituted by Amino acids units.

Judging by its functions Proteins are classified as fibroses (p.e. Keratin, collagen), contractile (ex. myosin, actin) and globular (hormones and enzymes, p.e. insulin).

However all Proteins are natural polymers constituted by high number of basic units of Amino acids bonded by peptide linkage.

1,2 – Occurrence, composition and importance

Proteins are macromolecules which constitute about ¾ of dried weight of the majority of animals, and are involved in the structure and function of any living organism.

Some Proteins have pure structural function (as example Keratin which is the important component of skin, hair and nails or Collagen which is component of fibres and tendons and forming bones, myosin and actin as components of muscles). Many other Proteins have catalytic functions (enzymes), allowing the occurrence of chemical reactions in living systems. Other Proteins have regulation functions acting as hormones in many physiological processes (growth, metabolism, reproduction and functioning of many organs). For example, insulin controls the metabolism of carbohydrates and lipids. Yet other Proteins participate in the immunologic system protecting the organism (antibody).

It’s is calculated that in human body exist around 5.000.000 of different Proteins, each of them doing specific and necessary functions for the good development and life or organisms.

The amount of Proteins differs from specie to specie and among individuals from the same specie.

Formative assessment 1:

– Define and classify proteins!
– What is the function of proteins in the organism?

Task 2: Amino acids

Task two, offers an overview on basic units of proteins (Amino acids) as well as the historic development of it’s discovering.

In 1820, was found out that when heated gelatin protein with diluted acids, they would break down in its basic components.

It was seen that one of the main components was the molecule of Glycine NH2CH2COOH, which is the simplest of the compounds known as Amino acids.
Structurally, Glycine can be considered as a derivative from Acetic acid, CH₃COOH replacing one Hydrogen atom (H) by an amino group (-NH₂).

\[
\begin{align*}
\text{COOH} & \quad \text{COOH} \\
\text{I} & \quad \text{I} \\
\text{H – C – NH₂} & \quad \text{Amino acid} & \quad \text{H – C – NH₂} & \quad \text{Glycine} \\
\text{I} & \quad \text{I} \\
\text{R} & \quad \text{H}
\end{align*}
\]

2.1 – Structure of Amino acids

Amino acids (AA) are bifunctional compounds that contain one acid function due to the presence of a carboxyl group and one basic function originated from the presence of an amino group.

Amino acids, in general, can be differentiated according to the group Amino position in acids a, b, c, d etc. amino carboxylic.

From 1820 to 1935, various experiments were made to identify all the amino acids that make up a Protein. Although in this process there were found many amino acids in nature, it was observed that only 20 of them occur regularly in Protein.

The \(\alpha\)-amino acids are the most important ones, given that they make up the structural units of Proteins, which can be produced by hydrolysis.

All known amino acids, form isomers except Glycine which doesn’t have an Asymmetric carbon.

Most natural amino acids that form intracellular Proteins have an L configuration, but in some natural substances there were found substances of the series D, mainly in microorganisms. For example, in Streptococcus Faecalis there is a D-Alanine content of 39-50%, this value can reach 67% in Staphylococcus Aureus.

D-amino acids were also identified as substances that are products of the biological activity of these microorganisms.

Amongst all amino acids Serine was conventionally established as the referent amino acid for the series D and L having as standard the position of \(\alpha\)-amino group.

\[
\begin{align*}
\text{COOH} & \quad \text{COOH} \\
\text{I} & \quad \text{I} \\
\text{H₂N – C – H} & \quad \text{H – C – NH₂} \\
\text{I} & \quad \text{I} \\
\text{CH₂OH} & \quad \text{CH₂OH} \\
\text{L – Serine} & \quad \text{D- Serine}
\end{align*}
\]
However, most natural amino acids differ only in the structure of the organic residue linked to Carbon $\alpha$.

Of the AA that is found in nature, only about 20 are components of Proteins in the living organisms. The others are either intermediary products or final products of metabolism.

### 2.2 Properties of Amino acids

Contrary to Amines and carboxylic acid amino acids are crystalline solid, non volatile, and melt in decomposition, at very high temperatures.

They are soluble in water and insoluble in organic non polar solvents, just like petroleum ether, o benzene, diethyl ether, etc.

The respective aqueous solutions behave like solutions of high dipole moment.

Its acidic and basic constants are excessively small, compared with the carboxylic acid’s constants (-COOH) and of amines (-NH$_2$).

A Glycine, for example, has $K_a = 1, 6 \times 10^{-10}$ and $K_b = 2, 5 \times 10^{-12}$, while the majority of the carboxylic acids have $K_a$ values of about $10^{-5}$ and the majority of aliphatic amines have $K_b$ values of about $10^{-4}$.

The R-CH(NH$_2$)COOH molecule contains an acidic group and a basic group, but in fact this species does not exist in the solid state nor does it exist as a solution, but forms an internal corresponding salt.

$$\begin{array}{c}
\text{R- CH(NH}_3\text{) COO} \\
\end{array}$$

### 2.3 Amino acids reactions

Although the AA have two functions, one basic and one acid, because of the presence of the carboxylic and amino groups in their structure, in fact these compounds are found in the form of bipolar ions, and not in the ionized form. These way, the AA have a saline structure (of an internal salt) dipolar.

$$\text{R – CH – COOH } \xrightarrow{\text{–}} \text{R – CH – COO}$$

$$\begin{array}{c}
\text{NH}_2 \\
\text{NH}_3
\end{array}$$

Acid basic structure          Saline structure

Because of the bipolar structure the AA can take protons of give them away, this meaning, they behave like acids and bases: they are amphoterics. In the presence of a strong acid (H$3$O$^+$) the AA react like bases, accepting protons.
\[
R - CH - COO + H3O+ \rightarrow R - CH - COOH + H2O
\]

\[
+ I \quad \quad + I
\]

\[
NH3 \quad \quad NH3
\]

Strong base      strong acid      weak acid      weak base

In the presence of a strong base AA gives away one proton.

\[
R - CH - COO + OH \rightarrow R - CH - COO + H2O
\]

\[
+ I \quad \quad I
\]

\[
NH3 \quad \quad NH2
\]

Strong acid      strong base      weak base      weak acid

Resumed:

\[
- \quad -
\]

\[
OH \quad - \quad OH \quad -
\]

\[
R - CH - COOH \rightarrow R - CH - COO \rightarrow R - CH - COO
\]

\[
+ I \quad H+ \quad I \quad H+ \quad I
\]

\[
NH3 \quad +NH3 \quad NH2
\]

### 2.4 Essential amino acids

In the human species there are eight (8) “essential amino acids” that cannot be synthesized by the organism (Leucine, Isoleucine, Methyonine, Tryptophan, Valine, Tyrosine and Phenylalanine) these are compulsory in taken through our diet, already as complete structures. These are called essential amino acids not because they are the only indispensable for our organisms normal functioning but because they are essential in our diet.

The other 12 amino acids can be synthesized in the cells from simpler products that have C, H, O and N.

Although, AA’s and Protein’s production from inorganic compounds are only possible in plants.

**Formative Assessment 2:**

What do you understand by amino acid?

What are the properties of amino acids?

What are essential amino acids?
Task 3: Peptides

In this task you will get familiar with the formation of Proteins basic structures.

Peptides result from the fusion of amino acids through the Amine groups of one amino acid with the carboxylic group of another amino acid.

Proteins are characterized by the amide group (-NH-CO-) called Peptide bond.

Formally the peptide bond is formed by the “fusion” of the amino and carboxylic groups of two amino acids with the release of water.

Subsequent polymerizations are possible, this because the presence of a free amino group (NH2) and of a carboxylic group (COOH) in the peptide which can be bonded with the other amino acid molecules. The resulting molecule of two amino acids, containing, only one peptide bond, is called dipeptide, derived of three amino acids and a tripeptide. It is common to call the molecule class resulting from the relatively small peptides of amino acids, and the class of molecules with a high number of amino acids (with more than 70 units) of Peptides or Proteins.

3.1 Structure of the Peptide bond

The peptide bond – COHN-, that unites the acidic and basic residues in the proteins have a specifically plane constitution. All four atoms of the bond are found on the same plane. The link N-C is shorter comparing to aliphatic amines (R-NH2) where their length is 0, 147nm. These reduction of length and the disposition of the bonds is because of the existence of conjugation N-C and C=O and of the dislocation of the electronic density, this means, the bond N-C is partially double and the C=O is partially simple.
The existence of a double partial double bond N-C stops the rotation of the molecule around this bond. Although the most important is the possibility of rotation through the links with the carbons α of the amino acids residues, allowing that way the formation of various conformations.

### 3.2 Formation of the Peptide bond

The formation of the peptide bond isn’t a process as linear as it was presented above. This process is very energetic, for that it is resorted to derivates with a lot of energy.

\[
\begin{align*}
\text{O} & + \text{NH}_3 \\
\text{II} & \\
\text{CH}_2 - \text{C} - \text{Cl} & + \text{H}_2\text{N} - \text{CH} - \text{COOR} & \rightarrow & \text{CH}_2 - \text{CONH} - \text{COOR} & \rightarrow & \\
\text{I} & \quad \text{I} & \quad \text{-HCl} & \quad \text{I} \\
\text{Cl} & \quad \text{CH}_3 & \quad \text{Cl} & \\
& \rightarrow & \text{CH}_2 - \text{CONH} - \text{CH} - \text{COOR} & \\
& \quad \text{I} & \quad \text{I} \\
& \quad \text{NH}_2 & \quad \text{CH}_3
\end{align*}
\]

The modern synthesizing methods have three phases:

- a. Introduction of the protector group.
- Use of catalysts that increase gain of the peptide link.
- Decrease on the minimum tendency of amino acids’ racemic modification.
b. Formation of the peptide bond

It is used to derive amino acids N-terminus rich in energy, mainly halides, azides etc.

\[
\text{Amino acid} + \text{H}_2\text{N} - \text{CH} - \text{COOR} \rightarrow \text{Peptide bond}
\]

\[
- \text{HCl}
\]

\[
\text{Amino acid}
\]

c. Separation of the protector group

d. Catalytic hydrogenation

Introduction of bromide water/ glacial acetic acid or acid triflouroacetic anhydrous

\[
\text{Peptide}
\]

\[
\text{Product of reduction}
\]

3.3 Recognition of a Peptide link

The Peptide bond can be amongst others recognized by the reaction of the amino acids.

