Gamification Using Labyrinths and Mazes to Learn Biomolecule's Nomenclature of Biochemistry in Chemistry Degree

Josep J. Centelles
Departament de Bioquímica i Biomedicina Molecular, Facultat de Biologia, Universitat de Barcelona, Avda. Diagonal 643, 08028-Barcelona, https://orcid.org/0000-0002-6289-9678

Estefania Moreno
Departament de Bioquímica i Biomedicina Molecular, Facultat de Biologia, Universitat de Barcelona, Avda. Diagonal 643, 08028-Barcelona, https://orcid.org/0000-0002-2491-5753

Pedro R. de Atauri
Departament de Bioquímica i Biomedicina Molecular, Facultat de Biologia, Universitat de Barcelona, Avda. Diagonal 643, 08028-Barcelona, https://orcid.org/0000-0002-7754-7851

Abstract: Gamification is a very useful technique, that has been fully increasing in the last years. During the CoVid19 pandemic, our innovation teaching group sent to our students several games, that were used by them for self-studying. Considering that many numerical problems can be proposed in Biochemistry, rather than numerical games (sudoku, adding and subtracting number games, …) word games were preferred to learn biomolecule nomenclature. Among these word games, we adapted to Biochemistry: connecting dots, labyrinths, mazes, matching two sets, amidakuji, logic games, crossword puzzles, word search puzzles, knight's tour games or anagrams. In this work, we present several games related to labyrinths and mazes. Connecting dot games were adapted to Biochemistry by using intermediate metabolite of a pathway instead of numbers to develop a picture when connecting the dots. Anyway, as pathways don't contain a big number of metabolites, no difficult pictures can be used. Thus, a labyrinth with questions and answers and letters connecting questions with answers can be better used. Correct answers can develop the letters of a biomolecule's name. Other kind of labyrinth can be those where the letters can be taken from the shortest route. Labyrinths can also be used to develop a word following the route in labyrinths and taking letters to get the word, as an anagram. Several examples are shown hereby, adapted for Biochemistry students of Chemistry degree.

Keywords: Games, Labyrinth, Maze, Biochemistry

Citation: Centelles, J. J., Moreno, E. & de Atauri, P. R. (2023). Gamification Using Labyrinths and Mazes to Learn Biomolecule's Nomenclature of Biochemistry in Chemistry Degree. In M. Koc, O. T. Ozturk & M. L. Ciddi (Eds.), *Proceedings of ICRES 2023- International Conference on Research in Education and Science* (pp. 17-29), Cappadocia, Turkiye. ISTES Organization.

Introduction

Game-based learning is a term that is difficult to define, although it is often described as learning that involves game boards, cards, or dice, as well as video games [Stojanovska and Velevska, 2018]. According to Prensky [Prensky, 2000], it is crucial that students become fully engaged in the game process. To achieve this, games must contain six key elements for them to be effective: (1) rules of the game; (2) goals and objectives; (3) results and feedback; (4) conflict, competition, challenge, and opposition; (5) interaction; and (6) representation of a story or performance [Huang and Soman, 2013]. In fact, gamification is a popular method, that is increasingly being used to help students to acquire more knowledge and skills [Kim, 2013]. Traditional teaching methods in science, technology, engineering, and mathematics (STEM) often involve passive learning, which can lead to boredom and a lack of interaction on some students. The Moodle environment is highly suitable for gamification on self-learning tool, as it allows teachers to offer a wide range of games to students and analyzes which ones they prefer and how frequently they are used. This possibility of Moodle allows teachers to observe the interests of each student and encourages their personal fulfillment, just as is sought in the Montessori method [Palmarola, 2017]. According to this method, the teacher must promote students' interests by adapting the material to suit everybody individually. However, while some H5P activities can show if the student has been frequently connected, not all the games can be directly evaluated by Moodle.

In Biochemistry, gamification is not generally used since it is a more suitable methodology for non-scientific subjects. Learning based on solving numerical problems or medical cases is more commonly used. However, the nomenclature found in textbook glossaries [Stryer et al., 2015; Nelson and Cox, 2018] is complex and difficult to remember. For this reason, our consolidated teaching innovation group (GINDOC-UB/180) thought that gamification could be applied to self-learning the nomenclature and structure of biomolecules. After the pandemic we prepared several games based on four main groups: (a) words lacking a syllable or a group of letters [Centelles et al., 2021] [Centelles et al., 2022a] [Centelles et al., 2022b], (b) anagrams and labyrinths, (c) translation of codes [Centelles et al. 2022c], and (d) dominoes and other games to chain words [Centelles et al. 2022d] [Moreno and Centelles, 2021]. The aim of this work is to classify and apply the games that use anagrams and labyrinths (group b) to help Biochemistry students to self-learn the nomenclature of biomolecules.

