Learning Biochemical Biomolecule's Structure and Nomenclature by Using Words Games

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Abstract: Games are fully accepted by students, as they stimulate memory, activate reasoning capacities in brain, improve the knowledge and keep out the stress. Our innovation teaching group is interested in using games for teaching Biochemistry of the Chemistry degree. Most of the individual games found in Internet are classified in numerical games (sudoku, calculation games, a grid to paint black squares depending on the file and column numbers, …) and word games (anagrams, crossword puzzles, word search puzzles, connecting dots, mazes, labyrinths, matching two sets, amidakuji, logic games, or knight's tour games). Biochemistry books often contain glossaries and word index, and usually students must learn many difficult words, including biomolecules. In Chemical degree, it is important that students also know the structure of these biomolecules. In this work, we present some examples of chained-words games. Some of these games can be difficult to prepare, as most of the biomolecules end in –ose (most carbohydrates), –ase (most enzymes), whereas not many biomolecules begin with e–. Thus, domino games can be a good option to learn two aspects of biomolecules: structure and nomenclature. Dominoes tiles contain two zones (one with a structure of a molecule, and the other with the name of another molecule). Student must fit the structure of one molecule with its name, thus learning both structure and name. Depending on the dominoes, this game can be played individually or in groups of students. The game was very appreciated by all our students.

Keywords: Games, Biomolecules, Biochemistry

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Introduction

One of the difficulties in Biochemistry lessons consists in the nomenclature of the numerous molecules that the students must know, to understand metabolism and remember intermediate's names. Thus, several Biochemistry books contain a glossary of words (and often also of authors), needed to understand the texts [Stryer, 2015; Nelson and Cox, 2018]. These words include the nomenclature of cellular structures, biomolecules, or metabolic intermediates. Students should know these words to understand explanations of metabolic reactions, and of protein functions, being catalysators, transporters, or receptors are the main ones. To learn Biochemistry, in addition to theory classes, other activities such as numeric problems [Dawes, 1980] or laboratory practices [Lozano-Teruel and Tudela, 1988] are usually performed, and these lessons are evaluated mainly using problem resolution and a choice of questions tests [Fernandez and Ruiz, 2018]. Problem classes are based on the resolution of numerical questions, usually distributed to students with paper sheets containing problem statements with their results. Students can solve these problems and obtain a satisfaction in observing that their results fit with the solutions shown in the sheets. Although problems can be sometimes considered by students as games, it is not possible to prepare problems in each topic of Biochemistry. For this reason, learning based on gamification [Mirás-Calvo and Sánchez-Rodríguez, 2008; Marín et al., 2021; Moreno and Centelles, 2021] or through the analysis of practical cases [Ñique-Carbajal, 2020] could be an alternative for those lessons without numeric problems. Games, as problems, could be also enjoyable for students, and could be an alternative to learn. This is known as learning based in problems resolution.

Some of the word related games allow players to increase their vocabulary and understand better Biochemistry. Among these games, the most used to entertain children and that allow them to increase their vocabulary are the enchained games (or linked words), the hangman game, the game of synonyms and antonyms, and the stop game (based in writing the largest number of words that begin with a certain letter). After analyzing these word games and their use, we wanted to apply them to the Biochemistry students of the Chemistry degree, in order that they could learn the nomenclature of biomolecules and other words related to cellular structures. In our previous works, we classified word games into 4 groups depending on their essential characteristics. These groups were: 1. words lacking a syllable or a group of letters, 2. anagrams and labyrinths, 3. codes to translate words, and 4. dominoes and other enchained words games. In this work we focus our study on the search for several games based on dominoes and other enchained words games.

Method

From the glossaries of several Biochemistry books [Stryer, 2015: Nelson and Cox, 2018], we first collected the most important words that Biochemistry's students should know and classified them into several groups, in which we included biomolecules (carbohydrates, amino acids, proteins, lipids and other nitrogenous compounds) and cells (subcellular organelles, metabolic pathways, methodologies). These words were analyzed to find common aspects between them, to prepare word games.

