

Translation: The Amino Acid Card Game

Who should play?

- Number of players: 2-4
- Ages: 12 and up

What is this game about?

Translation: The Amino Acid Card Game is a deck building game. During the game, you will spend action points to create a deck of powerful mutations, which you will apply to translate amino acids from a nucleotide sequence. The more amino acids of the same group that you collect, the higher your score will become.

This game does not require any knowledge of biology to play. In fact, it is designed to sneak information about the amino acids and their properties into game play, and to help you learn and remember them as you play.

Parts

The game is composed of the following parts.

- 20 amino acid cards
- 20 nucleotide cards
- 22 action cards, of 9 different types
- 1 water level card (ON/OFF)
- 1 card to mark the 5' end
- 1 white 8-sided die with A, T, C, G x 2 on each side
- 1 black 8-sided die with A, T, C, G, W, S, Y, R on each side
- These instructions

Biological background

You do not need to read this section to play the game, but it will help you understand what is going on, and why the cards are the way they are.

Every living thing is made of cells, and all cells contain DNA. DNA codes for proteins, which are the functional components of cells. You may have heard that DNA is a double helix; this means that it is composed of two strands that are twisted together. Each strand is a chain of nucleotides, which are also called base pairs. There are 4 types of nucleotide: A, C, T and G.

Each nucleotide on one strand is paired with a nucleotide on the other strand, but the pairing is not random. A will always pair with T, and C will always pair with G. If you look at the nucleotide cards, you will see A and T on one side, and C and G on the other side, representing the two possible pairs. The top of the card is one strand, and the bottom of the card is the other strand. The nucleotide pairs reach across the strands, like the rungs on a ladder. The DNA sequence has a direction, and it is always read from the 5' end to the 3' end. Both strands are read 5' to 3', but the ends are reversed on the two strands. To continue the ladder analogy, imagine that you can only climb up the ladder on the left hand side, and you can only climb down on the right hand side. During the game, only one strand will be active at a time – the 5' end that you read from will be indicated by the 5' card. When you translate an amino acid, you must make sure that you are

reading on the active strand, and in the correct direction.

To produce a new protein, the rungs on the ladder are broken to pull apart the strands. Then the sequence of nucleotides is copied into a new chain of nucleotides, called mRNA. The mRNA is subsequently translated into protein. This game ignores the complexity of mRNA – game play proceeds directly from DNA to protein.

To create a protein, the nucleotide sequence is read 3 nucleotides at a time (by a large protein called a ribosome). Each possible sequence of 3 nucleotides represents an amino acid (except for 3 that mark the end of the protein), and these sequences of 3 nucleotides are called codons. As each codon is read, the amino acid that corresponds to the codon is fetched (by something called a tRNA), and the amino acid is added into a new chain that will become the protein. It would be a very long game if we were to build any real proteins, so instead the game ends when all amino acids have been translated once.

Biology Summary









- DNA is a chain of nucleotides: A C T G.
- Nucleotides are read 3 at a time, and each sequence of 3 nucleotides (one codon) identifies an amino acid.
- A protein is a chain of amino acids that have been translated from codons.

Meet the amino acid family

Each of the 20 amino acids has a first name that corresponds to their 1 letter abbreviation. Since some amino acids begin with the same letter, their first names may help you remember their abbreviations. Feel free to rename them if you think of better names!

10 of the amino acids are hydrophilic (they love water), and the other 10 are hydrophobic (they run away from water). A hydrophilic amino acid can only be translated when the water is ON, and vice versa for hydrophobic amino acids. This is described further in the section **Translating amino acids**.

Each amino acid is a member of at least 1 group, according to its properties, such as whether it is acidic, aromatic, contains sulfur, and so forth. 4 amino acids are members of 2 groups. At the end of the game, you will score extra points for collecting amino acids that belong to the same group.