Labyrinths are structures with one or several paths that deceive the visitor and make it difficult to find the center and the exit. In Greek mythology, labyrinths were used to hide something or someone inside them, and the labyrinth of Crete, for example, hid the Minotaur. Theseus was able to defeat the Minotaur and to escape the labyrinth because Ariadne showed him how to find his way back by unwinding a thread as he entered the labyrinth. In the Middle Age, labyrinths were Christianized, and the word "Ecclesia" was written in the center, or a cross was drawn, and their function was to protect this center. Only people initiated in the faith could access the labyrinth to follow the path to salvation. According to the path, the labyrinths are classified as unicursal and multicursal [Rivera-Dorado, 1995], where the unicursal labyrinths are those that have a single and complex path (labyrinth), while the multicursal labyrinths are composed of several paths (mazes). While the unicursal paths

follow a route from the entry point to the center of the labyrinth, and from there to the exit point, without the need to make decisions; multicursal labyrinths have dead-ends and sections not connected to the perimeter. A well-known unicursal labyrinth is the labyrinth of Chartres Cathedral, 16 m in diameter and 11 concentric circles, which traces a path of 264 m from the outside to the center of the labyrinth. This road was called the "Jerusalem Road" and had to be traveled on one's knees reciting the miserere to obtain an indulgence similar to that of pilgrimage to the Holy Land. On the other hand, the multicursal labyrinths are those that were designed in the romantic gardens at the beginning of the 19th century, such as the labyrinth in the Horta labyrinth park (Barcelona). The park is dedicated to love and its aspects, with allusions to Narcissus, Echo, the kidnapping of Europe, …, and of course, Ariadne's thread.

In the field of education, labyrinths can be used as a tool to facilitate learning and promote problem-solving skills. They can be designed in different ways, including as mazes with dead-ends or as unicursal paths leading to a point. By navigating through these labyrinths, students can improve their cognitive abilities and enhance their understanding of complex concepts. Anagrams are another tool that can be used in gamification to facilitate learning. Anagrams are words or phrases formed by rearranging the letters of another word or phrase. They can be used to help students to learn vocabulary, spelling, and grammar. By rearranging letters and forming new words, students can develop critical thinking and problem-solving skills.

Method

Biochemistry glossaries enable the identification of the most frequent biomolecules [Stryer et al., 2015; Nelson and Cox, 2018]. The words in the glossaries were classified into six groups: (1) carbohydrates; (2) lipids; (3) amino acids and proteins; (4) nitrogenous bases, nucleosides, and nucleotides; (5) intermediates of metabolic pathways; (6) cell components and other related words. Once the most important words that students should know were identified, we analyzed possible games within the "anagrams and labyrinths" section, that could be used as pastimes to identify these words. We decided to use anagrams or alphagrams inside the labyrinth, to make the game more challenging to solve and more enjoyable for our students.

Anagrams or alphagrams

There are many anagram generators available on the Internet [Anagram generator], which makes it easy to prepare this type of games. However, it is also easy for students to solve these anagrams if they use them. Alphagrams, which involve sorting the letters in alphabetical order, are easier to prepare, if possible, than anagrams. However, for the players, anagrams or alphagrams are equally challenging to solve. If the anagrams make sense, they can provide an added value that helps players remember the new word more easily by simply recalling the anagram.

Unicursal labyrinths or labyrinths

For Catalan speakers, labyrinths are divided in two groups: unicursal or multicursal. Unicursal labyrinths are those that show only one road, that goes from origin to destiny, and although they are easy to solve, they could be long lines with several changes of direction, and this makes difficult to see the solution at first sight. Multicursal labyrinths or mazes contain several roads, and their aim is that to obtain the shorter way that goes from origin to destiny. In labyrinth (unicursal labyrinths), there is only one road that leads from origin to destiny.

Multicursal labyrinths or mazes

Multicursal labyrinths or mazes are those that show several roads, dead-end zones, and the player should find the shorter way from entrance to exit. A possibility to play a game with a maze consists in taking the letters found in the shortest road. The collected letters can form a word directly, or from them an anagram can be obtained that reveals the asked word. Another possibility consists in a maze containing labels connected with a letter, or questions and answers also connected with a letter. When answering the questions correctly, an anagram can be formed or a word can be obtained directly, just like in the labyrinths of letters found on the road.

Adapted amidakuji

We adapted the Japanese Amida lottery to a unicursal labyrinth, to connect two sets containing the same numbers of elements. After connecting the road, the second set of elements contained a question in order that the student could answer a test of true-false answer. This game could be more enjoyable than a simple test.

