1. Introduction
Dealing with topics such as the digestion and excretion of nutrients and cellular metabolism is a complex issue. This motivated us to develop a didactic tool to facilitate their understanding. The project was limited to the fundamental processes generated in the human body beginning with the ingestion of carbohydrates, lipids and proteins and the different metabolic and waste disposal channels.

2. Materials and Methods
The project was built up in multiple and simultaneous stages. First, a compilation of the available bibliographical material on the topics was made [1]-[11]. The way and order in which the processes take place in the cell were sketched (considering where they happen, substrates, products, connections with other metabolic paths) in order to establish the best interrelation of the metabolic cycles and to gain a better understanding of them.

On the basis of these sketches, the animations that show the metabolic cycles were carried out (with Macromedia Flash MX 6.0), exploiting the advantages of visual representation and using a variety of colors and forms to represent the different metabolites involved. On each screen a video of the animation, references of the substances that participate in it and an explanatory text of the reactions is shown (see figures 1 and 2).

Each biomolecule (carbohydrates, lipids and proteins) is associated to the color of the different screens. Thus, in case of a crossover of the metabolic paths, the evident change of color marks this crossing.

In parallel with this, the programming of software was made (in Delphi 4.0 Build 5.33), implementing the necessary code to present the appropriate options on the different screens [12]-[15].
3. Development

Matter and energy exchange begins with the ingestion of exogenous material in the shape of food. During digestion, food is hydrolyzed to produce the corresponding monomers: monosaccharides, fatty acids, amino acids, purines and pyrimidines, etc. The monomers are absorbed and they are incorporated into the different cells.

These monomers and other identical ones that come from the degradation of cellular material, can follow two fundamental directions: oxidative degradation (catabolism) into CO₂, H₂O and urea with energy production (ATP and heat), or cellular material biosynthesis (anabolism) for storage or replacement of destroyed molecules with energy consumption.

In the catabolic process, two stages are distinguished. The first is usually specific to each type of biomolecule and leads, through an oxidative process, to intermediary metabolites, e.g. pyruvate, acetyl fragments and ammoniac. The second stage is common to the different types of biomolecules and includes the complete oxidation of the intermediary metabolites to waste products (CO₂, H₂O and urea). In the specific stage and, mainly, in the common stage, the catabolic processes are accompanied by liberation of energy.
The anabolic processes use intermediary metabolites as raw material, they consume energy and use the information contained in proteins and nucleic acids. Therefore, monomers biosynthesis is obtained. These can be organized in polymers which have storage, structural or informative functions.

The substances that constitute the three main metabolisms can be interchanged in the following way:

- **Transformation of carbohydrates into lipids.** The glucose by glycolysis generates:
  - Pyruvate is converted into acetyl-CoA and acetyl-CoA, by biosynthesis, generates fatty acids (FA).
  - Dihydroxyacetone-phosphate that, by reduction with NADH + H⁺, originates glycerol-3-P. This glycerol-3-P and FA (previous activation to acyl-CoA) are incorporated to the synthesis of fats.

- **Transformation of lipids into carbohydrates:**
  - FA by β-oxidation is converted into acetyl-CoA which is completely oxidated in the Krebs cycle.
  - Glycerol is activated generating glicerol-3-P. This is oxidated to dihydroxyacetone-phosphate, which is incorporated to gluconeogenesis to originate glucose.

- **Transformation of carbohydrates into proteins:** Carbohydrates originate α-ketoacid, which could be converted into α-amino acids which are incorporated to the biosynthesis of proteins.

- **Transformation of proteins into carbohydrates:** α-amino acids can be converted by transamination or deamination into α-ketoacids. These α-ketoacids can generate glucose by gluconeogenesis.

- **Transformation of proteins into lipids:** α-amino acids can generate acetyl-CoA or acetoacetyl-CoA. Acetyl-CoA can generate lipids by biosynthesis (ketones, cholesterol, FA).

The complexity of these topics resides in the difficulty of interconnecting the different metabolic paths and their common points because the product of one of them could be used as a substrate in other's.

On this basis, “Biomoléculas” is a software tool that analyzes what happens inside cells, how metabolites are formed and their destination, as well as the interrelation between the different intervening reactions. Thus, cells are far from being a 'black box' where substances arrive and leave. To achieve this, it was necessary to integrate chemistry, biology and anatomy concepts and to apply them to physiology using informatics and designing tools to present a difficult topic in a more interesting way.

### 4. Results

The software begins with the incorporation of main biomolecules (carbohydrates, lipids, proteins and oxygen) into the organism, and shows their digestion, absorption and assimilation by cells, in which the different metabolic paths are developed to generate energy and, thus, the essential biological construction blocks for life. These processes are aimed at providing the necessary tools to keep both the cell and the entire organism alive. Finally, it shows the different excretion means the body has to evacuate unwanted substances.

“Biomoléculas” consists of a series of screens that follow a given order. Each screen is composed of a video in which the corresponding reactions are shown with their references and an explanatory complementary text of what is shown. Using the “Siguiente” button or the options that appear at the bottom of the screen, the user can access to the different possible routes the metabolites formed in the previously shown reactions may take. The program also has a menu by means of which the user has access to the selected screen.

The developed software presents a basic initial structure that consists of the main support in which a menu and a standard tool kit are presented for the reproduction of videos with the following functions: “Reproducir”, “Pausa”, “Detener”, “Cuadro adelante”, “Cuadro atrás”.

The software consists of two different stages: an introductory stage and another in which the specific topics are developed.
The first stage begins by the selection of the option “Archivo/Inicio”. This displays the first screen on which the basic elements for the development of the different processes are presented. It allows, in turn, to go to the group of biomolecules (carbohydrates, lipids or proteins) by pressing the button “Comenzar” after selecting the one chosen to be explored. This decision will take the user to the second stage.

The following stage begins with the additional options to explore Carbohydrates, Lipids, Proteins and Vitamins and minerals that contain the corresponding metabolic processes. By pressing the button “Reproducir”, the user will be able to visualize the selected process (see figure 3).

As a secondary tool, a bar of time is provided to allow moving the video quickly. The user can select it in “Ver/Barra de tiempo”.

For each biomolecule, the visualization of some of the processes can be randomly selected while others can only be seen in a specific order, as we consider that for their better understanding, it is necessary to have seen certain previous screens.

The software also provides a help file which can be consulted not only for information about how the processes take place and their limitations, but also about the instructions for the correct use of this software.

![Figure 3. Proteins screen. Synthesis.](image)

5. Conclusions

“Biomoléculas” is used by the Physiology and Biophysics chair as a complementary tool to facilitate the understanding of theoretical issues, and as a guide for practical work assignments of topics such as the digestive system and energy metabolism.

This project, carried out by students and aimed at students, arises as feedback from the educational process and plays the role of edutainment. The visualization of “the molecules” in action facilitates the understanding of the metabolic processes, as it shows their continuous renovation by destruction and synthesis. On the other hand, the image colours help towards fix in mind and associate the structures to their functional dynamics.

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