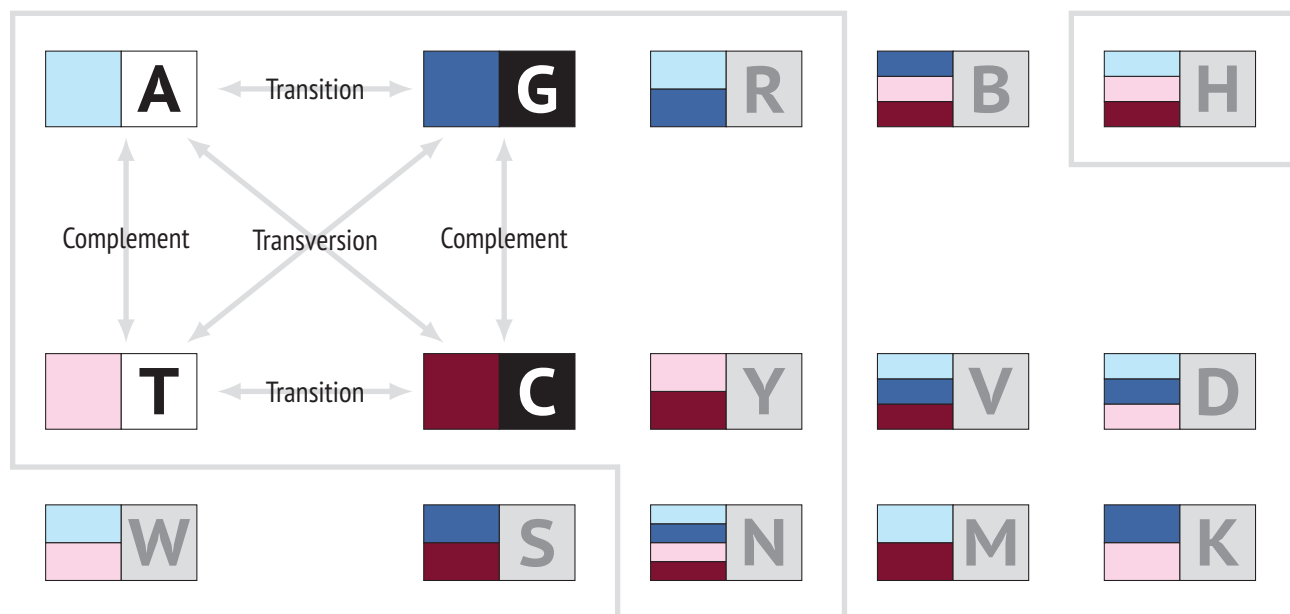
Group	Symbol	Amino Acids
Aliphatic		5
Aromatic		4
Small Polar		4
Basic		3
Acidic		2
Acid Deriv.		2
Sulfur		2
Unusual		2

Since there are 20 amino acids and $3^4=64$ different codons, some amino acids can be translated by more than one codon. A larger number of codons means that there are more possible ways to translate an amino acid (the easier it is to make). 3 amino acids have the largest number of codons at 6 each, and 2 amino acids can be translated by only 1 codon. How to translate amino acids is described in the section **Translating amino acids**.

	First Name	Amino Acid	Codons	Hydrophobic		Groups
A	Ala	Alan	Alanine	4		Aliphatic
R	Arg	Redbeard	Arginine	6		Basic
N	Asn	Nancy	Asparagine	2		Acid Deriv. Small Polar
D	Asp	Devin	Aspartate	2		Acidic
C	Cys	Cy	Cysteine	2		Sulfur Small Polar
Q	Gln	Queen	Glutamine	2		Acid Deriv.
E	Glu	Edwin	Glutamate	2		Acidic
G	Gly	Gladys	Glycine	4		Unusual
H	His	Hillary	Histidine	2		Aromatic Basic
I	Ile	Isa	Isoleucine	3		Aliphatic
L	Leu	Lucy	Leucine	6		Aliphatic
K	Lys	King	Lysine	2		Basic
M	Met	Matt	Methionine	1		Aliphatic Sulfur
F	Phe	Fred	Phenylalanine	2		Aromatic
P	Pro	Paul	Proline	4		Unusual
S	Ser	Sarah	Serine	6		Small Polar
T	Thr	Thor	Threonine	4		Small Polar
W	Trp	Wendy	Tryptophan	1		Aromatic
Y	Tyr	Yvonne	Tyrosine	2		Aromatic
V	Val	Valerie	Valine	4		Aliphatic

Nucleotides

There are 4 colours for the nucleotides: dark red, dark blue, light red (pink) and light blue. The colours of the nucleotides have been chosen so that there is similarity between the nucleotides of the same colours (red and blue) and between nucleotides of the same lightness (light and dark). Abbreviations for groups of nucleotides are shown in the following diagram. Only those within the grey box are used in the codons for the amino acids.