Results

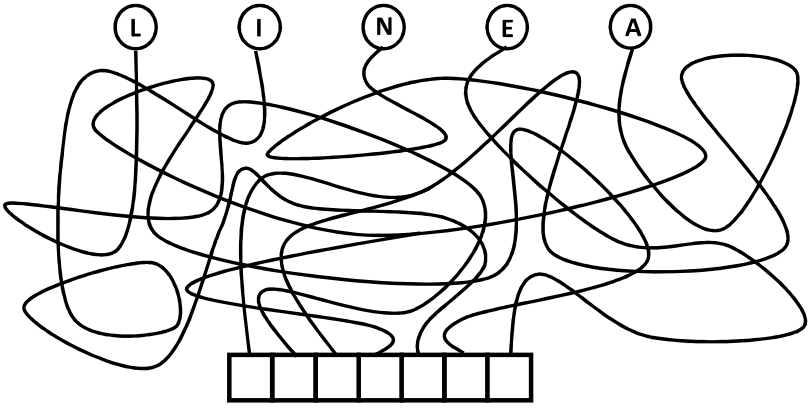
Unicursal labyrinth or labyrinths are roads with only one individual path. These kinds of games can be compared with anagrams or alphagrams, as the letters can be easily sawn, although not their positions in the word. Nevertheless, labyrinths are easier to solve than anagrams or alphagrams, as it is easier to find the way than to try different possibilities. If roads are shorter or there are not so many roads, game is easier to solve, whereas complex roads lead to complex solutions. Multicursal labyrinths or mazes, instead, can show several paths. Nevertheless, the player should usually find the shorter way from the beginning to the end.

Unicursal labyrinth or labyrinths containing branched paths.

In the following games, some letters are repeated in the solution word, but they are only written once at the statement. The game can be prepared showing only one word, or several words. When solution contains only one word, the game is easier, whereas it is more difficult when several words must be found.

Labyrinths with branches paths developing only one word.

Follow the paths for each letter, that lead to the grid of the word. The name of an amino acid will be developed.

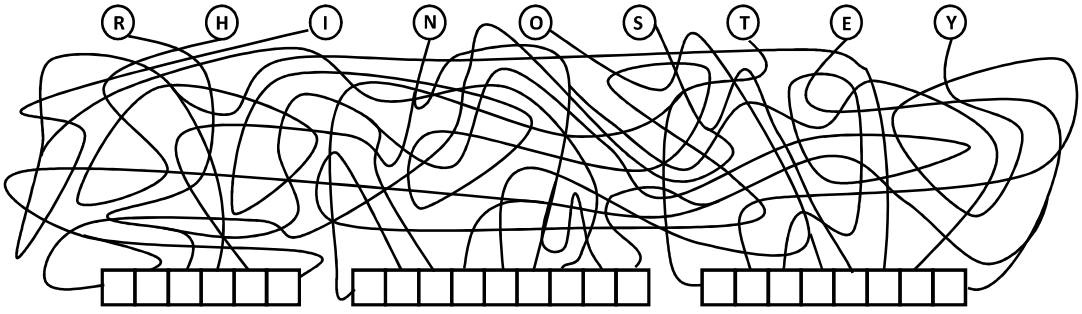


SOLUTION: Alanine

A and N have branched paths, as the letters are repeated twice in the solution word.

Labyrinths with branched paths developing several words.

Follow the paths for each letter, that lead to the grids of the words. The name of three amino acids containing hydroxyl groups will be developed.



SOLUTION: Serine, Threonine, Tyrosine

Serine and threonine are aliphatic amino acids, whereas tyrosine is aromatic. Serine contains a primary alcohol, threonine a secondary alcohol, and tyrosine a phenol.

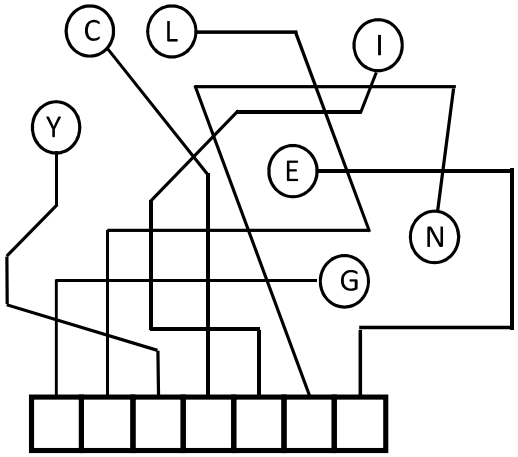
In this game, although H and Y have lineal paths, S, O and T appear twice in the grids, I and R three times, N four times and E five times. Paths for the last letters (S, O, T, I, R, N and E) are branched, in order that they arrive to the boxes of the grid several times.

Unicursal labyrinth or labyrinths containing lineal paths.

In the following games, although some letters could be repeated in the solution word, all the letters are written at the statement. The game can be prepared, as the previous one, showing only one word, or several words. When solution contains only one word, the game is easier, whereas it is more difficult when several words must be found.

