Title
Interactive Hangman teaches amino acid structures and abbreviations

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Abstract

We developed an interactive exercise to teach students how to draw the structures of the 20 standard amino acids and to identify the one-letter abbreviations by modifying the familiar game of “Hangman.” Amino acid structures were used to represent single letters throughout the game. To provide additional practice in identifying structures, hints to the answers were written in “amino acid sentences” for the students to translate. Students were required to draw the structure of the corresponding letter they wished to guess on a whiteboard. Each student received a reference sheet of the structures and abbreviations, but was required to draw from memory when guessing a letter. Preassessments and postassessments revealed a drastic improvement in the students’ ability to recognize and draw structures from memory. This activity provides a fun, educational game to play in biochemistry discussion sections or during long incubations in biochemistry laboratories. © 2014 by The International Union of Biochemistry and Molecular Biology, 42(6):495–500, 2014.

Keywords: Interactive game; amino acid structures; amino acid abbreviations; Hangman; active learning

Introduction

Biochemists proclaim that an intimate knowledge of chemical structures contributes informative insights into the molecular function and behavior of biochemical processes [1, 2]. A typical requirement for introductory biochemistry classes is to learn the structures of the 20 standard amino acids and the single-letter abbreviations. Students can then reference these throughout their academic and professional careers. Devoting structures to memory allows students to immediately recall properties and relative sizes of side chains without tediously sorting through mnemonics of which R groups are polar and uncharged or which absorb ultraviolet wavelengths, and so forth. Once comfortable with the amino acid structures, students can apply this knowledge to accomplish higher cognitive tasks such as readily explaining the steric and intermolecular consequences of a point mutation in an active site and specifically how it affects substrate specificity and enzyme activity without consulting a textbook.

Literacy in the single-letter abbreviations is essential for analyzing professional protein papers. The International Union of Pure and Applied Chemistry (IUPAC) and the International Union of Biochemistry (IUB) developed a succinct alternative to the three-letter code by establishing the single-letter notation to achieve brevity and to compare large protein sequences [3, 4]. Knowing the corresponding structure when reading the one-letter code allows students to glean deeper insights into potential interactions or mechanisms. When compared with students who are structurally ignorant, for example, informed students can readily ascertain the nuances between the biomedically relevant mutations of R406W in tau for dementia and Alzheimer’s disease [5], E6V in hemoglobin for sickle cell anemia [6], Y402H in complement factor H for age-related macular degeneration [7], or R117H in cystic fibrosis [8].

Previous attempts to teach amino acid structure and single-letter abbreviations have involved complicated rhymes [9], emphasis on structural similarities to acetyl-
CoA, pyruvate, and other metabolic intermediates [10], and the rote memorization of nonsensical acronyms [2]. Once mastered, these approaches may confer a degree of comprehension; however, some of these devices may require more tedious studying than just learning the structures and abbreviations directly.

Games have been identified as effective educational tools since the 1920s [11]. Interactive games have already been developed to teach aspects of protein folding such as hands-on activities in the classroom [12] and the online crowd-sourcing sensation, Foldit [13]. In the latter, gamers identify novel folding conformations with computational design, and many of these proteins have biomedical and renewable fuel applications. For example, the crowd-sourced players identified a new way to fold an alderase to increase its activity by 18-fold [14]. However, these games provide information on the chemical properties of an amino acid sequence, and they do not rely on the players’ knowledge of the monomeric structures. To specifically teach the structures and the single-letter abbreviations of the 20 standard amino acids, the modified version of “Hangman” described here uses the three primary aspects that make games successful: motivation, practice, and reinforcement [15]. Students are motivated to learn material destined to appear on examinations, they practice drawing structures during the activity until they can confidently reproduce it in front of an audience, and they receive positive reinforcement by solving puzzles and thinking of their own Hangman clue(s). The only mnemonics used during this game included the simple devices developed during the foundation of the single-letter code such as pronouncing Asp as “aspar-D-ic acid” and Gln as “Q-tamine” [4] as well as an original baby-like pronunciation of Trp as “tWyptophan.” After playing four rounds of Hangman with amino acid structures instead of English alphabet characters, students exhibited substantial improvement in both drawing the structures from memory and correctly labeling given structures with the single-letter abbreviation.

Methods

Preliminary Instructions

Students were informed during the first biochemistry class of the semester that the amino acid structures were
cumulative material and would appear on the three examinations throughout the course. Three weeks after the announcement, interactive Amino Acid Hangman was played in the laboratory section during the incubation periods of primary and secondary antibodies. The exercise was appropriate for laboratory sessions because of the relatively smaller class sizes when compared with lecture and the longer periods of available time. Students were informed that the linear appearance of the “amino acid sentences” were NOT indicative of the actual stereochemistry formed by a peptide bond (Fig. 1).

Assessment
In the beginning of the laboratory session, the instructor announced, “I like science and I like having fun and playing games. Since you will need to know your amino acid structures for the exams, we’re going to play a game to help you learn them. You will also have a chance to earn up to 12 points extra credit.”

