



Puzzling Proteins

Gr. 2-6 Activity Write Up

Puzzling Proteins

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Terms of Use

Prior to using this activity or parts thereof, you agree and understand that:

- It is your responsibility to review all aspects of this document and the associated activity write ups, and ensure safety measures are in place for the protection of all involved parties.
- Any safety precautions contained in the “Safety Considerations” section of the write-ups are not intended as a complete list or to replace your own safety review process.
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About Actua

Actua is creating a Canada where every child has the skills and confidence they need to achieve their full potential. As a leading science, technology, engineering and mathematics (STEM) outreach organization, Actua includes over 40 universities and colleges, engaging 500,000 youth in 600 communities each year. For 25 years, Actua has focused on identifying and removing the barriers for entry into STEM and now have national programs dedicated to engaging Indigenous youth, girls and young women, Black youth, those facing economic barriers and youth in Northern and remote communities. For more information, please visit us online at www.actua.ca and on social media: Instagram, LinkedIn, Facebook and YouTube! For more information, please visit us online at www.actua.ca and on social media: [Instagram](#), [Facebook](#), [LinkedIn](#), [TikTok](#) and [YouTube](#)!



Puzzling Proteins

Activity Summary

In this activity, participants will explore proteins and discover how AI is revolutionizing microbiology. They'll learn how proteins are built from amino acids and why their 3D shape is the key to understanding how they work. Then, it's time to crack the protein code! Using a codon wheel, participants will decode genetic sequences into amino acids and color beads to match. Next, they'll bring proteins to life by creating models and folding them based on "chemical rules", discovering how amino acids interact to shape these essential molecules.

Developed by Actua, 2025

Delivery Environment	Activity Duration	Intended Audience	Tech
In-Person	45 minutes	Grades 2-6 (Ages 7-12)	Facilitators should have access to a laptop, projector, speakers, and a screen or blank wall to project onto. <ul style="list-style-type: none">• Projector• Speaker• Screen/Blank Wall• Laptops/Tablets



Achievement Goals

Learning Goals

Following this activity, participants will:


- **Understand** what proteins are and that they are made of amino acids.
- **Decode** a nucleotide sequence using a codon wheel.
- **Create** a model of a folded protein using their sequence.

Success Criteria

Following this activity, participants can express:

- **I can decode** nucleotide sequences using a codon wheel.
- **I can model** how proteins fold in 3 dimensions.
- **I can explain** how artificial intelligence is used to solve protein folding puzzles.

Logistics (Timing, Group Sizing, Materials)

Section Title	Time	Group Size	Materials
Opening Hook	5 minutes	<i>Whole Group</i>	Facilitators <ul style="list-style-type: none">• Puzzling Proteins - Activity Slide Deck (<i>Appendix C</i>)•  Protein folding explained (Google DeepMind, 1:51s)
Section 1: Codon Wheel	15 minutes	<i>Individual</i>	Facilitators <ul style="list-style-type: none">• Puzzling Proteins - Activity Slide Deck (<i>Appendix C</i>) Per Participant <ul style="list-style-type: none">• Codon Wheel - Activity Page (<i>Appendix C</i>)• Brass fastener• Scissor



Section Title	Time	Group Size	Materials
			<ul style="list-style-type: none"> • Colouring pencil
Section 2: Bead Folding	20 minutes	<i>Individual</i>	Facilitators <ul style="list-style-type: none"> • Puzzling Proteins - Activity Slide Deck (<i>Appendix C</i>) Per Participant <ul style="list-style-type: none"> • Codon Wheel - Activity Page (<i>Appendix C</i>) • Pony beads • Pipe cleaners • Scissor
Reflection & Debrief	5 minutes	<i>Whole Group</i>	Facilitators <ul style="list-style-type: none"> • Puzzling Proteins - Activity Slide Deck (<i>Appendix C</i>)

Safety Considerations

Safety considerations have been provided below to support safety during this activity, however they are not necessarily comprehensive. It is important that you review the activity and your delivery environment to determine any additional safety considerations that you should be implementing for the delivery of these activities.

Emotional Safety

- Facilitators should understand that participants have different lived experiences and prior knowledge about AI safety, AI, and digital citizenship. This activity may involve or lead to discussions of sensitive topics, such as ethical implications of AI. Facilitators should encourage open, respectful discussions and acknowledge all perspectives. Facilitators should always keep the participants' emotional safety in mind in these discussions, and defer to training from their institution and training received.