Labyrinths with lineal paths developing only one word.

Follow the paths for each letter, that lead to the grid of the word. The name of an amino acid will be developed.



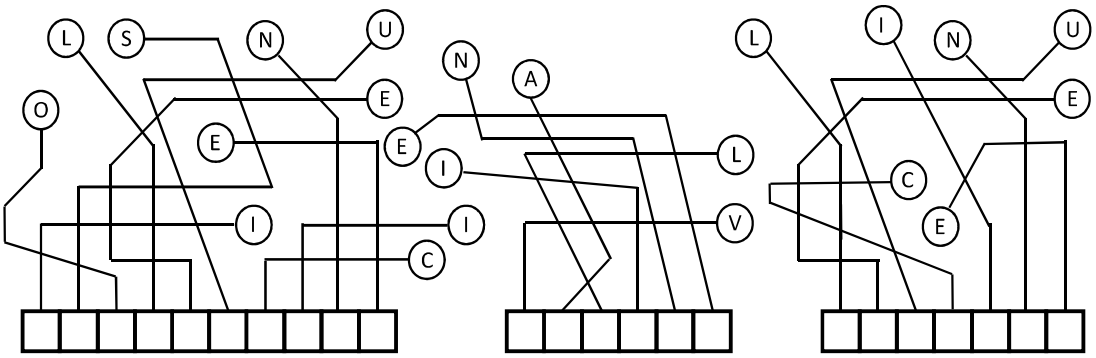
SOLUTION: Glycine

Glycine is the smaller amino acid in proteins. It is the only achiral amino acid in proteins.

The game is easier than a simple anagram or alphagram, since the lines reduce the number of options.

Labyrinths with lineal paths developing several words.

Follow the paths for each letter, that lead to the grids of the words. The name of the three branched chain amino acids will be developed.



SOLUTION: Isoleucine, Valine, Leucine

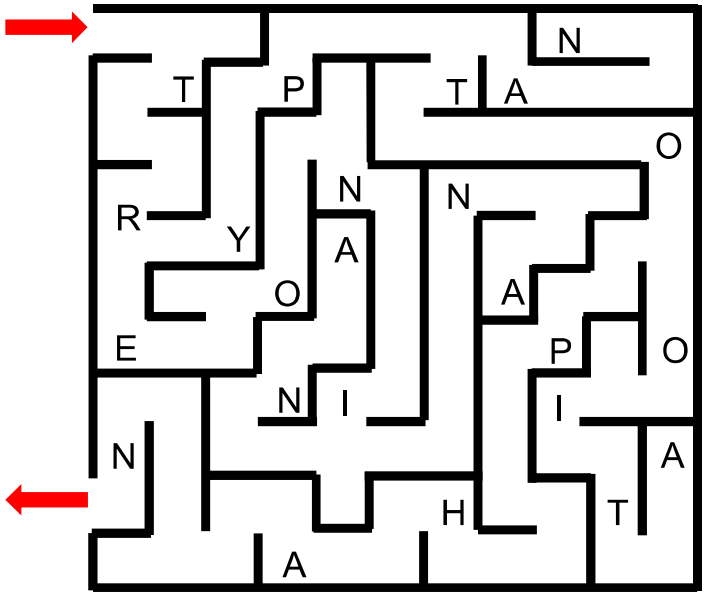
Valine contains 5 carbons, whereas leucine and isoleucine contain 6 carbons. All are branched chain amino acids.

Multicursal labyrinth or mazes taking letters on the road.

In the following games, some letters could be taken when walking through the correct path. Those letters could directly form a word, or an anagram and the word should be constructed from the anagram.

Mazes developing one word by following the road.

Follow the road through this labyrinth from the entrance (top arrow) to the exit (bottom arrow). Take all the letters found in the shorter path. The hidden word is the name of an aromatic amino acid.

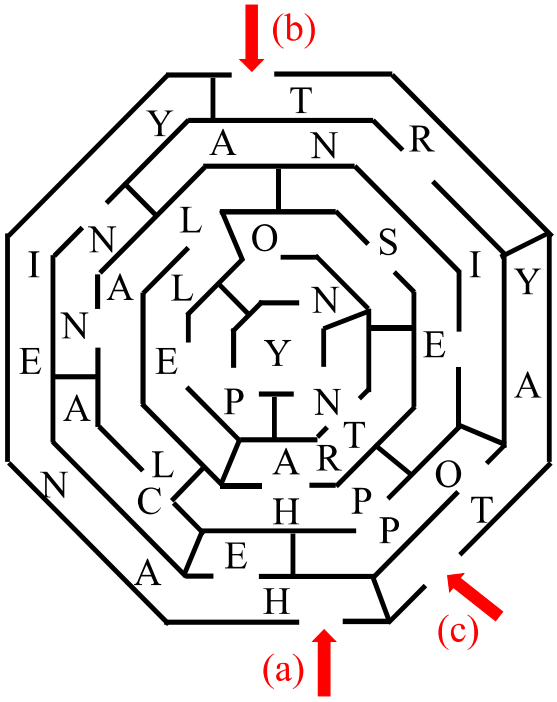


SOLUTION: Tryptophan.