The conceptual framework of this work consists in the preparation of games, to be used by the students for self-learning. In the Chemistry Degree at the University of Barcelona, Biochemistry was taught during the fourth semester of the degree, but this subject changed in the last year to the seventh semester. Due to this change of semester, the number of students was very low, and although it seems that they liked the games, it was not possible to obtain enough responses to analyze data and to get a robust opinion. Games found on the Internet and adapted to Biochemistry were classified into the 4 groups previously explained in the Introduction section. In this work we classify the games of group 4 (dominoes and other enchained words games) into several subgroups. In the following sections, some of these subgroups are discussed.

Games with Chained Words using Letters

In Catalan language it is easier to prepare games where the chained word begins with the same syllable as the previous word [JuegosJuegos, 2021], although in Biochemistry many words end in –na or –sa and few words begin with na– or sa–. Nevertheless, English syllables contain more letters than Catalan syllables, and therefore it is even more difficult to construct a game with these characteristics. Thus, games were constructed in English chaining only the last letter of each word with the first letter of the following word. This game, using only the last letter of the word, was also used in Catalan language, but depending on the words, sometimes the game allowed several solutions.

Games with Chained Words using Codes

In this game, words are chained if they begin with a letter in a certain position of each of the words, which does not have to be the last one. This letter can be the same for all the words (constant code), or it is possible to give a numerical code in which each word will have a different letter position depending on the order of each word in the solution (variable code). In the second case, the code is more difficult to solve, as if the word is in a different position, it can be followed by another word beginning with a different letter.

Games Organizing Biomolecules from a List considering a Property

These games can show a list of words of biomolecules, that should be ordered depending on a known characteristic of the molecule. In Biochemistry, it is possible to list several biomolecules and ask the student to order them depending on one characteristic, that should be known by the student. This characteristic could be their molecular weight, the length of the carbon chain, or other structural aspects. Thus, the student not only learns the name of the biomolecule, but also its structure and properties.

Games Organizing Words from their Definitions

This game is related with the previous one, but the list of words can me omitted in the game. Words should be ordered depending on an ordered list of definitions, as it happens with crosswords. When the list of words is

omitted, the game could be more difficult to solve, and it may be better to define the number of letters that the word contains so that the definition would be more unique. The game could also be transformed in a crossword game, giving either definitions or a list of the words, that should fill the crossword grid.

Games using Dominoes

Dominoes is a board game for up to four players using 28 rectangular tiles with one face divided into two equal squares marked with one to six black dots or none. Each player has seven tokens and in turns place one token on the table after another, where the free square of the first token has identical dots as the second token placed. The player who finishes his token first is the winner. To play with the words of Biochemistry, the token should have two different aspects in each square, in order that they can be chained one after the other in an ordered way.

Domino Games with a Single Solution

In this game, the two different squares of tokens contain two different sets of the same number of elements, and a relationship allows to pass from one set to the other one, in a unique way. Among these types of games, it could be considered:

a) Molecules names and their chemical structures (glycine and NH2–CH2–COOH).
b) Fatty acids names and their abbreviated biological nomenclature (palmitic and C16:0).
c) Amino acid names and their three-letter abbreviation (glycine and Gly).

Domino Games with Several Solutions

This game is based on rectangular tiles divided into two equal squares, presenting in each of these squares two different sets with different numbers of elements in each one, and a relationship that allows to pass from a set with more elements to the other with fewer elements, so that several elements of the first set are related to a single element of the second set. Among these types of games, it could be considered:

a) Molecules names and biomolecules' families (palmitic and lipids).
b) Carbohydrates names and carbons that contain (glucose and hexoses).
c) Carbohydrates names and functional group families (glucose and aldoses).
d) Amino acids names and isoelectric point (glycine and neutral).
e) Amino acids names and ketogenic/glucogenic (alanine and glucogenic).
f) Fatty acids names and saturated/unsaturated (palmitic and unsaturated).

Results

This section shows some examples of the chained word games, that could be applied to the study of Biochemistry in the Chemistry degree of the University of Barcelona, in order that students can learn by playing the

nomenclature and other aspects of the main biomolecules. These games will be used, in the future, by the students for self-studying the nomenclature and structure of biomolecules, and some of them could be placed in an Escape-room for a better enjoy of the students. The chained games were classified into 5 subgroups: 1. Games with chained words using letters; 2. Games with chained words using codes; 3. Games organizing biomolecules from a list considering a property; 4. Games organizing words from their definitions; 5. Games using dominoes. In this paper some examples are presented for each subgroup.