Cuts

- Remind participants of how to use scissors properly and safely. Ensure participants are sitting down and have age appropriate scissors. Offer assistance when cutting thick materials, such as corrugated cardboard or popsicle sticks to help prevent injury.

Curriculum Links

This activity aligns with these components found in the [UNESCO AI Competency Framework for Students](#):

Human-Centered Mindset: Human Agency

- Learners are expected to be able to recognize that AI is human-led and that the decisions of the AI creators influence how AI systems impact human rights, human-AI interaction, and their own lives and societies (p. 29-30).

AI Techniques and Applications: AI Foundations

- Learners are expected to develop basic knowledge, understanding and skills on AI, particularly with respect to data and algorithms, and understand the importance of the interdisciplinary foundational knowledge required for gradually deepening understanding of data and algorithms. They should also be able to connect conceptual knowledge on AI with their activities in society and daily life, concretizing a human-centred mindset and ethical principles through an understanding of how AI works and how AI interacts with humans (p. 32-34).

AI Techniques and Applications: Application Skills

- Learners are expected to be able to construct an age-appropriate knowledge structure on data, AI algorithms and programming, and acquire transferable application skills. (p. 41).



This activity can be connected to the following subject areas:

Science

- Identify and describe the basic needs and essential characteristics of living things.
- Investigate and describe the relationship between structure and function in biological systems.
- Understanding the role of science and technology in society and daily life.

Community Connections

Community connections are suggestions from Actua, grounded in our approach, on how facilitators can adapt the activity to reflect the strengths, interests, and priorities of the community where or with whom it is delivered. Consider the following guiding questions to adapt the activity in meaningful ways:

- **Consult with community:** Are there local organizations, Knowledge Keepers, or community members who could contribute insight or context to this topic?
- **Draw on youth experience:** How can you give participants opportunities to share, reflect on, and apply how this learning is relevant to them or their community? Invite participants to identify what knowledge, who, and where they already learn from.
- **Integrate local examples:** How can you tailor this activity to local or regional interests, industries, or community priorities (e.g. land and environment, health, technologies)?



Activity Procedure


To Do in Advance

SECTION	PREPARATION
General	<ul style="list-style-type: none">● Think ahead and be ready to adapt:<ul style="list-style-type: none">○ Determine your delivery method and leverage ideas from the delivery recommendations and adaptations sections.○ While estimated times are provided, it will be helpful to think about how much time you would like to spend on different activities and discussions.○ While group sizes (individual, pairs, groups) are suggested, many activities are flexible for whatever will work in your classroom.● Prepare for the content:<ul style="list-style-type: none">○ Have answers in mind to share with participants for the various reflection questions asked.○ Examine the provided materials to determine if they are suitable for your participants.● Equipment:<ul style="list-style-type: none">○ Ensure device, screen and projector are set up.○ Prepare participant devices for use in the activity.

Opening Hook

1. Using the Puzzling Proteins - Activity Slide Deck (*Appendix C*) as a guide, introduce proteins to participants.
 - a. **Proteins** are large molecules made of building blocks called amino acids. We need to eat protein to stay healthy! Proteins are used to make medicines and other helpful substances.



2. Show participants the renderings of the 3D structure of proteins. Explain that the 3 dimensional shape of a protein is super important to figuring out how it works. The 3D structure of so many proteins is unknown, and it's too complicated and expensive for scientists to figure them out all on their own.
3. That's where **Artificial Intelligence (AI)** comes in! Show the DeepMind protein folding video.
4. Explain that AlphaFold is a database of protein structures generated by AI. This is helping us discover the 3D structure of proteins at an unprecedented rate!
 - a. Play the  Protein folding explained (Google DeepMind, 1:51s) to review protein folding and how AI might solve the structure of a protein.

Section 1: Codon Wheel

1. Using the Puzzling Proteins - Activity Slide Deck (*Appendix C*) as a guide, explain that proteins are made up of a code that uses four letters (nucleotides) - **G (guanine), A (adenine), C (cytosine), and U (uracil)**.
2. **Every three nucleotides codes for 1 amino acid.** Different letter codes make different amino acids.
3. Distribute the Codon Wheel - Activity Page (*Appendix C*) and explain how to read the codon wheel.
 - a. Start with the inner wheel and move outwards until you identify the colour (amino acid).
4. Instruct participants that they will be decoding the sequences found in their Codon Wheel - Activity Page (*Appendix C*). **Decoding** means figuring out which amino acid corresponds with the 3-letter code. They will colour in the bead with the decoded colour next to each sequence.
5. Have participants cut out the red arrow and secure it to the X in the centre with a fastener and give them time to decode their sequences.