Reaction with Ninhydrin

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>Ninhydrin</th>
<th>Product of reduction</th>
</tr>
</thead>
</table>

65
Task 4: Proteins

This task refers to an important class of bimolecular compounds, which do not only provide the body with Carbon and Hydrogen but also with Nitrogen and Sulphur.

As a side functions protein molecules protect the body against infection, mechanical support and catalysis of metabolic reactions.

Proteins are biological molecule important for animal and vegetal life.

Structurally they are polymer molecules formed by a large number of fundamental units, amino acids, bounded by peptide linkage. Proteins are multifunctional units, serving as much as structural material of plants and animals, as well as biological catalysts (Enzymes), and even as protectors (antibodies).

Generally proteins are mixes, made up of polypeptide chains with a molar mass that varies from 10 000 to various millions.

Proteins have a acidic side and a basic side representing by that amphoteric substances.

Proteins are divided in two classes: Fibrous proteins, insoluble in water, and globular proteins soluble in water or aqueous acids, bases or salts.

In water they form colloidal solutions.

The resulting solutions are colloidal, due to the great dimensions of the protein's molecules. These colloids precipitate and form flakes when they are added to a salty solution. This precipitation (only physical change) is reversible because it doesn’t result in a physical change of the chemical properties.
Protein’s solubility depends on the PH and the salt contents present in the solution. The difference, between the two classes as to what regards solubility, is related with the respective form of molecules which is coarsely shown by their respective names.

The fibrous molecules are long and filamentous and tend to be placed side by side, with the formation of fibers; in some cases the molecules keep this disposition due to numerous intermolecular hydrogen bonds. For this reason the intermolecular forces that a possible solvent has to win are very strong. The globular protein molecules are found folded on themselves in compacted units, with which frequently has spheroid shape. The folds are produced in a way that the lipophilic parts will turn inside out and towards each other tight in, for example- bristle to the exterior surface when drenched in water. The existing Hydrogen bombs are mainly intermolecular. The contact areas are comparatively weak.

In the presence of acids or bases the Protein suffers denaturation (a chemical reaction occurs).

The Proteins are also denaturated by heat (high temperature), by urea and guanidine salts.

The Proteins are generally identified by the chromatic reactions. (Reaction with Nyhnidrine, Biuret etc.)

**4.1 Primary structure**

The structure of a Protein is determined by the number, type and by the sequence of amino acids in the protein chain, linked by amidic bonds (peptide).

Protein’s macromolecules are made up of one or various peptide chains.

In the chain we call the side where we find the extreme Amid group N- terminus and the side with the extreme Carboxylic group C- terminus.

The molecular masses that characterize the polypeptide chain in the Proteins are about 20 000 what corresponds to 150 to 180 amino acids residue (the average molecular mass of a AA residue is ca. 120)

Although the primary structure, doesn’t explain the physiological properties nor the spatial configuration of the Proteins.

**4.2 Secondary structure**

The secondary structure represents a spatial configuration of the amino acid chain. It concerns the spatial relation between the close residues, due to way in which the polypeptide chains are arranged in space because of the ionic atractions or formation of Hydrogen bonds.

Of the primary structure (long sequences of amino acids) it would be expected shapeless and badly defined structures for the Proteins. But in fact practical observations show that many Proteins were isolated in crystalline form, which means that the polymer presents a well defined distribution. This structure is characterized by the formation of conformations, which result in the interaction between the amidic groups of the same molecule or different molecules forming Hydrogen bridges.
Given that amicic bonds (peptides)-CONH- have a planar shape, the Hydrogen bonds can be intracellular originating α helical structures (characteristic of the elastic proteins. For example, in keratin α in wool, hair and other body hair on animals) or can be intercellular originating a β structure, pleated sheet (pleated sheet -β). For example, fibroin in silk sheets, which are flexible but not much elastic.

### 4.3 Tertiary structure

The not well defined border with the previous structure, concerns more with the interactions between distant residues in the polypeptide chain because of the fold of this chain determined by the different types of bond previously referred to: nonpolars, ionics, of Hydrogen and even disulfide bods.

The tertiary structure results from the interaction of the functional groups of the chain. Describes as the spiral is bent and curved. When taking this spiral shape, what originates the appearance of a special configuration, the tertiary structure of Proteins, this meaning, the three-dimensional spiral shape that the protein molecule.

This structure is kept by the interaction between the functional groups of the chain. By a carboxylic group and a hydroxyl group, an Ester forms, the sulphur atoms form disulfide linkage (-S-S-).

This way we can get two types of Proteins: As fibrous, of regular shape in helical α or pleated sheet-β, and the globular, generally of a mixed structure, with various shape, these being the ones that most properly is applied the designation of tertiary structure. It is important to note that Enzymes always belong to this last category.

### 4.4 Quaternary structure

This designation is reserved in the case the Protein is made up of various sub units, equal or different, referring at how they are associated.

This is the most complex and less clarified.

It influences the chemical and biological activities of the Protein.

An example of this is Hemoglobin, which is made up of four sub units, two of each type, disposed alternately like quarters of an sphere.

**Formative assessment 4:**

1. Classify Proteins by their type?
2. What are the principal structures of Proteins?
Task 5: Proteide

Task 5 introduces a family of compounds proteics linked to components of different nature. These compounds have very specific functions in the organism.

In some cases, to determine the functions, the globular proteins combine with other non protean compounds, their designation coming from their nature.

The most important types are:

- Lipoproteins- Proteins linked to a lipid-, principal components of the plasmatic membranes;
- Mucoproteins- when Proteins link to Carbon hydrates-, components of intracellular fluids and blood plasma;
- Nucleoproteins- association of special Proteins and nucleic acids-, frequent state of nucleic acids;
- Metal proteins- Proteins combined with metallic elements or prosthetic group containing metallic elements- normally enzymes or pigments transporting small molecules, like Hemoglobin. This type of Proteins is called Proteide or conjugated proteins.

5.1 Proteide’s structure

In some Proteins, the molecule has a non peptide portion, called prosthetic group; these Proteins are called conjugated proteins of Proteide.

The Prosthetic group is closely related with the biological specificity of the Protein.

For example, Lipoproteins

The Protein is linked to a lipid.

5.2 Nucleoproteins

Are found in the nucleus of living cells. The prosthetic group are nucleic acids. Ex. DNA, RNA.

These macromolecules are called semantics because they transport information.

The Nucleoproteins can be isolated by the extraction of living cells with water, alkalis, sodium chloride or tampon solution (4-7).

After the extraction follows the precipitation of Proteins by acids, ammonia sulphate or calcium chloride.

Next follows a Hydrolysis that can be acidic or enzymatic.

A Hydrolyzed Protein is fractioned in various components namely:

a) Organic Nitrogen bases (purine and pyrimidine);

b) Monosaccharide (pentose: ribose and desoxiribose);

c) Phosphate group
The nitrogen bases derived off purin and pyrimidin.

Only five of them are used they are: Adenine and Guanidine (purin), cytosine, timin and uracil (pirimidinas).

<table>
<thead>
<tr>
<th>Purine bases</th>
<th>Pyrimidine bases</th>
</tr>
</thead>
</table>

There are two pentoses found in Nucleoproteins they are: ß-D-ribose and ß -D-2-desoxiribose. These carbohydrates differ only in the existence of one more oxygen atom in Ribose.

<table>
<thead>
<tr>
<th>ß-D-ribose</th>
<th>ß-D-2-desoxiribose</th>
</tr>
</thead>
</table>

The ß-D-ribose sugar is found in Ribonucleic acids (RNA) while ß-D-2-desoxiribose are found in Desoxi-Ribonucleic acids (DNA).

While in the dorsal spine the Protein molecule is a polyamidic chain (one polypeptide chain), the nucleic acid’s molecule’s is a polyester chain (called polynucleotide chain). The ester derives from phosphoric acid (the acidic part) and from a sugar (the alcoholic part):

```
  base          O          base          O          O
  |             |             |             |             |
sugar – O – P – O – sugar – O – P – O / Phosphate group - O – P - OH
  |             |             |             |             |
  O             O             O             OH
```
The Phosphate group functions like a linking bridge between the monosaccharide molecules; the basic skeleton of nucleic acids is in fact a long chain of alternate Pentoses with a Phosphate group.

The units of sugar have a furanosic shape and are linked to the Phosphates by the C-3 and C-5 Hydroxyl groups.

The organic bases are linked to the pentoses by glycosidic linkage. The set is called Nucleoside.

When the Nucleoside is esterified by Phosphoric acid, in the Hydroxyl group in position 5 transform into Nucleotide.

The Nucleotides like AMP can attain more Phosphate groups, that confer reactivity. The successive bonds (2nd and 3rd) have higher energy content and the resulting compounds (ADP and ATP) are used as some sort of energy reserve for the metabolic reactions that are needed by them.
Ribonucleic acid (RNA) consists of ribonucleosides bonded together in a polymer. The ribonucleoside subunits are linked by phosphate esters. The 5’hydroxyl group of each nucleoside riboforanoside is esterified to phosphoric acid. Ribonucleoside that is phosphorylated at its 5’carbon is called a ribonucleotide.