Games with Chained Words using Letters

In Biochemistry, it is very difficult to chain words using syllables, although easier in Catalan or Spanish compared to English. Thus, in English it is easier to chain words using only the last letter of each word. Hereby, an example is given of a game with chained words using letters.

Example game 1.- Chain the following words, so that a word that ends with a letter is chained with the following word that begins with the same letter:

Words:
ADENOSINE, CHOLESTEROL, CITRIC, DNA, ENZYME, EXON, HEXOSE, LIPID, NADH, NUCLEIC

Possible solutions:
NADH–HEXOSE–EXON–NUCLEIC–CITRIC–CHOLESTEROL–LIPID–DNA–ADENOSINE–ENZYME
NADH–HEXOSE–ENZYME–EXON–NUCLEIC–CITRIC–CHOLESTEROL–LIPID–DNA–ADENOSINE

Games with Chained Words using Codes

Words can also be chained using codes. In games, the code should be given in order that students can use it to chain the words. The code can be constant or variable. In this section, two different types of games, using a constant or a variable code, are shown:

Example game 2.- Chain the following list of words considering that, one word is linked with the next one, if the third letter of the first word is the same as the first letter of the second word (code = 3):

Words:
CYSTEINE, DOPAMINE, GLUCOSE, INOSITOL, LYSINE, NADH, ORNITHINE, PALMITATE, SUCROSE, URIDINE

Solution:
GL**U**COSE–UR**I**DINE–IN**O**SITOL–OR**N**ITHINE–NA**D**H–DO**P**AMINE–PA**L**MITATE–LY**S**INE–SU**C**ROSE–CYSTEINE

Example game 3.- Chain the following words, regarding amino acids names, considering that one word is chained with the next one, if in the given word the letter located at the code 647452334 coincides with the first letter of the following word, that is, the sixth letter of the first word matches the first letter of the second word and so on:

Words:
ALANINE, ASPARTATE, CYSTEINE, PHENYLALANINE, ISOLEUCINE, LEUCINE, LYSINE, PROLINE, SARCOSINE, TYROSINE

Solution:
PHENY**L**ALANINE(6)–LYS**I**NE(4)–ISOLEU**C**INE(7)–CYS**T**EINE(4)–TYRO**S**INE(5)–S**A**RCOSINE(2)–AL**A**NINE(3)–AS**P**ARTATE(3)–PRO**L**INE(4)–LEUCINE

Games Organizing Biomolecules From a List considering a Property

Another type of game is that related not only to the biomolecule's nomenclature, but also to the biomolecule's structure. Thus, this kind of game gives more information about the molecule and considers a characteristic of the compound. Hereby, we present two possible properties to order biomolecules: molecular weight or the length of the carbon chain.

Example game 4.- Order the following amino acids, considering their molecular weight:

Amino acids:
ALANINE, GLYCINE, HISTIDINE, ISOLEUCINE, LEUCINE, PHENYLALANINE, SERINE, TRYPTOPHAN, VALINE

Solution:
GLYCINE (75) < ALANINE (89) < SERINE (105) < VALINE (117) < ISOLEUCINE (131) = LEUCINE (131) < HISTIDINE (155) < PHENYLALANINE (165) < TRYPTOPHAN (204)

Example game 5.- Order the following unsaturated fatty acids according to their carbon chain length:

Fatty acids:
ARACHIDIC, BEHENIC, CAPRIC, LAURIC, LIGNOCERIC, MYRISTIC, PALMITIC, STEARIC

Solution:
CAPRIC (C10:0) < LAURIC (C12:0) < MYRISTIC (C14:0) < PALMITIC (C16:0) < STEARIC (C18:0) < ARACHIDIC (C20:0) < BEHENIC (C22:0) < LIGNOCERIC (C24:0)

Games Organizing Words from their Definitions

This game could be represented also as a crosswords game, looking the common letters of the words, and constructing a crossword grid. Students should order the position of each of the elements depending on the order given by the definitions. Games can be reduced to a single type of biomolecule or to all biomolecules. It is also possible that the game presents some words to choose or that the words are not given in the game. If words are given, the game results easier to solve, but if words are not given, clues should be shown to complete the game. Some clues could be the number of letters on each word.