Tryptophan is an aromatic amino acid. Neutral aromatic amino acids from proteins are phenylalanine, tyrosine, and tryptophan. Histidine is also an aromatic amino acid, but although phenylalanine, tyrosine and tryptophan are neutral amino acids, histidine is a basic amino acid.

Mazes developing anagrams of several words by following the road.

Follow the roads (a), (b) and (c) from the arrow to the center of the labyrinth. Take all the letters found in the 3 paths. Each road will develop an anagram of an aromatic amino acid. The hidden three words are anagrams of the three names of aromatic amino acids.



SOLUTION: (a) HANEINNALLEPY, Phenylalanine; (b) TRIESONY, Tyrosine; (c) TOPPHARTNY, Tryptophan.

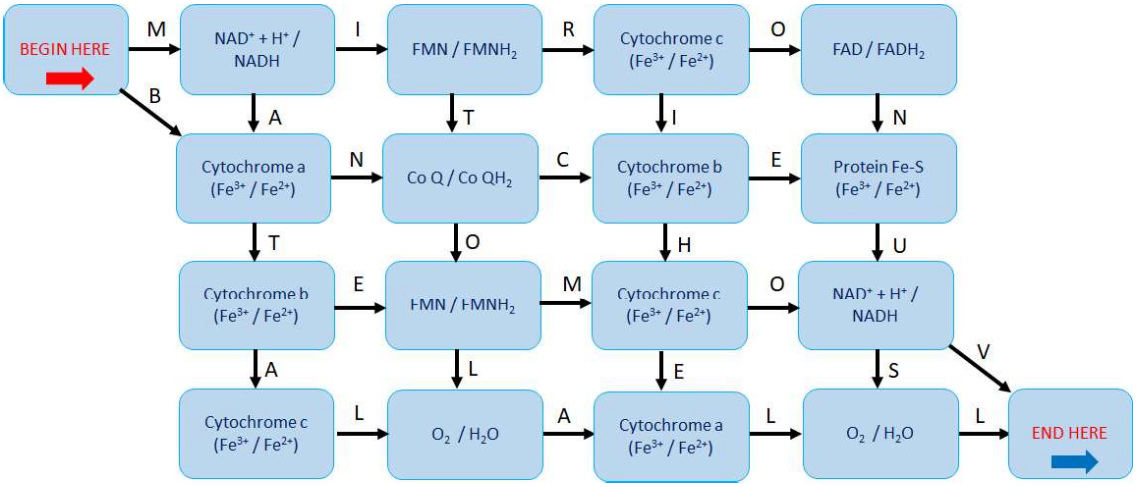
Neutral aromatic amino acids from proteins are phenylalanine, tyrosine, and tryptophan. Histidine is also an aromatic amino acid, but it is a basic amino acid.

Multicursal labyrinth or mazes with questions and answers.

The origin of this game in our group came originally from a dot-to-dot game, after labelling the dots as intermediate from a metabolic pathway [Centelles et al., 2022e]. As there were not many dots (not much intermediate in the metabolic pathway), we substituted the dot-to-dot figure with a label game. Different labels were connected by lines displaying a letter, and the students should order the labels following the metabolite intermediate in the order of the Biochemical pathway. Letters obtained in the road with the correct labels form a word (or an anagram or alphagram) related with the metabolic pathway. Later, a complex game was prepared using labels that contained questions and answers, and the letters collected between the questions and their correct answers could also form a word.

Mazes with labels of intermediates from a Biochemical pathway.

Beginning from the red arrow, order the intermediate of the electron chain. The letters that bind the labels show the surname of a scientist related with the electron chain metabolism.