5.3 Ribonucleic acid (RNA)

Ribonucleic acid (RNA) is a simple polymer of Nucleotides containing four to five mentioned nitrogen containing bases (Adenine, Guanine, Cytosine, Uracil) and only one of the two monosaccharide - β-D-ribose; normally occurs in two linear chains, but there are also cyclic shapes known.

5.4 Deoxyribonucleic acid (DNA)

Deoxyribonucleic (DNA) is much more complex and has molecular weight much higher than RNA. It is also a linear or cyclic polymer of Nucleotides with four nitrogen containing bases, but Uracil is now substituted by thymine.
On the other side, DNA does occur in simple chains, but in double chains twisted in helix (double helix), this structure is kept by Hydrogen bonds formed by the organic bases two by two: Adenine-Thymine and Guanine-Cytosine. The set resembles a rope ladder, strand made up of alternative residues of Deoxiribose and Phosphate and the degrees plan of the organic bases linked by the pairs.

DNA is an “instructional manual” for Protein synthesis; the instructions are coded and the code is simple arranged from the different organic bases throughout the chain- each group of three successive bases (named “codon”) specifies an amino acid, this way, the series of amino acids that makes up each Protein can be read in the DNA chain using proper techniques.

Generally, the instructions are “transcribed” to the ribonucleic acid found in the Ribosomes and there occurs the synthesis of the different Proteins. The agent of this transcription and transporter of the message is also a fragment of ribonucleic acid known as “messenger” (m-RNA).

DNA can also replicate itself, to pass on its information content when a cellular division happens, and the process involves the progressive untangle of a double helix (just like closing a zipper) and the concomitant formation of two new complimentary helixes from individual filaments and off neighboring swimming nucleotides, which will link once more in the order given by the ordering code of the organic bases. As always, the reactions are catalyzed by the appropriate enzymes.

The nucleic acids normally occur associated with Proteins, therefore being called Nucleoproteins. This is the material that makes up Chromosomes and, curiously, also the majority of viruses.
In fact viruses are primary form of protection of a particular set of information, nut lacking techniques for reading the information and materials that allows its auto reproduction; this is only possible through the “infection” of a host, for example a bacteria, which provides these requisites.

Formative assessment 5:

Define Proteide!

What is the composition of Nucleic acids

Define the following concepts: Nucleotide, and Nucleoside!

**Key terms**

<table>
<thead>
<tr>
<th>Amino acid</th>
<th>Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peptide</td>
<td>Peptide bond</td>
</tr>
<tr>
<td>Nucleoside</td>
<td>Nucleotide</td>
</tr>
<tr>
<td>Nucleoproteins</td>
<td>prosthetic group</td>
</tr>
<tr>
<td>RNA</td>
<td>DNA</td>
</tr>
</tbody>
</table>

**Amino acids**: Amino acids (AA) are bi-functional compounds that have an acidic function, due to the presence of a Carboxylic group, and a basic function, originated by the Amino group. It constitutes the basic units of Proteins.

**Protein**: Proteins are natural polymers made up of Amino acid units linked by a Peptide bond.

**Peptide**: Molecule formed by some Amino acids linked by Peptide bonds.

**Peptide bond**: Amid group (-NH-CO-) that makes the link between Amino acids in the Peptides and Proteins, named Peptide bond.

**Nucleoside**: Group made up of organic bases linked to Pentose by glycosidic bonds.

**Nucleotide**: Group made up of organic bases linked to Pentose by glycosidic bonds and esterified by Phosphoric acid, in the Hydroxyl group position 5.

**Nucleoproteins**: The association between special Proteins and Nucleic acids.

**Prosthetic group**: Non proteic group linked to a protein

RNA: Ribonucleic acid
DNA: Deoxyribonucleic acid
Formative assessment

Formative assessment 1:

Describe and classify Proteins!

Proteins are natural polymers made up of Amino acid units linked by a Peptide bond.

Depending on the function they are classified as fiber proteins (ex. Queratina Colagens), contracte Proteine (ex. Miosine, Actin) and globule Proteine (hormones and enzymes; ex. Insulin).

What is the function of Proteins in the organism?

Some Proteins have purely structural functions (ex. keratin or Collagen) others have catalyzing functions (enzymes), other Proteins have a regulating function acting as hormones in many physiological processes (growth, metabolism, reproduction and the functioning of many organs). Others participate in the immune system that defends the organism (antibodies).

Formative assessment 2:

What do you understand by Amino acids?

Amino acids (AA) are bi functional compounds that have an acidic function, due to the presence of a Carboxylic group, and a basic function, originated by the Amino group. It constitutes the basic units of Proteins.

What are the properties of Amino acids?

Amino acids are crystalline solids, non volatile, that melt in decomposition, at very high temperatures.

Are soluble in water. Its respective aqueous solutions behave like solution of high dipole moment.

Its acidic and basic constants are excessively small, when compared to Carboxylic acid’s (-COOH) constants and of the Amines (-NH2).

The R-CH(NH2)COOH molecule has an acidic and a basic group, but in fact this species does not exist neither in its solid state nor as a solution, but forms a correspondent internal salt.

\[ \text{R-CH(NH}_3\text{COO} \]

What are essential Amino acids?

In the human species there are eight (8) “essential amino acids” that cannot be synthesized by the organism (Leucin, Isoleucin, Methyonine, Tryptophan, Valine, Tyrosine and Phenylalanine) these are compulsory in taken through our diet, already as complete structures.
**Formative assessment 3:**

What are Peptides?

It is common to label the class of molecules resulting from a number relatively small of Peptide's Amino acids.

Peptides are characterized by a Amid group (NH-CO-) named Peptide bond.

Characterize a Peptide bond

The Peptide bond –CONH-, which unites the acidic and basic residues in the Proteins have specifically plane structure. All four atoms of the bond are on the same plane. The link N-C is shorter in relation to aliphatic amines (R-NH2) with a length of 0. 147nm. this decrease in length and the disposition of the bonds on a plane is caused by the existence of N – C and C = O conjugation and of the delocalization of the electronic density, this is, the bond N – C is partially double and C = O is partially simple.

**Formative assessment 4:**

Classify Proteins by their type?

Proteins are divided in two big classes: fibrous proteins, not soluble in water, and globular proteins, soluble in water or aqueous solutions whether they are acidic, basic, or salts.

In water they form colloidal solutions.

What are the principal structures of Proteins?

The principal structures of Proteins are four:

- Primary structure (Number, type and sequence of Amino acids)
- Secondary structure (α-Helix and β-pleated sheet)
- Tertiary structure (three dimensional structure, spiral or folded)
- Quaternary structure (Complex association of structures)

**Formative assessment 5:**

Define Proteide

They are Proteins, with a molecule that has a non peptide portion, known as prosthetic group; such Proteins are called conjugated proteins or Proteide.

What is the composition of Nucleic acids?

Nucleic acids are made up of:

- Organic nitrogenous bases (purine and pirimidine)
- Monosaccharide (pentoses: ribose and deoxiribose)
- Phosphate group
The Nucleic acid's molecule's spinal is a Polyester chain (known as Polynucleotide chain). The ester derives from the Phosphoric acid (the acidic part) and from a sugar (the alcoholic part).

Define the following concepts: Nucleotide, and Nucleoside

Nucleoside is a set made up of organic bases linked to pentoses by glycosidic linkage.

When a nucleoside is esterified by Phosphoric acid, in the Hydroxyl group position 5 it turns into a Nucleotide.
Learning activity 3

Title of learning activity: Lipids

Summary of the learning activity:

Learning activity 3 focuses on an important group of biomolecules with structural functions, the protection of reserves mainly energy reserves.

The concept of a Lipid covers a group of biomolecular compounds with varying composition with a common factor its solubility in non polar solvents.

In this activity we will examine the structures, reactivity and functions of Lipids.

The activity requires around 30 working hours.

List of REQUIRED readings:

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

http://pt.wikipedia.org/wiki/L%C3%ADpido (Definition and composition) / Structure /Classification

http://biology.clc.uc.edu/Courses/bio104/lipids.htm

http://www.cem.msu.edu/~reusch/VirtualText/lipids.htm (Oils and fats / Soaps and detergents)

List of relevant useful links:


http://pt.wikipedia.org/wiki/Fosfol%C3%ADpido (Phospholipids)

http://www.dbio.uevora.pt/jaraujo/biocel/lipidos.htm Definition/structure/classification/ Glycerides/conjugated lipids

List of relevant MULTIMEDIA resources:

Screm capture

http://www.scite.pro.br/tudo/pdf.php?-quimicamodulo

Detailed description of the activity):

Carefully read the references and take notes about the following points and answer the formative assessments:

- Concept of Lipids
- Composition of Lipids
Types of Lipids (Fats, oils, waxes)

Fatty acids
- Glycerides

Functions of Lipids

In order to help get the capabilities and abilities offered by this module the following task should be solved:

**Task 1: Lipids introduction**
- Concept of Lipids
- Function of Lipids

**Task 2: Fatty Acids**
2.1 – Structure and properties of fatty acids
2.2 – Identification of the properties of fats and fatty acids

**Task 3: Glycerides**
3.1 – Structure of Glycerides
3.2 – Classification of Glycerides
3.3 – Properties of Glycerides
3.4 – Phosphatides

**Task 4: Fats and oil fats**
4.1 – Chemical properties of fats
4.2 – Characterization of fats

**Task 5: Waxes**

**Formative evaluation**
Find included in the text formative activity for auto evaluation.

Learning activities (THE ACTIVITY(IES) THEMSELVES):

**Task 1: Lipids introduction**
Task one (1) of learning activity three introduces a heterogeneous class of bio compounds the organism cannot function without.
This group of compounds as well as having functions of support, protection, and energy, present the solubility of non polar solvents.