Example game 6.- Order the following compounds, considering the definitions indicated below:

Compounds:
ALANINE, ARGININE, ASPARTATE, CYSTEINE, GLYCINE, LEUCINE, PHENYLALANINE, PROLINE, SERINE, THREONINE

Definitions:
1.- Amino acid, that has a hydroxyl group on a primary carbon.
2.- Amino acid, that is abbreviated as A.
3.- Achiral amino acid.
4.- Branched chain amino acid, that is isomer of isoleucine.
5.- Nonpolar aromatic amino acid.
6.- Acidic amino acid, that contains 4 carbon atoms.
7.- Amino acid, that has a hydroxyl group on a secondary carbon
8.- Amino acid, that contains a mercapto group.
9.- Basic amino acid, that contains a guanidine group.
10.- Cyclic aliphatic amino acid.

Solution:
SERINE – ALANINE – GLYCINE – LEUCINE – PHENYLALANINE – ASPARTATE – THREONINE – CYSTEINE – ARGININE – PROLINE

Example game 7.- From the definitions, find the names of the molecules to which it refers and order them according to the numbering:

Definitions:
1.- Abbreviation for deoxyribonucleic acid (3 letters).
2.- Abbreviation of the reduced form of nicotinamide adenine dinucleotide (4 letters).
3.- Amino acid, that is abbreviated as A (7 letters).
4.- Disaccharide present in milk, whose hydrolysis yields glucose and galactose (7 letters).

5.- Salt of the glycolytic metabolic intermediate, which is transported to mitochondria to fill the Krebs cycle (8 letters).

6.- Basic amino acid, that in addition to belonging to proteins, participates as an intermediate in the urea cycle (8 letters).

7.- Amino acid belonging to proteins, that contains a mercapto group (8 letters).

8.- Monosaccharide present in fruits (8 letters).

9.- Salt of the most frequent fatty acid in humans, called in systematic nomenclature hexadecanoate (9 letters).

Solution:

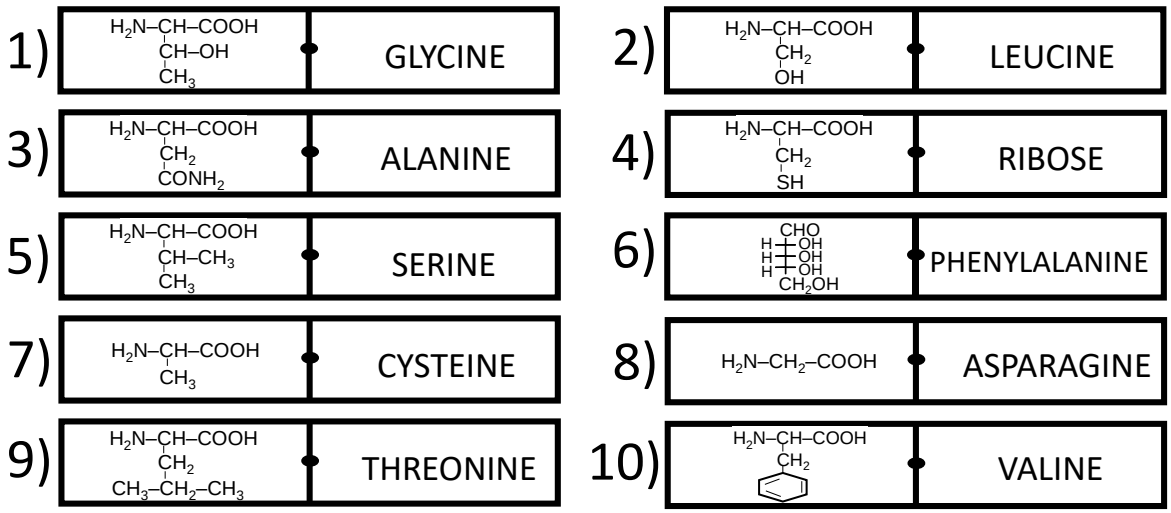
DNA – NADH – ALANINE – LACTOSE – PYRUVATE – ARGININE – CYSTEINE – FRUCTOSE – PALMITATE

Games using Dominoes

In this kind of games, tokens can be used to organize the game. It could be played individually or in groups (as in the typical domino game).