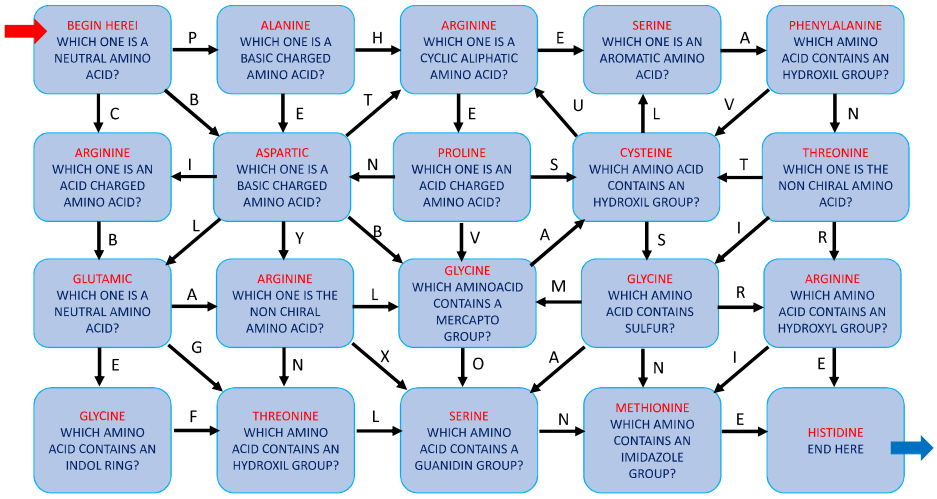


SOLUTION: $NAD^+ + H^+/NADH$, FMN/FMH_2, $CoQ/CoQH_2$, Cytochrome b (Fe^{3+}/Fe^{2+}), Cytochrome c (Fe^{3+}/Fe^{2+}), Cytochrome a (Fe^{3+}/Fe^{2+}), O_2/H_2O. MITCHELL

Peter Mitchell (1920-1992) proposed the chemiosmotic theory, where ATP is formed due to the H^+ gradient formed by the electron chain metabolism.

Mazes with questions and answers.

Beginning from the red arrow, answer the questions (in blue) and decide which is the label that contains the correct answer (in red) from the labels connected. Collect the letters that connect the labels and with all the letters collected form the name of an amino acid.



SOLUTION: Phenylalanine.

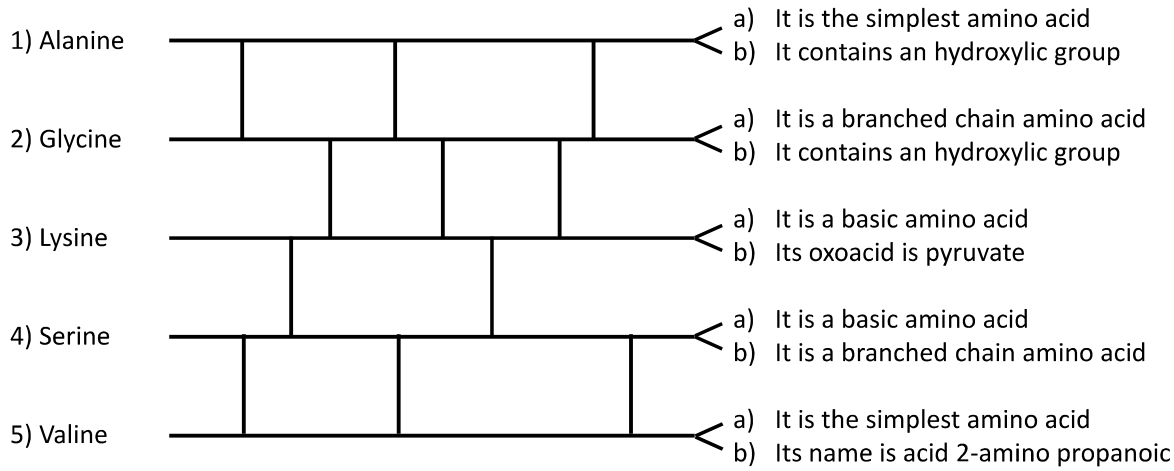
Which one is a neutral amino acid?: alanine / which one is a basic charged amino acid?: arginine / which one is a cyclic aliphatic amino acid?: proline / which one is an acid charged amino acid?: aspartic / which one is a

basic charged amino acid?: arginine / which one is the non-chiral amino acid?: glycine / which amino acid contains a mercapto group?: cysteine / which amino acid contains an hydroxyl group?: serine / which one is an aromatic amino acid?: phenylalanine / which amino acid contains an hydroxyl group?: threonine / which one is the non-chiral amino acid?: glycine / which amino acid contains sulfur?: methionine / which amino acid contains an imidazole group?: histidine.

Labyrinths adapted from an amidakuji.

This is not really a labyrinth, but it can be considered related since the game starts from one label and ends in another label that matches with the previous one. This puzzle has its origin in the Japanese Amida lottery, and it is also named Ghost Leg in China or Sadaritage (ladder climbing) in Korea. It is based on matching two sets containing the same components, for example, a set of numbers and a set of letters. Amidakuji is based on vertical lines connecting one set to the other, but to relate one number to one letter, several horizontal lines are drawn between two vertical lines. The number of horizontal lines is not important, but at least one line should be between each pair of adjacent vertical lines. To choose which number matches with a letter, the vertical line is followed until a horizontal line is reached, then it continues with the bound adjacent vertical line until the next horizontal line, or the end of the vertical line. In our adaptation, we changed the vertical lines to horizontal lines and added a question at the end, so that students must decide between two possibilities.