**Concept of a Lipid**

The animal and vegetal fats like lard, butter, olive oil, oil fats, natural waxes and Phosphatides are all known as Lipids. They are natural compounds with little or no solubility in water. In this group are also included mineral oils (Hydrocarbons) and etheric oils (terpens and steroids). In general they are esters of carboxylic acids with high molecular weight (fatty acids).

This is an interesting group of natural organic substances because other than having a great importance in our diet, they also make up the base for the manufacturing of other industrial products.

The majority of the use of fatty substances is found in the food industry, because fats are the most concentrated source of energy for humans, supplying more than double the amount of energy supplied by an equal amount of carbohydrates; but a diet with high levels of animal fat causes heart diseases; being as a substitution for them vegetal oil (peanut oil, sunflower oil, etc.).

The main varieties of fats and oils are soya oil, sunflower, palm, peanut, cotton, colza (a variety of spring greens used as fodder for cattle, a type of oil used in lighting is extracted from its seeds), olive oil, and fish oils.

These substances are also used in other industries, like the pharmaceutical industry (Ex. ricin oil is laxative, cod fish oil is reconstituent), polishes industry (linen oil, wood oil); industrial chemistry (production of fatty acids, soaps, glycerin, and tensioactive, etc.).

Even though fats are mainly Lipids they do not have any non lipid organic substances, so we will find essential components the Glycerides (mono-, di-, and triglycerides) and secondary components (saturated and non-saturated Hydrocarbons, Phosphoglycerides, vitamins, chorants and terpenic acids).

**Function of Lipids**

Fats are essential substances for the nutrition of organisms. They constitute the reserve substance of the organism and are the richest source of energy in the body.

Fats with around 40Kj/g have more than double the heat of physiological combustion of carbohydrates which offer (ca. 16.7KJ/g).

Linolic acid and linolenic Acidos linolic and linolenic “essential fatty acids” are indispensable for the human’s diet, that’s why they have to be added as solidified fats. Fat solidification (Norman 1909) has great economical importance. Low cost animal and vegetal oils are that way turned into valuable fat used in the technique.

Synthetic fats are used in soap production.
Formative assessment 1:

1. Define lipids
2. Give some functions and applications of lipids

Task2: Fatty acids

This task identifies and differentiates carboxylic acids of great molecular weight most frequent in Lipids. In this chapter there will also be practical tasks that can be done in a simple laboratory or even at home with objects used on a daily routine.

2.1 Structure and properties of fatty acids

Carboxylic acids with high molecular weight (ca. 12 to 20 carbon atoms) are called, Fatty acids. Fatty acids are subdivided into saturated and unsaturated.

The fatty acid that is the most important and of greatest molecular weight is Oleic acid (C17H33COOH), is an unsaturated acid with a double bond.

Oleic acid is found in practically every natural fat in varying amounts.

Vegetal fats (of coconuts, of palm) have amongst others lauric acid (C11H23COOH) and miristic (C13H27COOH).

Animal fats (butter, tallow, pig lard) have preferably Glycerides of palmitic (C15H31COOH) and estearic acid (C17H35COOH).

Natural fats are almost without exception made up of non branched fatty acids with an even number of carbon atoms (synthesized Glycerides for diet can also have odd number of carbon atoms).

Unsaturated fatty acids always show a cis (Z) configuration on the double bond.

Many compounds with the cis configuration hardly fit in the crystalline net and that’s why generally they melt at much lower temperatures its trans isomers (E).

The most frequent acids in that constitute Glycerides are:

<table>
<thead>
<tr>
<th>Name of the acid</th>
<th>Formula</th>
<th>Number of Carbons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palmitic Ac.</td>
<td>CH3(CH2)14COOH</td>
<td>16</td>
</tr>
<tr>
<td>Estearic Ac.</td>
<td>CH3(CH2)16COOH</td>
<td>18</td>
</tr>
<tr>
<td>Oleic Ac.</td>
<td>CH3(CH2)7CH = CH(CH2)COOH (cis)</td>
<td>18</td>
</tr>
<tr>
<td>Lauric Ac.</td>
<td>CH3(CH2)10COOH</td>
<td>12</td>
</tr>
<tr>
<td>Miristico Ac.</td>
<td>CH3(CH2)12COOH</td>
<td>14</td>
</tr>
<tr>
<td>Linoleic Ac.</td>
<td>CH3(CH2)4CH = CH-CH2-CH=CH(CH2)7COOH</td>
<td>18</td>
</tr>
<tr>
<td>Ricinoleic Ac.</td>
<td>CH3(CH2)5CH(OH)CH2-CH=CH(CH2)7COOH</td>
<td>18</td>
</tr>
</tbody>
</table>
Formative assessment 2:
Define and classify fatty acids!
Give examples about the occurrence of fatty acids!

Task 3: Glycerides

The activity in this task evolves around the basic structures of fats and oils.

The solid or semi-solid fats as well as fatty oils (liquid fats) are Glycerol esters and carboxylic acids with great molecular weight (ca. 12 to 20 carbon atoms) known as fatty acids. Due to the fact that they are Glycerol esters they are also called Glycerides. Natural fats also have different compositions given that Glycerol can be esterified with only one type of acid molecules (simple Glyceride) or simultaneously by various different fatty acid molecules (mixed Glyceride).

3.1 Glyceride’s structure

Natural fats can also have different compositions given that Glycerol can be esterified with only one type of acid molecules (Simple Glyceride) or simultaneously by various different fatty acids’ molecules (mixed Glyceride).

General structure of Glycerides

\[
\begin{align*}
CH_2 – O – CO & - R1 \\
\mid & \\
CH – O – CO & - R2 \quad \text{Glyceride or Glycerol ester} \\
\mid & \\
CH_2 – O – CO & - R3 \\
\mid & \\
CH_2 – O – CO & - C_{17}H_{35} \quad CH_2 – O – CO & - C_{17}H_{35} \\
\mid & \mid \\
CH – O – CO & - C_{17}H_{35} \quad CH – O – CO & - C_{17}H_{33} \\
\mid & \mid \\
CH_2 – O – CO & - C_{17}H_{35} \quad CH_2 – O – CO & - C_{17}H_{33}
\end{align*}
\]

Glyceride containing 3 molecules
Stearic acid
(Simple Glyceride)

Glyceride containing 1 molecule of stearic acid and 2 of oleic acid
(Combined Glyceride)

3.2 Classification of Glycerides

Because Glycerol is an trivalent alcohol, Glycerides based on the degree of Esterification can be classified in mono, di or triglyceride.
Learning activity 3

CH2 – O – CO - R1 CH2 – O – CO - R1 CH2 – O – CO - R1
|                             |                             |
CH – O H                     CH2 – O – CO – R2 CH2 – O – CO – R2
|                             |                             |
CH2 – OH                     CH2 – O H                   CH2 – O – CO – R3
Monoglyceride    Diglyceride           Triglyceride

3.3 Properties of Glycerides

There is a close link between the structure and aggregative state of fats. Fats that have mainly the remains of unsaturated carboxylic acids are generally liquids. In fats are predominant Glycerides of saturated acids, while in oils the acids are unsaturated. As a rule Glycerides of saturated acids have relatively superior fusion points when compared to the ones related to non saturated acids.

Ex.

Glyceride :
estéáric     oléic        linoléic      palmitic    palmitoleic
P.F. = 73,1oc P.F. = 5,5 oc  P.F. = -13,1oc  P.F. = 66,4oc  P.F= 2,3oc

With the increase of temperature the fats turn from a solid state to a liquid. They are not soluble in cold water, are not very soluble in hot water and well soluble in organic solvents (Ethanol, Ether, Tetrachloromethane etc.)

In general their density is inferior to water's (0.90 – 0.94).

The level of refraction increases as the level of insaturation increases.

Its viscosity is bigger than water's being higher in oils that have many Hydroxyl groups (Ex. Resin oil).

They are greasy

Stain paper and fabrics.

Formative assessment 3:

1. What are Glycerides!
2. How are Glycerides classified!
3.4 Phosphatides

Phosphatides or Phospholipoydes exist in every cell, particularly in the nervous cells, egg yolks, liver and kidneys.

They are Diesters of Phosphoric acid.

Phosphatides have importance in the formation of biological membranes. For examples of Phosphatides we have Lecitin and Kefaline. In these cases Glycerol is esterified with two moles fat acids and by Phosphoric acid.

RCOOCH2

<table>
<thead>
<tr>
<th>RCOOCH</th>
<th>O</th>
<th>CH3</th>
<th>Leticin</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CH2 – O – P – O – CH2 – CH2 – NÅ – CH3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O-</td>
<td></td>
<td>CH3</td>
<td></td>
</tr>
</tbody>
</table>

RCOOCH2

<table>
<thead>
<tr>
<th>RCOOCH</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>CH2 – O – P – O – CH2 – NH2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>O-</td>
<td></td>
</tr>
</tbody>
</table>

Task 4: Fats and fatty oils

The task offers a vision about Lipids with structural and energy supply functions

The solid or semi-solid fats as well as fatty oils (liquid fats) are Glycerol esters and carboxylic acids with great molecular weight (ca. 12 to 20 carbon atoms) known as fatty acids. Due to the fact that they are Glycerol esters they are also called Glycerides. Natural fats also have different compositions given that Glycerol can be esterified with only one type of acid molecules (simple Glyceride) or simultaneously by various different fatty acid molecules (mixed Glyceride).
4.1 Chemical properties of fats