Example game 8.- Place the dominoes one after the other, so that the systematic nomenclature of each biomolecule is next to the chemical structure of this biomolecule. Which molecule is not an amino acid?

Dominoes:



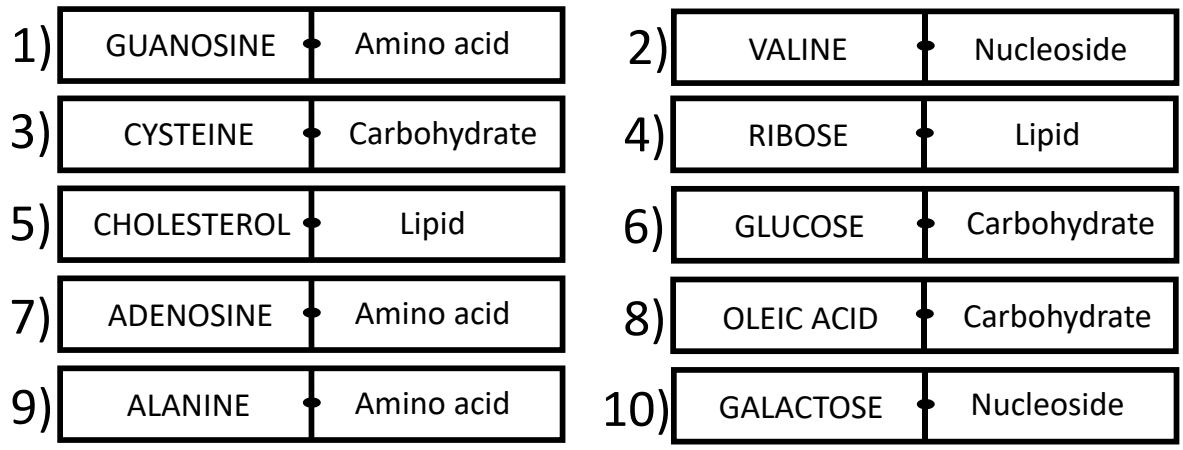
Solution:

1 – 8 – 3 – 7 – 4 – 6 – 10 – 5 – 2 – 9 – 1

RIBOSE is a carbohydrate. It is not an amino acid.

Example game 9.- Place all the dominoes one after the other, so that each biomolecule is next to its family.

Dominoes:



Possible solutions:

1 – 2 – 7 – 9 – 3 – 6 – 4 – 5 – 8 – 10 – 1

1 – 2 – 7 – 9 – 3 – 4 – 5 – 8 – 6 – 10 – 1

1 – 9 – 2 – 7 – 3 – 6 – 4 – 5 – 8 – 10 – 1

1 – 9 – 2 – 7 – 3 – 4 – 5 – 8 – 6 – 10 – 1

1 – 3 – 6 – 4 – 5 – 8 – 10 – 7 – 9 – 2 – 1

1 – 3 – 4 – 5 – 8 – 6 – 10 – 7 – 9 – 2 – 1

1 – 9 – 3 – 6 – 4 – 5 – 8 – 10 – 7 – 2 – 1

1 – 9 – 3 – 4 – 5 – 8 – 6 – 10 – 7 – 2 – 1

Discussion

In previous works of our consolidated innovation teaching group (GINDOC-UB/180), we carried out a search for games to be used to self-study Biochemistry's biomolecule names and structures. These games were based on the grammar games used to learn languages. We classify the games into four main groups: 1. words lacking a syllable or a group of letters, 2. anagrams and labyrinths, 3. codes to translate words, and 4. dominoes and other enchained games. Since the games were first used during the COVID19 pandemic lockdown and it was not possible to hold a competition between different players, they were thought for individual students for self-studying. Later, these games were also applied to find a key word that could be used to continue an Escape-room game. In this work, we focus on the games of group 4 (dominoes and other games enchained games). We classified this group of games into 5 subgroups: 1. Games with chained words using letters; 2. Games with chained words using codes; 3. Games organizing biomolecules from a list considering a property; 4. Games organizing words from their definitions; 5 Games using dominoes. Our goal was to apply them in a shortly future for the self-study of Biochemistry students, and thus were evaluated by the students, although there were few students in the class.