- R (puRine) refers to the two blue colours, A and G, which are purines, and their molecules have two rings.
- Y (pYrimidine) refers to the two red colours, T and C, which are pyrimidines, and their molecules have one aromatic ring.
- N (aNy) refers to any of the nucleotides.
- B, H, V and D refer to any nucleotide except A, G, T and C respectively. Only H is used in the game, and it appears in the codon for Isoleucine.
- W (Weak) refers to the two dark colours, A and T, which form base pairs with two hydrogen bonds, a relatively weak bond.
- S (Strong) refers to the two light colours, G and C, which form base pairs with three hydrogen bonds, a relatively strong bond.
- M (aMino) refers to A and C.
- K (Keto) refers to G and T.

Mutations

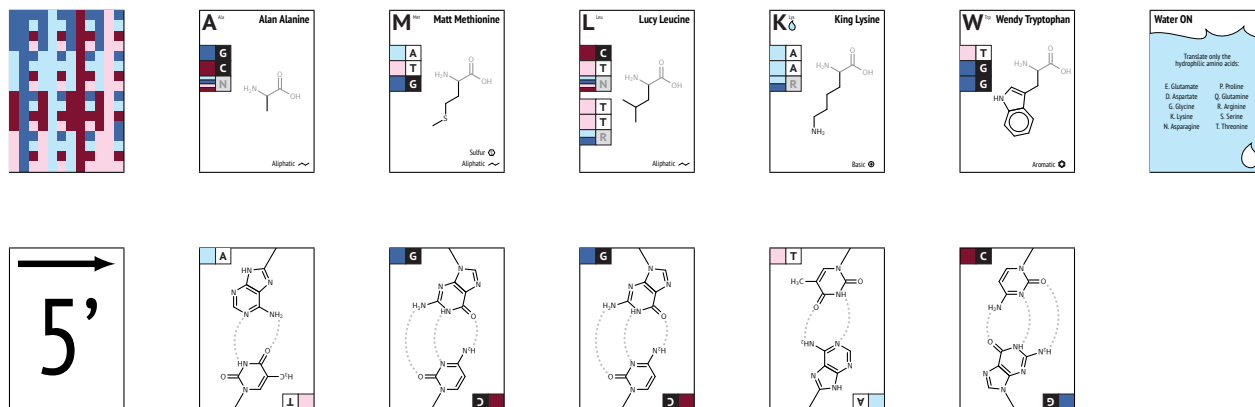
- Mutations that preserve lightness (ignoring colour) are called complements because they make a complementary pair (in the ladder analogy from the section **Biological background**, they are the rungs). Rotate a nucleotide card 180 degrees to give the complement.
- Mutations that preserve colour (ignoring lightness) are called transitions. Flip a nucleotide card horizontally to perform a transition.
- Mutations that preserve neither lightness nor colour are called transversions. Flip a nucleotide card vertically to perform a transversion.

Mutation cards are available for each type of mutation (complement, transition and transversion), and additionally there is also a mutation card, which allows you to mutate a nucleotide to any other nucleotide.

Setup to begin the game

1. Give each player 1 Toggle Water card and 3 Extend cards.
2. Find the number of action cards that should be in the game by dividing the number of players by 2 (round up with odd numbers). Sort the remaining action cards by type and lay out this many of each of type, arranged by cost.
3. Shuffle the amino acid cards, and deal 5 face up.
4. Roll the white die 5 times, and lay out a nucleotide sequence representing your dice rolls. Put the 5' card at the beginning of this sequence. You will always read the sequence from the 5' end to the (unmarked) 3' end, following the arrow indicated on the 5' card. Place the rest of the nucleotides aside.
5. Place the Water Level card in the playing area, and flip it so the water is ON.
6. Decide who goes first by some fair and balanced means.
7. Play proceeds clockwise around the table.

Example Game Layout



Taking a turn

On your turn, you have 5 action points available to you. If there are less than 4 nucleotides in the sequence at the start of your turn, then roll the white die to fill it up to four as a free action. Then, you may take any of the following actions, as many times as you'd like, in any order – given that you have enough points to do so.

Points	Action
1	Translate any of the face up amino acids.
1-3	Play a card from your hand.
2-5	Select an available action card from the resource pile to gain this card's ability for subsequent rounds.

You may translate multiple amino acids in one turn, provided you have the points to do so. You may not save points from one round to the next. You must exhaust all your points by the end of your turn – perhaps by extending the sequence multiple times.


Playing action cards

An action card may not be used in the same round it is purchased in; you must wait to use it until the following round to use it, but then it can also be used once in all subsequent rounds. Once an action card has been used, it cannot be used again in the same round. The one exception to this rule is the Extend card, which can be used multiple times in the same round, each time for a cost of 1 point. If you have two action cards of the same type in your hand, you may play them both in one round, given that you have enough points to do so.