4.1.1 Breakdown of fat

- **Hydrolysis**
In Hydrolysis fats forms fatty acids and Glycerol

\[
\begin{align*}
\text{CH}_2 – \text{O} – \text{CO} – \text{R}_1 & \quad \text{CH}_2 – \text{OH} & \quad \text{R}_1\text{COOH} \\
\vert & \quad & \vert \\
\text{CH} – \text{O} – \text{CO} – \text{R}_2 & + 3\text{H}_2\text{O} & \text{®} & \text{CH}_2 – \text{OH} & + & \text{R}_2\text{COOH} \\
\vert & \quad & \vert \\
\text{CH}_2 – \text{O} – \text{CO} – \text{R}_3 & & \text{CH}_2 – \text{OH} & & \text{R}_3\text{COOH}
\end{align*}
\]

**Fat**  **Glycerol**  **Fatty acids**

- **Saponification**
Like all esters Glycerides suffer Alkaline Hydrolysis (Saponification) forming Glycerol and fatty acid’s salts (soap).

\[
\begin{align*}
\text{CH}_2 – \text{O} – \text{CO} – \text{R}_1 & \quad \text{CH}_2 – \text{OH} & \quad \text{R}_1\text{COONa} \\
\vert & \quad & \vert \\
\text{CH} – \text{O} – \text{CO} – \text{R}_2 & + 3\text{NaOH} & \text{®} & \text{CH}_2 – \text{OH} & + & \text{R}_2\text{COONa} \\
\vert & \quad & \vert \\
\text{CH}_2 – \text{O} – \text{CO} – \text{R}_3 & & \text{CH}_2 – \text{OH} & & \text{R}_3\text{COONa}
\end{align*}
\]

**Glyceride**  **Glycerol**  **Soap**

4.1.2 Solidification (Hardening)

Through catalytic Hydrogenation Glycerides can be formed off unsaturated fatty acids in solid fats.

For example from oleic Glyceride we can get estearic Glyceride.

Ex.

\[
\begin{align*}
\text{CH}_2 – \text{O} – \text{CO} – \text{(CH}_2\text{)}_{7}\text{CH} = \text{CH(CH}_2\text{)}_{7}\text{CH}_3 & \quad \text{CH}_2 – \text{O} – \text{CO} – \text{(CH}_2\text{)}_{16}\text{CH}_3 \\
\vert & \quad & \vert \\
\text{CH} – \text{O} – \text{CO} – \text{(CH}_2\text{)}_{7}\text{CH} = \text{CH(CH}_2\text{)}_{7}\text{CH}_3 & + 3\text{H}_2 & \text{®CH} & \quad \text{O} – \text{CO} – \text{(CH}_2\text{)}_{16}\text{CH}_3 \\
\vert & \quad & \vert \\
\text{CH}_2 – \text{O} – \text{CO} – \text{(CH}_2\text{)}_{7}\text{CH} = \text{CH(CH}_2\text{)}_{7}\text{CH}_3 & & \text{CH}_2 – \text{O} – \text{CO} – \text{(CH}_2\text{)}_{16}\text{CH}_3
\end{align*}
\]
4.1.3 Sulphonic derivate

Glycerides of non saturated acids react with Sulfuric acid forming derived sulphonics having the group –SO3H; the sulfuric ester having the group- OSO3H

\[
\begin{align*}
-CH=CH- + HOSO_3H & \rightarrow -CH \backslash CH - \text{ sulphonic derivate} \\
| & | \\
OH & SO_3H \\
\end{align*}
\]

\[
\begin{align*}
-CH=CH- + HOSO_3H & \rightarrow -CH_2 - CH - \text{ sulphuric acid} \\
| & \\
OSO_3H \\
\end{align*}
\]

This reaction has great industrial importance in the production of detergents.

4.1.4 Halogenations

The unsaturated Glycerides add halogens

\[
\begin{align*}
-CH=CH- + I_2 & \rightarrow -CHI - CHI \\
\end{align*}
\]

This reaction has importance in the characterization of oils and fats through the level of Iodine.

4.1.5 Rancidity (Rancity)

Oils and fats in contact with air become rancid with time, meaning they deeply change getting a sour taste and strong smell. This is a complex phenomenon of oxidative chemical changes and of partial decomposition of Glycerides with the formation of substances of ketone and Aldehyde nature which are the most responsible for the rancid taste and smell.

In this process there are also formed free acids that increase the acidity of the oil.

\[
\begin{align*}
\text{CH}_3-(\text{CH}_2)_7-\text{CH} = \text{CH} - (\text{CH}_2)_7 -\text{COOH} + \text{O}_2 & \rightarrow \\
\text{CH}_3-(\text{CH}_2)_7-\text{CH} - (\text{CH}_2)_7 -\text{COOH} & \rightarrow \\
| & | \\
\text{O} - \text{O} & \\
\text{CH}_3-(\text{CH}_2)_7 -\text{CHO} + \text{HOC} -(\text{CH}_2)_7 -\text{COOH} \\
\end{align*}
\]
4.1.6 Secativity (Dryness)

Glycerides with a high degree of insaturation (oils) absorb oxygen without rancing.

Oxidative processes turn them into plastic products and resins that harden completely. This phenomenon is called Secativity.

The Secativity originates from the formation of peroxide which because of the strong insaturation, form dimers and finally Polymers; this is resinous products and hard.

\[
\begin{align*}
+ O_2 \\
\text{Oils secativity can be increased by heat and used in the making of polishes and oil paints.}
\end{align*}
\]

4.2 Characterization of Fats

Fats are technically characterized based on their capacity of absorbing (index) Iodine, Potassium Hydroxide or by the amount of free acids it has.

We have:

4.2.1 Iodine index

Is a measurement to the insaturation degree of acids in the Glyceride.

Is expressed as mass in grams of halogen (Iodine) that can be added 100g of fat.

4.2.2 Saponification degree

Number of mg of KOH needed for the Saponification of 1g of fat.

4.2.3 Acid degree

Measures the amount of free acids that exist in natural fats. Is expressed as the number of mg of KOH needed for the neutralization of free acids in 1g of fat.
Formative assessment 4:
Define the following concepts: Fat, and oil

1. How are fats characterized
2. Give two properties of fats

Task 5: Waxes

Waxes are esters of carboxylic acids with long chains (fatty acids) and primary superior monovalent alcohol.

They are in general solid materials, moldable and impermeable to water. There are different types of waxes.

Animal waxes were the first to be discovered. For example we have linen tallow, wax from bees, esparmacete (white and fat substance that is found in cachalote’s head with which candles and cosmetics are made off) etc.

Vegetal waxes, just like animal waxes are mixtures of esters of alcohols of long chains (superior alcohols) and superior carboxylic acids.

Basically waxes are fatty acids’ esters that are found both in the vegetal kingdom and animal kingdom.

There are also mineral waxes like Paraffin obtained from petroleum refinement.

Ex.

<table>
<thead>
<tr>
<th>Name</th>
<th>Formula</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Palmitate of mericil</td>
<td>CH3 – (CH2)14-COO(CH2)29CH3</td>
<td>bees (C26-C28) (wax from bees)</td>
</tr>
<tr>
<td>Cetil Palmitate</td>
<td>C15H33COOC16H33</td>
<td>Whales’ foam</td>
</tr>
<tr>
<td>Ceretineate of ceril</td>
<td>C15H51COOC26H53</td>
<td>China wax</td>
</tr>
<tr>
<td>Miriclester of palmitic Ac.</td>
<td>CH3 – (CH2)4-COOCC31H63</td>
<td>palmitic acid</td>
</tr>
</tbody>
</table>

Formative assessment 5:
What are waxes!
Mention the application of wax.

key terms

Lipid       Fat
Oil         Glyceride
Fatty acids Waxes
**Learning activity 3**

**Phosphatides**

**Saponification**

**Iodine index**

**Saponification index**

**Lipid:** The animal and vegetal fats like lard, butter, olive oil, oil fats, natural waxes and Phosphatides are all known as Lipids. They are natural compounds with little or no solubility in water. In this group are also included mineral oils (Hydrocarbon) and oleos etericos (terpens and steroids). In general they are esters of carboxylic acids with high molecular weight (fatty acids).

**Fat:** Are esters of Glycerol with carboxylic acids of high molecular weight (fatty acids) saturated.

**Oil:** Are esters of Glycerol with carboxylic acids of great molecular weight (fatty acids) unsaturated.

**Glyceride:** Glycerides are esters of Glycerol with fatty acids.

**Fatty acids:** Fatty acids are carboxylic acids with great molecular weight (C12-C29)

**Waxes**

**Phosphatides:** Are esters of phosphoric acid. In these cases Glycerol is esterified with two moles de fatty acids and by Phosphoric acid. Phosphatides or phospholipoydes exist in every cell, particularly in the nervous cells, egg yolks, liver and kidneys.

**Saponification:** Alkaline Hydrolysis of esters of carboxylic acids.

**Iodine index:** Is a measurement to the insaturation degree of acids in the Glyceride.

Is expressed as mass in grams of halogen (Iodine) that can be added 100g of fat.

**Saponification index:** Amount of KOH (mg) necessary to saponify 1g of fat.

**Formative assessment**

**Formative assessment 1:**

1. Define lipid!

2. List some application and functions of lipids.

**Formative assessment 2:**

1. Define and classify fat acids!

2. Give some examples of occurrence of fat acids!
Formative assessment 3:

1. What are Glycerides?
2. How are Glycerides classified?

Formative assessment 4:

1. Define fat and oil
2. How are fats classified?
3. List two properties of fats

Formative assessment 5:

a. What are waxes?
b. List two applications of waxes!
Learning activity 4

Title of learning activity: Practical work

The learning activity 4 provides opportunity for experimental application of knowledge and skills developed in learning activities 1, 2, and 3.

In this activity using easily accessible materials (for example from your everyday life) or with simulations computerized, students will be familiarized with basic techniques of practical work and handling of materials for identification of some vital biological compounds.

To do the suggested tasks the student will need approximately 10 hours.

When possible use material from your quotidian.