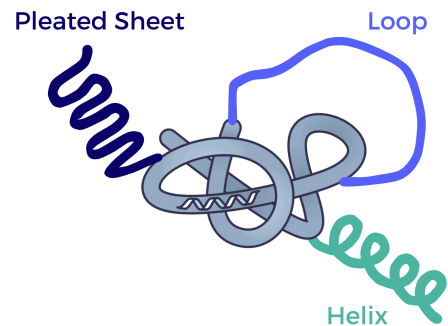
Section 2: Bead Folding

1. Now that participants have their sequences, it's time to bead! Instruct participants to thread on the correct colour beads **in order** onto a pipe cleaner.
2. Instruct participants to twist the ends of the pipe cleaner together and spread out the "amino acids" (beads).
3. Explain that some amino acids are better friends than others. Blue and pink are best friends!
4. Explain that the attraction between amino acids is one way that proteins get their shape - they fold to get as close together as possible.
5. Participants should then match up the blue and pink amino acids and twist the pipe cleaner on either side. There are two blue/pink pairs in the sequence.
6. Once the protein is all folded, add some other structures with other pipe cleaners.
 - a. Bend back and forth to make a pleated sheet.
 - b. Curl around a pencil to make a helix.
 - c. Twist ends together to make loops



Reflection & Debrief

1. Debrief by discussing how AlphaFold has been used by over half a million scientists to solve protein structures. Thanks to AlphaFold, we now have a new malaria medication and enzymes that digest plastic pollution!



2. Encourage participants to share their creations and what they learned in this activity.
3. Discuss the different careers listed in *Appendix A: Career & Mentor Connections*.



Delivery Adaptations

How might you adapt the time, space, materials, group sizes, or instructions to make this activity more approachable or more challenging? **Modifications** are ways to make the activity more accessible, **extensions** are ways to make the activity last longer or more challenging.

Modifications

SECTION 2: BEAD FOLDING

- Provide participants with the sequence needed.
- Demonstrate how to fold their protein step-by-step.
- Remove the option of adding secondary structures OR pre-make secondary structures for participants to add.

Extensions

SECTION 1: CODON WHEEL

- Have participants do research on what foods contain protein.
- Instructors can make up their own sequences to have participants decode.
- Have participants research other impacts of AI on healthcare.

SECTION 2: BEAD FOLDING

- There is a bonus sequence in the slideshow that participants can try to fold. This one is much more challenging!
- Make up different folding rules for participants to try, like keeping red and black away from each other (enemies).



References & Gratitude

AlphaFold. Google DeepMind. (2024). deepmind.google/technologies/alphafold/

Clancy, S. & Brown, W. (2008) *Translation: DNA to mRNA to Protein*. Nature Education 1(1):101.

United Nations Educational, Scientific and Cultural Organization. (2024). *AI competency framework for students*. UNESCO. unesdoc.unesco.org/ark:/48223/pf0000391105



Appendices

Appendix A: Career & Mentor Connections

BIOMEDICAL ENGINEER

- Biomedical engineers design technology to be used in a healthcare setting (such as the traditional and whirly-gig centrifuge) and technology that directly treats patients such as pacemakers, prosthetic limbs.

CHEMIST

- Chemists study the composition of matter and its properties. They work often in the laboratories to make experiments and work collaboratively with chemical engineers.

MICROBIOLOGIST

- A microbiologist studies microscopic organisms and non-living pathogens such as viruses! They might study them to learn more about disease, their role in an ecosystem, or for agriculture.

SOFTWARE ENGINEER

- Software engineers design and develop computer software. They are often fluent in multiple programming languages such as Python, Javascript or Swift.



Appendix B: Background Information

PROTEINS

Proteins are made up of smaller units called amino acids, which are linked together in specific sequences to form long chains. There are 20 different amino acids, and the sequence in which they are arranged determines the structure and function of the protein. Some proteins, like keratin, provide structural support in hair and nails, while others, like enzymes, speed up chemical reactions in the body.