Games with chained words using syllables are the most frequent in Catalonia within the chain games [JuegosJuegos, 2021]. However, in Biochemistry there are numerous words that end in -ose or -ase (carbohydrates or enzymes), -ic (acids), -ate (salts), or -ine (amino acids), and it is difficult to find words beginning with those syllables. In English, as ending syllables use frequently more than 2 letters, it is even more difficult. Thus, another possibility was to chain the words using only the last letter (games of subgroup 1). It was easier in Biochemistry to find words that started only with one letter. This game must include the words to be chained, and it is a simple game to be solved.

Games of subgroup 2 (games with chained words using codes) are more difficult to solve, especially those with a variable code, which depends on the position of the word. In the easier game using a constant code, a specific letter position can be defined to chain the next word (see example game 2). Solving this constant code game is like solving subgroup 1 games. In subgroup 1, the letter used as initial for the second word is the last one, whereas in constant code subgroup 2, the letter occupying a constant position inside the word. When all the words are ordered with a letter that is in the same position (example game 3), it is possible to mark this letter in all the words and easily see the possibilities of words beginning with this letter. More complex is the game using a variable code as that shown in example game 4, where the initial letter from the next word is not always in the same position. The code can be as complex as wished (for example, different numbers in different positions, as 142857) or the same code repeated periodically (for example, 272727). Variable codes can be given as a number (as before) or as a fraction (for example, 1/7 = 0.142857; or 3/11 = 0.272727).

Sorting games are another type of game that, despite not chaining words, the words are included in a list, as if they were lists of chained words. These types of games include games that order words in a list (subgroup 3) and games that chain words from their definitions (subgroup 4). For games of subgroup 3, a characteristic that allows ordering the words is necessary, so words should be regarding the same family of biomolecules. Among biomolecule's characteristics, the structure can be considered. Biomolecules can be ordered depending on their molecular weight, length of the carbon chain, etc. It is difficult to look for differential characteristics for some molecules that have the same chain length or similar molecular weight (as in the case of carbohydrates).

Easier to prepare are subgroup 4 games, in which a common characteristic is not needed, but only a clear definition of the word. Thus, in subgroup 4 games it is not necessary that words refer to biomolecules. In this subgroup, the game is simplified if the words are included within the game, only deciding which word corresponds to each of the definitions. It is more difficult to solve the game if words are not included in the game. In this second case, it is better to provide some additional data about the resulting words (such as, for example, the number of letters that the word contains, or a letter that is in a determined position of the word as if it were a crosswords game).

Finally, subgroup 5 games (games using dominoes) are the most difficult to solve, as students must know biomolecule's names and structures. These games could be played individually (for games with only one solution) or in a group (for games that could have more solutions). A simple game that can be played by a single

player is like that shown in example game 8, that contains two sets with the same number of elements (name of the biomolecule and its chemical structure). It is also possible to relate the names of amino acids with its 3-letter abbreviation. As only one sequence is possible in both cases, game should be played individually. However, it is also possible to complicate the game, and even propose it for two or more players, by relating the names of biomolecules to the type of biomolecule (carbohydrate, lipid, amino acid, nucleotides) as in the case of example game 9, or names of carbohydrates and their structural characteristics (aldoses or ketoses) or their length of the carbon chain (hexoses or pentoses). These examples allow several solutions, although in our example, the path that includes all the tokens was requested. However, due to the double tokens, it is possible to obtain several solutions in which all tokens can be used.

Conclusion

Games with chained words using letters are easy to solve, and sometimes can also have several solutions.

Games with chained words using codes can contain constant or a variable code. When the code is constant, games are like those of subgroup 1 (easy to solve and to prepare). When the code is variable, games are more difficult to solve, as word chaining depends on the position of the word in the solution.

Games of subgroups 3 and 4 allow an additional learning, as the students learn also about the property of biomolecule, or the definition of the word. Subgroup 4 games are like crosswords.

Games using dominoes are also complete games, as students can learn about structure and nomenclature of biomolecules.

Notes

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