Match each amino acid expressed with number with one of the sentences at the end of the line. To play, move along the horizontal line, and when encounter a vertical line, change to the other horizontal line. Continue in this way until you find the end of one horizontal line, and afterwards decide whether the correct answer is a. or b.



SOLUTION: 1. Alanine, b. Its oxoacid is pyruvate; 2. Glycine, a. It is the simplest amino acid; 3. Lysine, a. It is a basic amino acid; 4. Serine, b. It contains an hydroxylic group; 5. Valine, a. It is a branched chain amino acid.

Discussion

In Internet there are many anagram generators, that could make easier to solve individual anagram games, although unicursal labyrinths can be solved in an easier way than games with only anagrams, just only following the road of each letter. Students can "cheat" with anagram generators [Anagram Generator]. When unicursal labyrinths contain branched paths, solution is more difficult to achieve, as anagram generators cannot be used to get the solution. Most of the students obtain the solutions by going from the letters to the grid, but other solve the game by going from the grid to the letter. Of course, games developing one word are easier than games developing several words, although in some cases it is easier to conclude the words. For example, for the branched chain amino acids, it could be easier to know that these amino acids are valine, leucine, and isoleucine, and afterwards to write them in the 10-grid, 6-grid and 7-grid places. Or to solve the 6-grid valine; and remember that the other two amino acids should be leucine and isoleucine. In all the cases, students will remember the three branched chain amino acids.

However, single unicursal labyrinths are easier to solve, since words contain a relatively low number of letters. Collective unicursal labyrinths are more complex than single ones and prevent anagram generators from being used to solve them. It is also easier to solve unicursal labyrinths when all the repeated letters are repeated also in the game. When some letters are missing, it is not possible to use anagram generators to "cheat". Regarding to multicursal labyrinths or mazes, the usual shapes are rectangular, but any shape can be used (triangular, round, square, hexagonal, even star shape, and other shapes). Hereby we presented a square maze and a hexagonal maze. Anyway, all the mazes should have an entrance and an exit, although in some cases there are different possibles roads to arrive to the center. In children's games, they could show a mouse and a cheese and ask to the children to find the road in order that the mouse could find and eat the cheese. In other cases, they can also show a mouse trap and ask to the children to find the road to the cheese but not the mouse trap. In our examples, we show letters for the roads.

In Biochemistry, we first though on a maze with only one road and the easy way was to write several letters inside the maze. The student should collect all the letters that he finds at the road. The game is more difficult if those letters are an anagram, and an added value is obtained when the anagram has a meaning. Nevertheless, if this anagram is an alphagram or is not a word, it could be difficult to find the right road, as the found letters give no clues about how to continue the road. Mazes with several roads can be used to collect families of biomolecules, where the letters obtained in each road generate the name of a biomolecule. In these cases, later it is possible to ask a question about the family of biomolecules obtained. Mazes with questions and answers are those that can give more knowledge to the student. Students should answer a question to solve this maze, and letters are collected from the line that connects the question with the answer. Students have several possible answers, and they must decide, which is the correct one. If they don't answer correctly, they can get soon into a dead-end road, either because none of the answers is the correct one or because they get into a loop and they cannot get to the exit. Students have then to go back to the question answered with doubts. By the other hand,

the letters collected can also give a clue regarding the word obtained at the end of the maze. The game can be complicated if the word is an anagram or even more if it has no sense before solving.

Mazes with questions and answers evolved from our label games, where labels were intermediate of Biochemistry metabolism, and students should connect those labels by ordering these intermediates. In fact, these games were initially thought as dot-to-dot games. The new game is now more complete, as allows three games in one: to find the way inside the maze, to play answering the questions, to look for a word from the obtained anagram.

Regarding the amidakuji, the road is found following easy rules. In fact, a maze can be also solved by turning always to the right or to the left inside the labyrinths, although the road can be longer as can contain several dead-end roads and returning to original places. Thus, amidakuji can be considered as a special labyrinth, that we included in this paper.

Conclusion

Anagrams can be easily solved by using anagram generators in Internet. Unicursal labyrinths (or labyrinths) are easier to solve than multicursal labyrinths (or mazes). Adapted amidakuji is a sort of labyrinth, and the last question is more enjoyable than a simple true-false question. The most enjoyable games presented here are the mazes taking letters on the road or the mazes with questions and answers, as they allow several games inside the same game.

Notes

All authors belong to the QuiMet group (Metabolism in the Chemistry Degree) teaching innovation group consolidated (GINDOC-UB/180) and acknowledge to RIMDA, University of Barcelona, for recognizing our work. This work was possible by the project 2022PMD-UB/020 from RIMDA (Universitat de Barcelona).