The sequence of amino acids in a protein is determined by genetic instructions stored in DNA (deoxyribonucleic acid). DNA is a long molecule made up of four chemical bases: adenine (A), thymine (T), cytosine (C), and guanine (G). A pairs with T and C pairs with G. These bases are arranged in a unique order to form genes, which act as blueprints for making proteins.

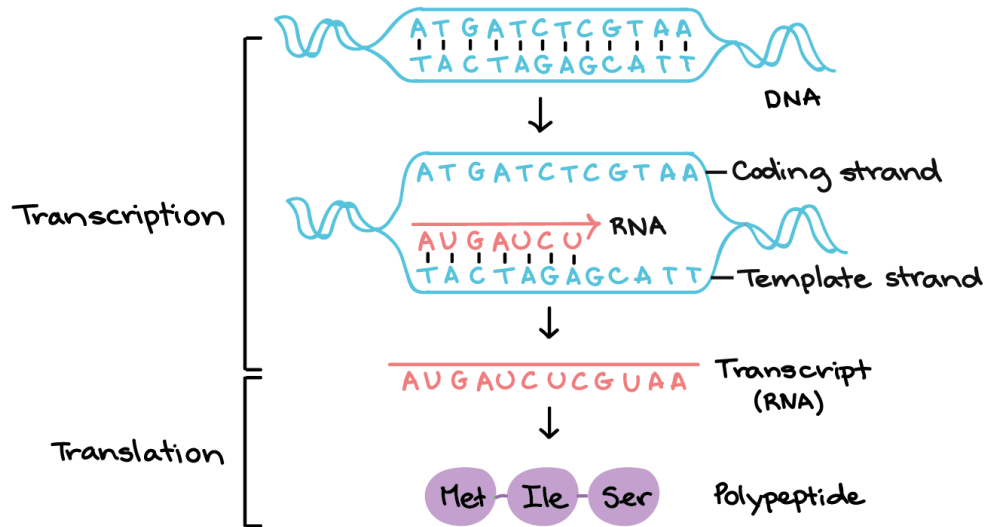
However, DNA itself does not make proteins. Instead, cells must first convert DNA instructions into an RNA (ribonucleic acid) message and then use that message to assemble amino acids into a protein. This happens in two major steps: transcription and translation.

Transcription, Translation, and the Codon Wheel

Transcription takes place in the nucleus of a cell. Since DNA cannot leave the nucleus, its genetic information must first be copied into a different type of molecule called messenger RNA (mRNA). This process is carried out by an enzyme called RNA polymerase, which binds to a gene, unwinds the DNA, and assembles an RNA strand using the DNA sequence as a template.

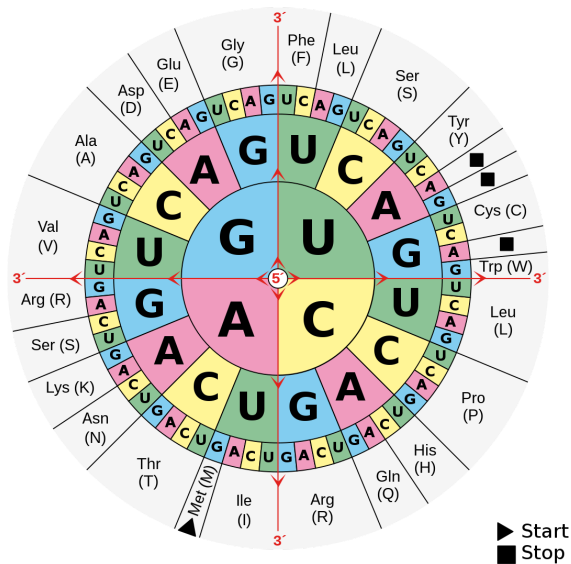
Unlike DNA, which uses T (thymine), RNA uses U (uracil) instead. So, if a DNA sequence reads TAC, the complementary mRNA strand will be AUG (T/U bonds with A, C bonds with G). Once the mRNA is complete, it moves out of the nucleus and into the cytoplasm, where the next step—translation—takes place.





Khan Academy (n.d.)

Translation happens in the ribosome, a structure that reads the mRNA sequence and assembles the corresponding amino acids into a protein. The ribosome reads the mRNA in groups of three-letter codes called codons. Each codon corresponds to a specific amino acid.