List of REQUIRED readings:

http://www.google.com/search?hl=en&q=Caracter+redutor+do+acucar
(identification of carbohydrates / proteins / lipids)

List of relevant useful links:

http://www.google.com/search?hl=en&q=Identificacao+da+ligacao+peptidica&lr=lang_pt
(protein identification/ peptide bond)

List of relevant MULTIMEDIA resources:

Detailed description of the activity

Read the instructions

1. Provide at your home or institution of education recommended apparatus and substances.
2. Following instructions do the experiments.
3. Carefully take note of all observations
4. Write the equations of main reactions you do.
5. Write a short summary with main conclusions.

Formative evaluation

Learning activities

Task 1. Properties of carbohydrates

i. Proof of carbon in sugar
ii. Production of starch from potatoes
iii. Preparation of starch’s glue
iv. Reaction of starch’s glue and Iodine
v. Acid hydrolyze of starch

Task 2. Proteins

2.1 Preparation of proteins’ solution
2.2 Precipitation of proteins with ammonium sulphate
2.3 Biuret test
2.4 Proof of sulphur in proteins
2.5 Test of proteins in potatoes (Biuret reaction)

Task 3. Properties of fats

3.1 Identification of multiple bounds
3.2 Proof of solubility
3.2 Proof of fat acids

Tasks 1, 2 and 3:

These activities complement learning acquired in units 1, 2 and 3.

These tasks provide opportunities to manipulate and to observe some basic properties of vital macromolecular compounds for the biological system.

a. Carbohydrates

b. Proof of carbon in Sugar

c. Apparatus and reagents: porcelain capsules, pint of sugar, concentrated sulphuric acid.

Procedure

1. Pour a little of water into porcelain capsule with sugar. Add to the mixture dripping 1ml of concentrated sulfuric acid.

2. Take note of your observations.

1.2. Production of Starch from Potatoes

Apparatus and reagents: Becker (250ml) or normal glass, shredder/grater, cloth to filter, Erlenmeyer flask, rod, spatulas, potatoes.
Learning activity 4

Procedure 1

1. Shred potatoes until you get approximately 100ml of the mass of volume. Keep part of the mass (5-10ml) in a test tube. In the Becker container with the rest of potatoes mass add 150ml of distillated water and shake.

2. Filter the mixture. Leave the filtered product for approximately 10 minutes and decant the mixture. Add water to the precipitated which formed in the filtered product shake and decant again. Repeat this operation two times.

3. Keep the purified precipitated (starch) for the following experiments.

4. Preparation of ‘starch glue’

5. Apparatus and reagents: Becker, rod, starch (prepared in the preceding task).

Procedure 2

1. Mix starch with approximately 20ml of cold water and shake. Then, pour starch glue into a glass (becker) containing approximately 100ml of boiling water.

2. Take notes of your observations and explain.

3. Reaction of starch glue and Iodine

4. Apparatus and reagents: tube for reaction, dropper, starch glue, Lugol solution (Iodine/KI).

Procedure 3

Introduce in a test tube approximately 3ml of diluted solution of egg-white and add equal volume of saturated solution of ammonia and shake (proteins and globulins will precipitate). Wait for 5-6 minutes and filter. In the filtered product, there are still albumins.

To precipitate albumins, add to the filtered, ammonium sulphate crystalline up to complete saturation. (In this way albumins will be precipitated). Filter to separate.

Finally do the Biuret test to the filtered product.

2.3 Biuret test

Apparatus and reagents: test tubes, solution of protein, solution of sodium hydroxide 10% and 30%, solution of cuprum sulphate 1%.

Procedure

Pour 2ml of solution of egg-white into the test tube and add 4ml of sodium hydroxide solution 30%. Mix carefully and add two or three drips of cuprum sulphate 1%. Leave the test tube for a moment and observe the contact zone between the two interfaces.
2.4 Proof of Sulphur in Proteins

Apparatus and reagents: Test tubes, solution of egg-white, feather of a bird (white), solution of sodium hydroxide 11%, lead acetate.

Procedure

Heat small amounts of proteins with 5ml of sodium hydroxide until boiling. After the protein is dissolved add 1ml of lead acetate.

2.5 Test of proteins in potatoes (Biuret reaction)

Apparatus and reagents: reaction tube, dropper, grated potatoes (exp. 1) sodium hydroxide (11%), cuprum sulphate (II) (11%).

Procedure

Add into a test tube 3ml of potatoes mass and NaOH solution. Then add 3-4 drips of cuprum (II) sulphate and shake well.

3. Properties of fats

Apparatus and reagents: Test tube, filter paper, pipette, fat, oil, ethanol, bromine water, iodine water, distilled water, rancid butter, KOH 5% and phenolphthalein.

Procedure

3.1. Identification of multiple bonds

In a test tube, pour approximately 0.5ml of fat and add some drips of bromine water solution, shaking. Repeat the same operation with iodine water.

3.2 Proof of Solubility

In three test tubes pour approximately 3ml of water, 3ml of ethanol and 3ml of diethyl ether respectively. Add into each other, 2-3 drips of fat and shake.

With pipette take out some drips from each test tube and drop on different places of the filter paper. Wait for the spots to dry and observe.

3.3. Proof of fat acids

Dissolve in a test tube 2g of butter and 5ml of ethanol under heat.

Heat in another test tube solution of sodium hydroxide and add some drips of phenolphthalein. Add drip by drip, the second solution on the first and observe.
Module Developer Writing Tip. This section contains short, concise definitions of terms used in the module. The key concept section is often called glossary, it helps learners with terms with which they might not be familiar in the module. Learners especially appreciate glossaries in an open and distance education context because there is no teacher in front of them, when they encounter an unfamiliar word and cannot easily figure out its definition in the text.

Module Developers should select at least the 10 most important terms to include in the glossary. When writing the entries in the glossary, the term needs to be in capital letters and boldface type. The definition must be brief, concise and clearly written. For example:

**ISOTOPE.** An isotope is any of several different forms of an element each having different mass. Two isotopes of an element will have nuclei with the same number of protons (the same atomic number) but different numbers of neutrons. Therefore, isotopes have different mass numbers, which give the total number of nucleons - the number of protons plus neutrons. The word isotope, from Greek meaning «at the same place», comes from the fact that all isotopes of an element are located at the same place on the periodic table. (source: Wikipedia, consulted August 9, 2006).

It is important to highlight that glossaries differ from dictionaries. Glossaries only provide the uses of the terms that are relevant to the content of the module. Dictionaries provide more complete definitions.

**Glucids**

Carbohydrates or Glucids are chemically Aldehydes or Ketones containing polyhydroxyl group or compounds which by hydrolyze, can be transformed in Aldehydes or Ketones.

**Monosaccharide**

Simple sugars constituted by basic unit non hydrolysable, generally with 5-6 atoms of carbon.

**Oligosaccharide**

Sugars constituted by 2 to 10 basic units of monosaccharides. Oligosaccharides are hydrolysable in simpler compounds (monosaccharides)

**Polysaccharides**

Are carbon hydrates which can hydrolyze in many units of monosaccharides (can reach ca 10000 units).

**Aldose**

Sugar which main functional group is the aldehyde group.

**Ketose**

Sugar which main functional group is the aldehyde group.
**Oxycycle-tautomerism**

Equilibrium of three tautomeric forms, of monomers α, β and the cyclic form of sugar denominated oxo-cycle-tautomerism.

**Mutarotation**

The occurrence of changes in the deviation angle of monomers α, β up to the magnitude of equilibrium is denominated mutarotation.

**Reducer sugar**

Sugar with at least one free functional group capable of doing reaction of oxidation and reduction.

**Asymmetric carbon**

Carbon with four different substituents. Chiral carbon.

**Amino acids**

Amino acids (AA) are compounds bifunctionals which have one acid function due to the presence of carboxyl group and one basic function originated by the presence of amino group. They are basic constituents of proteins.

**Proteins**

Proteins are natural polymers constituted by units of amino acids bounded by peptide bond.

**Peptide**

Molecule formed by some amino acids bounded by peptide bond.

**Peptide bond**

**amide group**

(-NH-CO-) which links amino acids in peptides and proteins.

**Nucleoside**

Group constituted by organic bases linked by glycosidic linkage.

**Nucleotide**

Group constituted by organic bases linked by glycosidic linkage and esterified by phosphoric acid, in the position 5 of the hydroxyl group.

**Nucleoproteins**

Association of specials proteins and nucleic acids.

**Prosthetic group**

Non proteic group linked to protein.
RNA
Ribonucleic acid.

DNA
Deoxyribonucleic acid

Lipids
Animal and vegetal fats like lard, butter, olive oil, fatty oil, natural waxes and phosphatides are all called lipids. They are natural compounds insoluble or not much soluble in water. In this group are also included mineral oils (hydrocarbons) and etheric oils (terpenes and steroids). In general they are esters of carboxylic acids of high molecular weight (fatty acids).

Fat
Are esters of glycerol and saturated carboxylic acids of high molecular weight (fatty acids).

Oil
Are esters of glycerol and unsaturated carboxylic acids of high molecular weight (fatty acids).

Glyceride
Are ester of glycerol and fatty acids

Fatty acids
Are carboxylic acids of high molecular weight (C12-C29).

Phosphatides
Are esters of phosphoric acid. In this case glycerol is esterified with two moles of fatty acids and phosphoric acid. Phosphatides or phospholipoids exist in all cells, particularly in nervous cells yolk of eggs, liver and kidney.

Saponification
Alkaline hydrolyze of carboxylic acids’ esters.

Index of Iodine
Is a measurement for the level of unsaturation of acids in Glyceride. It is defined as the mass in grams of the halogen (Iodine) to which can be added 100g of fat.