References

Anagrams generator (English (en), Castillian (es), Deutsch (de), French (fr)): https://aigram.org/en/home. Inge's Anagram Generator. Create anagrams in Danish, English, French, German, Italian, Norwegian (bokmål and nynorsk), Spanish or Swedish. https://ingesanagram.com/

Centelles J.J., Imperial S., de Atauri P., Moreno E. (2021). *Gamification in the subject of Biochemistry in the Chemistry degree using puzzles (Gamificació en l'assignatura de Bioquímica del grau de Química utilitzant passatemps)*. 10es JEQC. La Química davant els reptes actuals. Col.legi de Químics de Catalunya. pp. 4-12 (2021). ISBN: 978-84-124850-3-5

Centelles J.J., de Atauri P., Moreno E. (2022a). *A new way to study biochemistry words by using games*.

Proceedings of International Conference on Humanities, Social and Education Sciences 1, 61-71 (2022). Editors: Omid Noroozi and Ismail Sahin. ISBN: 978-1-952092-33-6.

Centelles J.J., de Atauri P., Moreno E. (2022b). *Utilización del contexto digital en docencia de Bioquímica: Pasatiempos para aprender la nomenclatura de biomoléculas. Sociedad digital, comunicación y conocimiento: retos para la ciudadanía en un mundo global*, 58, 791-809. Coords. Lorena R. Romero Domínguez y Nuria Sánchez Gey Valenzuela. Editorial Dykinson, S.L. ISBN: 978-84-1122-082-8.

Centelles J.J., Moreno E., de Atauri P. (2022c). *Juegos de palabras basados en códigos para el autoaprendizaje de la nomenclatura de biomoléculas. Sociedad digital, comunicación y conocimiento: retos para la ciudadanía en un mundo global*, 58, 769-790. Coords. Lorena R. Romero Domínguez y Nuria Sánchez Gey Valenzuela. Editorial Dykinson, S.L. ISBN: 978-84-1122-082-8.

Centelles J.J., Moreno E., de Atauri P. (2022d). *Aplicación de la gamificación en Bioquímica: Juegos de palabras encadenadas para aprender los nombres y estructuras de las biomoléculas. (Gamification Application in Biochemistry: Chained Words Games to Learn Biomolecule's Names and Structures)*. Revista de Aprendizaje 8 (2), 1-15. Publicado y Sostenido por Common Ground Research Networks. ISSN: 2575-5544 (printed version); ISSN: 2575-5560 (electronic version).

Centelles J.J., de Atauri P., Moreno E. (2022e). *Capítulo 39. Utilización del contexto digital en docencia de Bioquímica: Pasatiempos para aprender la nomenclatura de biomoléculas*. En: "Sociedad digital, comunicación y conocimiento: retos para la ciudadanía en un mundo global", 58, 791-809 (2022). Coords. Lorena R. Romero Domínguez y Nuria Sánchez Gey Valenzuela. Editorial Dykinson, S.L. ISBN: 978-84-1122-082-8.

Huang, W.H. and Soman, D. (2013). *A practitioner's guide to gamification of education*. Toronto, ON: Rotman School of Management University of Toronto.

Kim, B. (2013). *Keeping Up With ... Gamification. American Library Association*. https://www.ala.org/acrl/publications/keeping_up_with/gamification

Moreno, E. and Centelles, J.J. (2022). *Juegos sencillos destinados a aprender la nomenclatura de las biomoléculas. Innovación docente y prácticas educativas para una educación de calidad*, Conocimiento contemporáneo 47, 338-364. Coord. Carmen Romero García. Editorial Dykinson, S.L. ISBN: 978-84-1377-920-1.

Nelson, D.L.; Cox, M.M. (2018). *Lehninger. Principios de Bioquímica. 7ª Edición*. Ediciones Omega.

Palmarola, J. (2017). *Guia práctica del Método Montessori: Con más de 100 actividades para hacer en casa de 0 a 6 años (Libros de actividades Montessori en casa y en clase)*. ISBN-10: 1973357615; ISBN-13: 978-1973357612.

Prensky, M. (2000). *Digital game-based learning*. New York: McGraw Hill.

Rivera Dorado, M. (1995). *Laberintos de la antigüedad*. Alianza Editorial.

Stojanovska, M. and Velevska, B. (2018). *Chemistry Games in the Classroom: A Pilot Study*. Journal of Research in Science, Mathematics and Technology Education, 1(2), 113-142. Doi: 10.31756/jrsmte.121

Stryer, L; Berg, J.M.; Tymoczko, J.M. (2015). *Bioquímica con aplicaciones clínicas. 7ª Edición*. Editorial Reverté,S.A.