Action Card	Buy	Use	Available	Result
Toggle Water	0	1	N	Flip the water card to toggle the hydrophobicity of amino acids that can be translated.
Extend	0	1	N	Roll the white die to select a nucleotide, and add it to the end of the nucleotide sequence. May be used multiple times in one round.
Delete	2	1	N/2	Delete one nucleotide from anywhere in the nucleotide sequence.
Insert	3	1	N/2	Roll the black die to select a nucleotide, then insert it anywhere in the nucleotide sequence. A roll of W, S, R or Y gives you the choice of either of the two nucleotides that abbreviation refers to.
Reverse Complement	3	1	N/2	Swap the 5' and 3' ends by moving the 5' card to the opposite end of the deck and rotating it so that the arrow points towards the nucleotide sequence. The sequence will now be read in the opposite direction (reverse) on the opposite strand (complement) as the original sequence.
Complement	3	2	N/2	Rotate any nucleotide in the nucleotide sequence 180 degrees to select its complement. (Turn red colours into blue colours and vice versa.)
Transition	3	2	N/2	Flip any nucleotide horizontally along its long axis to transition it. (Turn dark colours into light colours and vice versa.)
Transversion	3	2	N/2	Flip any nucleotide vertically along its short axis to transversion it (Change both the colour and the lightness).
Mutate	5	3	N/2	Rotate or flip one nucleotide as you choose.

Translating amino acids

Three conditions must be satisfied to translate an amino acid:

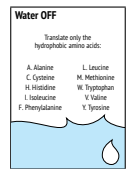
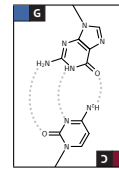
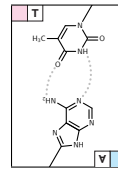
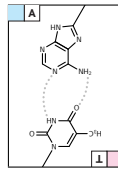
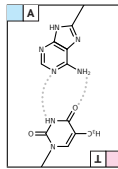
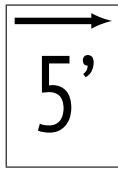
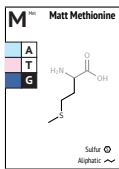
- **Codon match** The nucleotides in the nucleotide sequence must match the codon on the amino acid card that you want to translate. All but two of the amino acids can be translated by multiple codons, which differ only in the last nucleotide in the codon. The letters R, Y, N and H that occur in the third position each refer to at least two nucleotides, any of which can be used to translate the amino acid. For example, R represents A and G, so an amino acid asking for GAR can be translated with either GAA or GAG. Three amino acids can be translated by six codons, which are shown in two blocks on the amino acid cards. Matching any of their codons is sufficient to translate the amino acid.
- **Strand** The nucleotides must be in the correct order in the 5' direction. The 5' end of the nucleotide sequence is the end marked by the 5' card. Always read 5' to 3', and read along the strand indicated by the arrow on the 5' card. Any codons that are on the opposite strand, or in the opposite order are not available to be translated.
- **Hydrophobicity**  of the amino acid must match the water level. If the amino acid is hydrophilic (marked on the amino acid card by a water drop next to the one letter abbreviation) it can only be translated when the water is ON. Conversely, if the amino acid is hydrophobic (not shown on the card), it can only be translated when the water is OFF. The water level can only be changed by playing a Toggle Water card.

Note for biologists: In this game, you do not need to worry about the nucleotides being in frame.

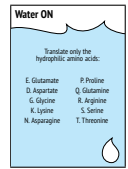
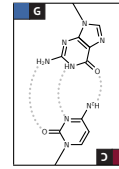
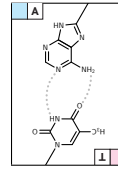
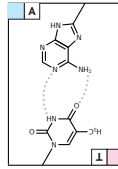
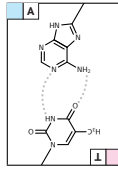
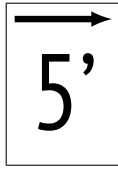
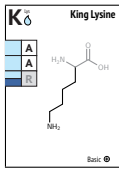
When an amino acid is translated, take the following actions:

1. Collect the translated amino acid in your hand, to be scored at the end of the game.
2. Flip over a new amino acid card from the top of the face down deck.