Index of saponification
Number of mg of KOH necessary to saponify 1g of fat.
Module Developer Writing Tip. In open and distance education, learning often takes place through reading. In this section, Module Developers should provide readings to the students. At least three relevant readings (approximately 5-10 pages each) must be provided for each module. These readings should help learners understand the topics covered in the module. For each reading, Module Developers need to provide the complete reference (APA style), as well as a 50 word abstract written in a way that motivates the learner to read the text provided. The rationale for the reading provided should also be explained (maximum length : 50-75 words). An electronic version of each reading is required.

Important note : the readings must be copyright free. That is, they must either be written by the Module Developer or be from open access content. Open access (OA) is the free online availability of digital content (Wikipedia). Module Developers can consult the Directory of Open Access Journals (http://www.doaj.org/) for readings that could be relevant. Modules that do not comply with this will not be accepted.

Reading #1

Complete reference:

Origin of carbohydrate: Wikipédia, free encyclopedia


2. http://www.cem.msu.edu/~reusch/VirtualText/carbyd.htm (Carbohydrates / general concepts/ Mono s/ Dissac)


Abstract

Reference 1 (one) offers information about function of Glucids in the organism, nomenclature, classification as well as main characteristics of monosaccharide, disaccharides and polysaccharides.

Reference 2 (two) elaborates on the concept of carbohydrate, discuss and apply knowledge about carbohydrates (mono-, disaccharides).

Reference 3 (three) deals with carbohydrates reactivity. Shows reducing character of sugars and allow practical work.

The above references 1, 2 and 3 provide basic knowledge for the student about carbohydrates namely:
Concept, nomenclature, classification and examples of reactivity.

**Reading #2**

Complete reference:

- [http://pt.wikipedia.org/wiki/Liga%C3%A7%C3%A3o_pept%C3%ADdica](http://pt.wikipedia.org/wiki/Liga%C3%A7%C3%A3o_pept%C3%ADdica)

Abstract

The above references (11, 12) provide information about Amino acids, structure and types of Amino acids. This complements information about peptide bond and also deepens knowledge about proteins (DNA, NRA).

**Rationale**

Working with this references confer to the student knowledge and important skills about vital biological compounds (Amino acid and Proteins)

**Reading #3**

Complete reference:

- [http://pt.wikipedia.org/wiki/L%C3%ADpido](http://pt.wikipedia.org/wiki/L%C3%ADpido)
- [http://biology.clc.uc.edu/Courses/bio104/lipids.htm](http://biology.clc.uc.edu/Courses/bio104/lipids.htm)
- [http://www.cem.msu.edu/~reusch/VirtualText/lipids.htm](http://www.cem.msu.edu/~reusch/VirtualText/lipids.htm)

Abstract:

Reference 16 present lipids, discuss it’s structure and classification.

Reference 17, 18 deepens knowledge about basic structure of Amino acids and peptide bond, provides information about oils, fats and their bonds (soaps and detergents).

In the same article are also deepen knowledge and skills about carbohydrates.

**Rationale**

The literature offered presents an overview about important biological molecules (Lipids, proteins and carbohydrates) as well as it’s properties.
Module Developer Writing Tip. In this section, Module Developers should provide at least two, copyright free, relevant, resources other than a written text or a web site. These could be a video file, an audio file, a set of images, etc. For each resource, Module Developers should provide the complete reference (APA style), as well as a 50 word abstract written in a way that motivates the learner to use the resources provided. The rationale for the resource provided should also be explained (maximum length : 50-75 words). An electronic version of each resource is required.

Important note : the resources must be copyright free. That is, they must either be created by the Module Developer or be from open access content. Module Developers are encouraged to use open content learning objects from the following resources:

- **GEODE** ([http://www.uw-igs.org/search/](http://www.uw-igs.org/search/)) or “Global Education Online Depository and Exchange,” is a repository of Global Studies learning objects maintained by the Institute of World Affairs at the University of Wisconsin-Milwaukee. The edited collection may be searched by country, region, file format, language, or keyword.

- **MERLOT** ([http://www.merlot.org/](http://www.merlot.org/)), short for the “Multimedia Educational Resource for Learning and Online Teaching,” is a free and open resource designed primarily for faculty and students of higher education. MERLOT includes links to online learning materials along with annotations such as peer reviews and assignments. To learn more about the MERLOT project, visit [http://taste.merlot.org/](http://taste.merlot.org/). For the latest news from MERLOT, visit [http://taste.merlot.org/portal/grapevine/](http://taste.merlot.org/portal/grapevine/). Finally, to browse the subsets of the whole MERLOT collection that are focused on specific disciplines, visit [http://www.merlot.org/home/Sites.po](http://www.merlot.org/home/Sites.po).

- **Canada Learning Object Project eduSource** ([http://www.edusource.ca/](http://www.edusource.ca/)). eduSource is a Canada-wide project to create the infrastructure for a network of interoperable learning object repositories. A repository differs from standard web materials by providing teachers, students and parents with information that is structured and organized to facilitate the finding and use of learning materials regardless of their source location. The eduSource project is based on national and international standards; it is bilingual (French/English) and it is accessible internationally.

- **Burrokeet** ([http://www.burrokeet.org/](http://www.burrokeet.org/)) is an Open Source Software tool that assists in the creation of Learning Objects from existing content. It is able to take, as input, a wide range of document formats and export them as consistently styled content within Learning Objects. This frees the content developer to focus on the quality of the content without having to overly concern themselves with presentation. Similarly, editors of learning objects need not concern themselves with ensuring authors use the same development tool, they are free to use whatever the tool with which they are most familiar. As a result Burrokeet enhances the reusability of content within learning objects.
VLORN (http://www.flexiblelearning.net.au/vlorn/). The VET Learning Object Repository Network (VLORN) is a network of organizations in the Australian vocational education and training (VET) that contribute via agreed standards to enable the discovery and use of learning objects. VLORN was established in 2004 through Australian Flexible Learning Framework funding. See http://www.flexiblelearning.net.au/ for more information on the Framework.[edit]

LON-CAPA (http://www.loncapa.org/) is a distributed network with participants from currently over 40 colleges and universities, as well as 40 K-12 schools (mostly in the US), who share a common pool of approximately 150,000 reusable learning objects.

Module Developers are also encouraged to visit the following web site: Collections of learning objects (http://www.uwm.edu/Dept/CIE/AOP/LO_collections.html). Modules that do not comply with this will not be accepted.

COMPILED LIST OF USEFUL LINKS

Module Developer Writing Tip. In open and distance education, learning often takes place through reading information presented on a web site. In this section, Module Developers must provide a list of at least 10 relevant web sites. These useful links should help students understand the topics covered in the module. For each link, Module Developers should provide the complete reference (Title of the site, URL), as well as a 50 word description written in a way to motivate the learner to read the text provided. The rationale for the link provided should also be explained (maximum length: 50 words). A screen capture of each useful link is required. Note that Toby Harper, Dr. Thierry Karsenti’s assistant, will help all participants with that aspect.

Important note: the links listed should be as stable and come from official sources, as much as possible.

Useful Link #1

(THE TOTAL LIST OF ALL THE LINKS REFERRED TO IN THE LEARNING ACTIVITIES ABOVE)

Title: NAME 5 Carbohydrate’s metabolism

http://www.probiotica.com.br/artigos.asp?id=110&tabela=saudelInformativo

Screen capture: IF YOU WOULD LIKE ASSISTANCE CREATING A LOW-RESOLUTION .JPG OF THE PAGE YOU ARE LINKING TO, PLEASE ASK.

Description

The reference focus on carbohydrates’ metabolism. It offer useful information about metabolic absorption and storage of carbohydrates in the organism.

Rationale

The reading can help to understand the importance of carbohydrates in organisms.
Useful Link #2
Title: Inverted sugars (6)
URL: http://www.google.co.ke/search?hl=en&q=a%C3%A7ucar+redutor&btn=Seas
Description
The article focus on sugars’ properties.
Correlations sterochemical are explained based on Saccharose.
Rationale
The article makes links between structure and properties of compounds.

Useful link 3
Title: Properties of sugars
Screen capture:
Description
The reference deepens information of the module about properties of sugars namely: monosaccharide, disaccharides.
Rationale
Monosaccharide are basic units of oligosaccharides and polysaccharides. Are compounds with energetic functions and structures.

Useful Link #4
Title: General biochemistry (8)
Description
The reference presents hydrates of carbon and links it with important functions in the organism.
The chapter establishes links between sugars, nucleic acids and lipids.
Rationale: The readings deepen information about importance and function of biomolecules.

**Useful link #5**

Title: Carbohydrates’ analyze (9)

URL: http://www.campus.fct.unl.pt/gdeh/mestrado/Teoricas/An%E1lise%20de%20carbohidratos.pdf

(Carbohydrates analysis/ experimental activity

Description

The chapter introduces the analyze of carbohydrates.

It is an important contributes to the developments of skills to practical work.

Rationale

The article abilities the student to recognize the basic characteristics of carbohydrates.

**Useful link #6**

Title: Sweet like sugar (10)

URL: http://www.qmc.ufsc.br/qmcweb/artigos/sugar.html

(Concept/Functions/organism’s basic necessities

Screen capture : 

Description

The reference presents information about concept of sugar, functions of sugars and human basic needs.

Rationale

The article deepens knowledge about sugars as well as human needs in regard this compounds.

**Useful Link #7**

Title :General Biochemistry (13)


(Carbon Hydrates/Nucleic acids/lipids
The reference deals with structure of amino acids and of proteins. It includes differentiation between simple proteins and conjugated proteins.

Rationale: The readings above provide relations between structure and functions of amino acids and proteins.

**Useful Link #8**

Title: Protein structure (14) (14a)

http://www.amtechs.com/folding/education/prstruc.html

The articles provide information about structure and formation of proteins.

**Useful Link #9**

Title: Protein structure (14b)

URL: http://www.google.com/search?hl=en&q=Estrutura+das+proteinas

The references present primary, secondary, tertiary and quaternary structures of proteins.