Prior to receiving the reference sheet, students took two pretests. The first displayed the 20 single-letter abbreviations, and the students were requested to draw the corresponding structure. The second pretest displayed the 20 structures, and the students were instructed to assign the correct single-letter abbreviations. The instructions for both pretests were “Drawing/Identifying >10 correct will earn +3 points extra credit. One wrong answer negates any extra credit.” The latter stipulation aimed to prevent rampant guessing based on the idea that grades, even extra points, are precious currency to the students [16].

After the activity, the exact same tests were distributed in the same order with the same instructions. The number of correct answers and structures were quantified.

Playing the Game
To play traditional Hangman, one player picks a word or phrase for the audience to guess and draws horizontal dashes for each letter in the answer. The remaining players propose letters to fill in the blanks. If a letter appears within the word, the first player writes it in the appropriate space(s). If an incorrect letter is guessed, one body part is drawn on a cartoon gallows. The object of the game is to guess the word or phrase before a complete “hangman” is drawn.

To play Amino Acid Hangman, students first received a reference sheet with the amino acid structures and abbreviations (Fig. 2) and were allowed to refer to this sheet at their laboratory bench throughout the game. They were not permitted to bring it to the board. The instructor also wrote hints to the Hangman answers using structures instead of English alphabet characters (Fig. 1a and Table 1). Audible translation of the hint or the answer by a student would negate any extra credit. To guess a letter, students drew the corresponding structure from memory on the whiteboard in front of the class. If it appeared in the answer, the instructor indicated the appropriate space(s), and the student redrew the structure as it would appear at pH 7 to gain additional practice (Fig. 1b) [15]. If filling a space adjacent to a previously drawn amino acid, the student indicated which atoms participated in the dehydration reaction of the peptide bond formation, only referring to the instructor’s assistance when needed. If the proposed structure did not appear within the answer, however, the student drew it again in the top corner of the whiteboard and the instructor added a body part to the Hangman (Fig. 1c). To avoid discouraging or embarrassing the student, the instructor ensured that hands, feet, and facial features would also be drawn. “Solving the puzzle” in one attempt was not allowed. The only way to complete the Hangman answer was for volunteers to draw individual structures, which maximized the number of participants.

After each puzzle was solved, the entire section went through the clue together: the instructor pointed to each structure and the students responded with the full amino acid name. While the instructor drew the hint for the next round, students practiced drawing and identifying the amino acids from their reference sheet. Four rounds of Hangman were played in about 2 hours.

Surprisingly, a few students requested to draw their own hints for their own Hangman puzzle. One student was selected and was allowed to refer to the reference sheet while drawing her hint on the board (hint: SCARY SNAKES; answer: VIPERS). This student fulfilled the roles of the instructor for the entire round.

Results and Discussion
The post-test revealed a marked improvement in students’ ability to recognize and properly label the structures of all 20 amino acids (Fig. 3). Scarcely using a letter in the hints or answers did not preclude students from learning the single-letter abbreviation. For example, F and V were accurately assigned to the corresponding structure by 41% and 58% more students after the activity, respectively, despite only being used once during the game. Prior to Hangman, not one student correctly drew or identified M, but afterward, more than 40% of the class could accomplish both tasks. Methionine was only used three times. This suggests that the students consulted the reference sheet with the structures and abbreviations and practiced at their bench while playing the game. Therefore, the time devoted by the instructor to write the “structural sentences” of the next hint can be beneficial to students, and students should be encouraged to practice during the interludes between rounds.

Students’ ability to draw structures from memory was also improved for 17 amino acids after they played the Hangman game (Fig. 4). Before the game, the majority of the class could only draw G, the simplest amino acid. Afterward, more than half the class could accurately draw the
FIG 2

Reference sheet with the 20 standard amino acids at pH 7. Structures were drawn with Accelrys Draw 4.1 freeware.
structures of G, A, V, L, I, P, S, and F. Note that for nine other amino acids, not one student drew the correct structure before the activity, but many students could properly draw these structures after the game. Interestingly, no student attempted to draw N, Q, or R for either the pretest or post test. Perhaps this caution was due to the chance of losing extra credit. To incentivize mastery of complicated structures, additional points could be assigned to certain side chains. For each structure that was attempted, however, 5–65% more students were able to correctly sketch the amino acid after the activity than before playing Amino Acid Hangman. The higher number of accurate responses indicates that students improved their ability and perhaps even their confidence to draw and recognize the standard amino acid structures.

Students were enthusiastic to play when the game was presented as a means to extra credit while being a fun way to prepare them for relevant examination material. Humor and fun contribute to active learning [17, 18]. For example, students were advised that they could write a love letter in amino acid structures if they had a particular nerdy sweetheart or they could write clandestine, encrypted messages. Overall, we suggest that Amino Acid Hangman is a fun, educational, and interactive exercise that improves students’ ability to draw and correctly assign the single-letter code to amino acids.

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