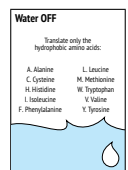
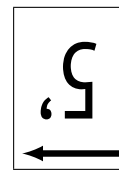
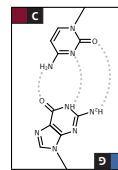
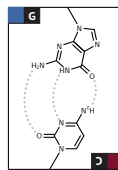
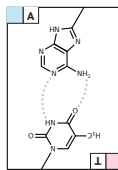
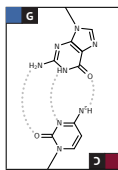
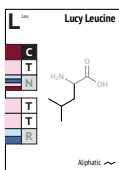
☺ Methionine is translated by ATG



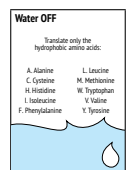
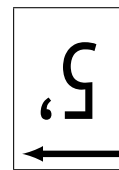
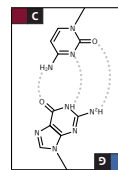
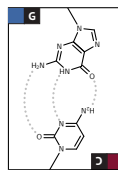
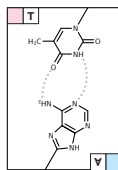
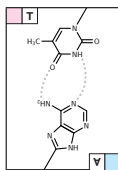
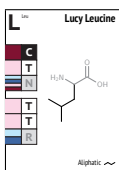
☺ Lysine is translated by AAA



☺ Leucine is translated by CTC

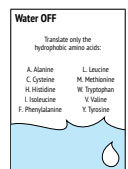
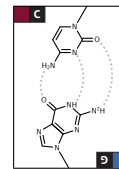
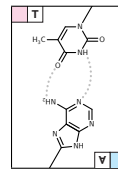
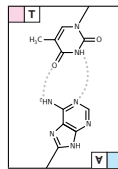
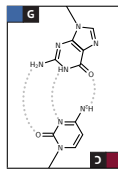
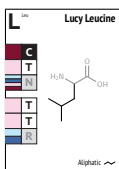


☹ Not translated: TTG is on the wrong strand



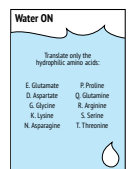
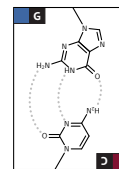
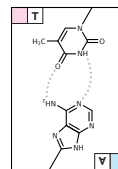
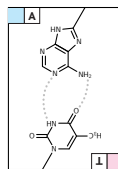
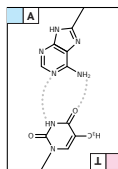
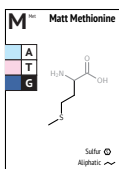
To correct this, play a Reverse Complement card, then you will be able to translate Leucine with TTG.

☹ Not translated: TTG is on the right strand, but in the wrong order



To correct this, you could for example Complement the C to a G and then translate TTG.

☹ Not translated: hydrophobicity is incorrect



To correct this, play a Toggle Water card first.

Ending the game

The game ends when the last amino acid has been translated.

Scoring























Your final score is composed of two parts:

- Score 1 point for each amino acid.
- Score an additional 2 points for every pair of amino acids that are part of the same group.

Count all pairs formed; three of a kind counts as 3 pairs, four of a kind as 6 pairs, and five of a kind as 10 pairs. An amino acid that is member of multiple groups, can be counted in multiple groups. For example Histidine is a member of the Aromatic and Basic groups, and can be counted towards both if the player has both another Aromatic and another Basic amino acid.

The player with the most points wins!

Scoring Examples

Amino Acids Collected					Number of Pairs	Total Points for this hand
 Phe	 Gly				1	4
 Glu	 Asp	 Lys	 Arg		2	8
 Lys	 Arg	 His			3	9
 Lys	 Arg	 His	 Try		4	12
 Ser	 Thr	 Arg	 Cys		6	16
 Ala	 Met	 Leu	 Ile	 Val	10	25

Acknowledgements

Translation: The Amino Acid Card Game was designed by Helen V Cook between 2012 and 2014.

Many thanks to the many people who have contributed to this game in terms of playtesting and ideas. A full list of credits is available online. Special thanks to Saul Pwanson for the inspiration for the game, his critical eye throughout the design process, and his encouragement.


Additionally, many thanks to the \TeX community at StackExchange for having already answered my questions before I thought to ask them.

The cards and instructions for Translation: The Amino Acid Card Game were typeset in \LaTeX using the packages tikz and chemfig, and the fonts PTSansCaption and PTSansNarrow.

Version

This is version 1.3, released September 15th 2014.

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Connect

PDFs of the cards and instructions and a full listing of the credits is available at: <http://github.com/bitmask/amino-acid-card-game>