Rationale: The student will find illustrations of proteins’ structure correlated with its functions.

**Useful Link #10**

Title: Fats (18)

URL: http://pt.wikipedia.org/wiki/Gordura

In the article the student will find introduction on the concept of structure, classification and sources of fats.

Rationale
The article disserts about biological compounds with structural and energetic functions in organism.

**Useful Link #11**

Title : Lipids (16)
URL : http:www.


Screen capture :
Description
The article presents the concept, structure and important functions of lipids.
Rationale:The article provides links between structure and properties of lipids.

**Useful Link #12**

Title : Phosphalipids
URL : http:www.

http://pt.wikipedia.org/wiki/Fosfol%C3%ADpido(fosfolipidos)

Screen capture :
Description
The article presents the structure of esterified lipids with phosphoric acid.
Rationale:Lipids are compounds of diverse nature which composition is closely linked with its function in the organism.

**Useful Link #13**

Title : Lipids (21)
URL : http:www.

http://www.dbio.uevora.pt/jaraujo/biocel/lipidos.htm

Defi/ structure/classific/glycerides/conjugated lipids
Screen capture :
Description
The reference presents lipids, its classification and basic structures (Glycerides). It also presents aggregated lipids and other structures.
Rationale
Glycerides are basic structures of lipids resulting from glycerol esterification.
Synthesis of the Module

Module Writing Tip. Module Developers should write a synthesis of the most important content learners are expected to know at the end of the module. This summary of the content could take the form of a written text (maximum length: 300 words).

In this module were presented and studied some of the representative macromolecular compounds in the biological system vital to the equilibrium, growth, maintenance and supplement of living organisms.

The module consolidates and expands knowledge gained in previous modules, especially about Aldehydes, Ketones and amino acids connecting them to vital functions of the organisms.

Module 8 (macromolecules in biological system) offers basic foundations about key theoretical and practical aspects of macromolecular chemistry.

It deals systematically with some of main classes of macromolecular organic biological compounds, respectively: Carbohydrates (Glucids), proteins and lipids.

In this module are analyzed relations between structure, properties, reactivity and chemical and physical behavior of organic compounds of high molecular weight.

The learning of this module deepens knowledge about organic compounds and helps to establish relations between matter structure and its properties.

Develops ability of reasoning and critical observation allowing (?) the best use of these compounds.

Carbohydrates are Aldehydes and Ketones containing Polyhydroxyl group. These compounds with chiral structure are usually classified in three groups (mono – di and polysaccharides) and they have energetic functions structures and in organisms.

Proteins constituted by basic units of amino acids are considered basilar units in the organisms’ compositions. They have protection, structural or metabolic functions according to their composition and structure..

Lipids, compounds of diverse nature are basically esters of glycerol and fatty acids.
Module Writing Tip. A summative evaluation can take different forms: a test (multiple choice, short answers, etc.), a project, a written production, a problem solving task, etc. The summative evaluation is usually what is used to provide students with a final mark for the module. This section is therefore designed to provide information to determine the amount of learning by a student at the end of the module. Module Developers should keep in mind that the summative evaluation must be conducted in a distance education context. They should also carefully consider what should be evaluated, and how it should be evaluated. Instructions provided to learners in a final evaluation must be clear, concise and well written. An answer key must be provided by Module Developers. For multiple choice exams, a significant database of questions (3 to 5 for each topic) must be provided so that exams can vary significantly from student to student. Also, Module Developers must indicate how learners will submit their answers to the instructor. Will the summary evaluation be emailed to the instructor? Will it be submitted online? Will there be an online test? Will there be an on-site evaluation? Finally, summative evaluations should include opportunities for students to respond to the module to provide feedback to the instructor.

THIS EVALUATES WHETHER THE LEARNER HAS ACQUIRED THE SKILLS AND/OR KNOWLEDGE THAT WAS SET OUT IN THE MODULE’S OVERALL OBJECTIVES.

REMEMBER TO INCLUDE THE ANSWER KEY AND ANY OTHER MATERIAL NECESSARY TO COMPLETE THE EVALUATION PROCESS

1. Glucids or carbohydrates are:
   a) – Compounds constituted exclusively by carbon and hydrogen
   b) – Compounds that contain water
   c) – Aldehydes and Ketones containing polyhydroxyl group
   d) – Compounds of fat family

2. Chemically fat are:
   a) – Esters of Glycerol and fat acids
   b) - Esters of superior alcohols and fat acids
   b) – Aldehydes with high molecular weight
   c) – Acids of high molecular weight

3. Proteins are compounds constituted by:
   a) – Glucose units bounded by glycosidic linkage
   b) – Amino acids units bounded by peptide bond
   c) – Monosaccharide units bounded by glycosidic linkage
   d) – Products from polysaccharides’ decomposition
4. Fat acids are:
   a) – Acid with many ramifications
   b) – Acid of fat people
   c) – Acid of high molecular weight
   d) – Carboxyl acids

5. Glycosidic linkage occurs between
   a) – Fat
   b) – Amino acids units
   c) – Monosaccharide units
   d) – Proteins

6. Peptide bond occurs between
   a) – Fats
   b) – Amino acids units
   c) – Monosaccharide units
   d) – Proteins

7. Polysaccharides are constituted by:
   a) – Thousands of units of acids bounded by glycosidic linkage
   b) – Thousands of amino acids units bounded by peptide bond
   c) – Thousands of monosaccharide units bounded by glycosidic linkage
   d) – Thousands of amino acids units bounded by peptide bond

8. Isomerism is the occurrence of:
   a) – Molecules of same molecular mass
   b) – Molecules absorbing all light
   c) – Existence of molecules with the same composition but different structure
   d) – Molecules differing in one segment constituted by one atom of carbon and two of hydrogen

9. Glucose is
   a) – Aldose
   b) – Ketose
   c) – Pentose
10. Fructose is
   a) – Aldose
   b) – Ketose
   c) – Pentose
   d) – Hexasose

11. The atom of carbon which determines series D in sugars is:
   a) – The closest to the main functional group
   b) – The furthest to the main functional group
   c) – The central atom
   d) – None of these

12. Reducer sugars are:
   a) – Easily soluble
   b) – Those which have free functional group
   c) – The sweeter
   d) – Those which do not have free functional group.

13. Oils are:
   a) – Esters of glycerol and saturated fat acids
   b) – Esters of glycerol and unsaturated fat acids
   c) – Esters of superior alcohols and saturated fat acids
   d) – Esters of superior alcohols and sulfuric acid.

14. Waxes are:
   a) – Esters of glycerol and saturated fat acids
   b) – Esters of glycerol and unsaturated fat acids
   c) – Esters of superior alcohols and saturated fat acids
   d) – Esters of superior alcohol and sulphuric acid.

15. Enantiomers are isomers:
   a) – Which differ in the position of the central atom
   b) – Which rotate the light in the same magnitude but opposite directions
c) – Which rotate differ in a position of the central atom
d) – Which rotate the light in different magnitude but same direction

16. Glycosidic linkage is:
   a) – Linkage between amino group and carboxyl group
   b) – Between two amino groups
   c) Between carboxyl and hydroxyl groups
   d) – between two monosaccharides

17. The typical bound in proteins is:
   a) – Glycoside
   b) – Peptide
   c) – Acetalic
   d) – None of these

18. Cellubiose is:
   a) - Monosaccharide
   b) – Disaccharide
   c) – Polysaccharide
   d) – None of these answers

**Answer key**

Glucids or carbohydrates are:
c) – Aldehydes or Ketones containing carboxyl group

Chemically fat are:
a) – Esters of glycerol and fat acids

Proteins are compounds constituted by:
b)– amino acids units bounded by peptide bond

Fat acids are:
c) – Acids of high molecular weight

Glycosidic linkage occurs between:
c) – Monosaccharides units

Peptide bond occurs between:
b) – Amino acids units
Polysaccharides are constituted by:
c) – Thousands of units of monosaccharides bounded by glycosidic linkage

Isomerism is the occurrence of
c) – Existence of molecules with the same composition but different structure

Glucose is:
– Aldose

Fructose is:
– Ketose

The atom of carbon which determines series D in sugars is:
– The furthest to the main functional group

Reducers sugars are:
b) – Those which have free functional group

Oils are:
b) – Esters of glycerol and unsaturated fat acids

Waxes are:
– Esters of superior alcohol and saturated fat acids

Enantiomers are isomers:
b) – Which rotate light in the same magnitude but in opposite directions.

Glycosidic linkage is:
– Between two monosaccharides

Typical linkage in proteins is:
b) – Peptide

Cellubiose is:
b) – disaccharide
Module Writing Tip. Module Developers should include all relevant references (minimum 10) for the content of the module, as well as all references used in writing the module. All references should be written using the APA style guidelines (see Annex 5 or 6, or consult the American Psychological Association Web site: http://www.apa.org/books/4200061.html). References that do not comply with the APA style guidelines will not be accepted.

  - Introdução a química da vida, Silva. J.J.R. Fraústo
    Edição Universidade Nova de Lisboa 1985
  - Organische Chemie, Christen, Vogtle. Band I/II
    Verlag Sauerlander, 1990
  - Química 5aEdição, Raymond Chang
  - Química Orgânica. Robert T. Morrison, Robert N. Boyd
    13a Edição Fundação Calouste Gulbenkian, 1996.
  - Química no contexto, Monjane, António; Cocho, Estevão; Ramos, Luís; Matos Elias. Edição Diname.2002.
  - Organische Chemie, Hauptmann, Siegfried.
    VEB Deutscher fur Grundstoffindustrie, Leipzig, 1985
Main Author of the Module

Module Developer Writing Tip. Module Developers should provide a brief biography (50-75 words), a picture, title and contact information (email).

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