Wikimedia (2009)



To determine which amino acid a codon represents, scientists use a codon wheel. This tool helps decode the genetic information by following a three-step process:

- Start with the first letter of the codon at the center of the wheel.
- Move outward to the second letter.
- Finally, use the third letter to find the corresponding amino acid.

For example, the codon AUG codes for methionine (Met), which is the "start" signal for protein synthesis. The codon UAA, UAG, or UGA signals a stop, meaning the protein chain is complete.

Another important molecule in this process is transfer RNA (tRNA), which helps bring the correct amino acids to the ribosome. Each tRNA has an anticodon that matches a codon on the mRNA, ensuring that the amino acids are added in the correct order. Once all the amino acids are linked together, the chain folds into a unique three-dimensional (3D) structure, which determines the protein's function.

Proper protein folding is crucial - if a protein does not fold correctly, it may not function properly, leading to diseases such as Alzheimer's, Parkinson's, or cystic fibrosis. This is why scientists have long been interested in understanding how proteins fold, but figuring out their 3D structures has been a major challenge.

ARTIFICIAL INTELLIGENCE

Artificial intelligence (AI) is a branch of Computer Science that deals with a machine's ability to simulate intelligent behaviour. This includes cognitive functions we associate with human minds, such as perceiving, reasoning, learning, and adapting.

AI is becoming increasingly vital in our lives. From digital assistants, GPS navigation, and autonomous vehicles to tools like Siri/Google Home and generative AI tools (e.g., OpenAI's Chat GPT), its impact on our daily lives is growing. AI plays a crucial role in various aspects of work, enhancing efficiency, and taking on hazardous or monotonous tasks. As AI applications grow, discussions on AI ethics and responsible practices are increasingly important.



AlphaFold

Determining the 3D structure of proteins has traditionally been a slow and expensive process, requiring advanced techniques like X-ray crystallography and cryo-electron microscopy. These methods can take years to analyze a single protein. However, in 2020, an AI system called AlphaFold, developed by DeepMind, changed everything.

AlphaFold is an advanced artificial intelligence program that can predict a protein's structure with remarkable accuracy in just hours. It uses deep learning, a type of AI that processes vast amounts of data and learns patterns. By analyzing known protein structures, AlphaFold can predict how a new protein will fold based on its amino acid sequence.

The impact of AlphaFold has been enormous. It has helped scientists:

- Develop new medicines, such as treatments for malaria.
- Understand viruses, like the proteins in COVID-19.
- Create enzymes that break down plastic pollution, offering potential solutions to environmental issues.

AlphaFold has predicted the structures of millions of proteins and made its data freely available to researchers worldwide. This breakthrough is accelerating discoveries in medicine, agriculture, and biotechnology, allowing scientists to design new drugs and study diseases more efficiently than ever before.

ETHICS AND AI

Artificial intelligence offers powerful tools and new possibilities. As these systems learn from data, make decisions, and shape our world, it is important to consider their ethical impacts. Actua has developed a resource (*Appendix C*) to support facilitators in leading discussions with youth about ethics and responsible AI use. Facilitators are encouraged to engage youth in meaningful conversations that empower them to think critically about how AI is designed, used, and experienced in the world around them. This resource emphasizes human agency and responsibility, supports values-based reflection, and creates space for curiosity, dialogue, and informed decision-making as digital citizens.



Appendix C: Additional Resources

GENERAL

Activity Slide Deck

- [Puzzling Proteins - Activity Slide Deck](#)
 - **Note:** This link will automatically download to your device.

Supporting Resource

- [AI in Context: Responsibility and Ethics in Artificial Intelligence](#)

OPENING HOOK

Video(s)

-  Protein folding explained (Google DeepMind, 1:51s)

SECTION 1: CODON WHEEL

Activity Page(s)

- Codon Wheel (refer below)

SECTION 2: BEAD FOLDING

Supporting Resource(s)

- Codon Challenge (refer below)

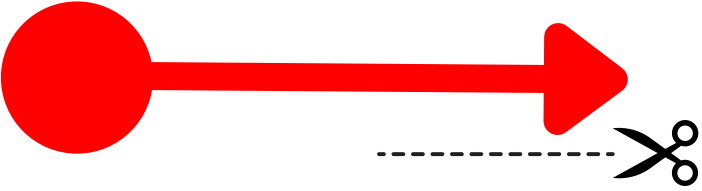
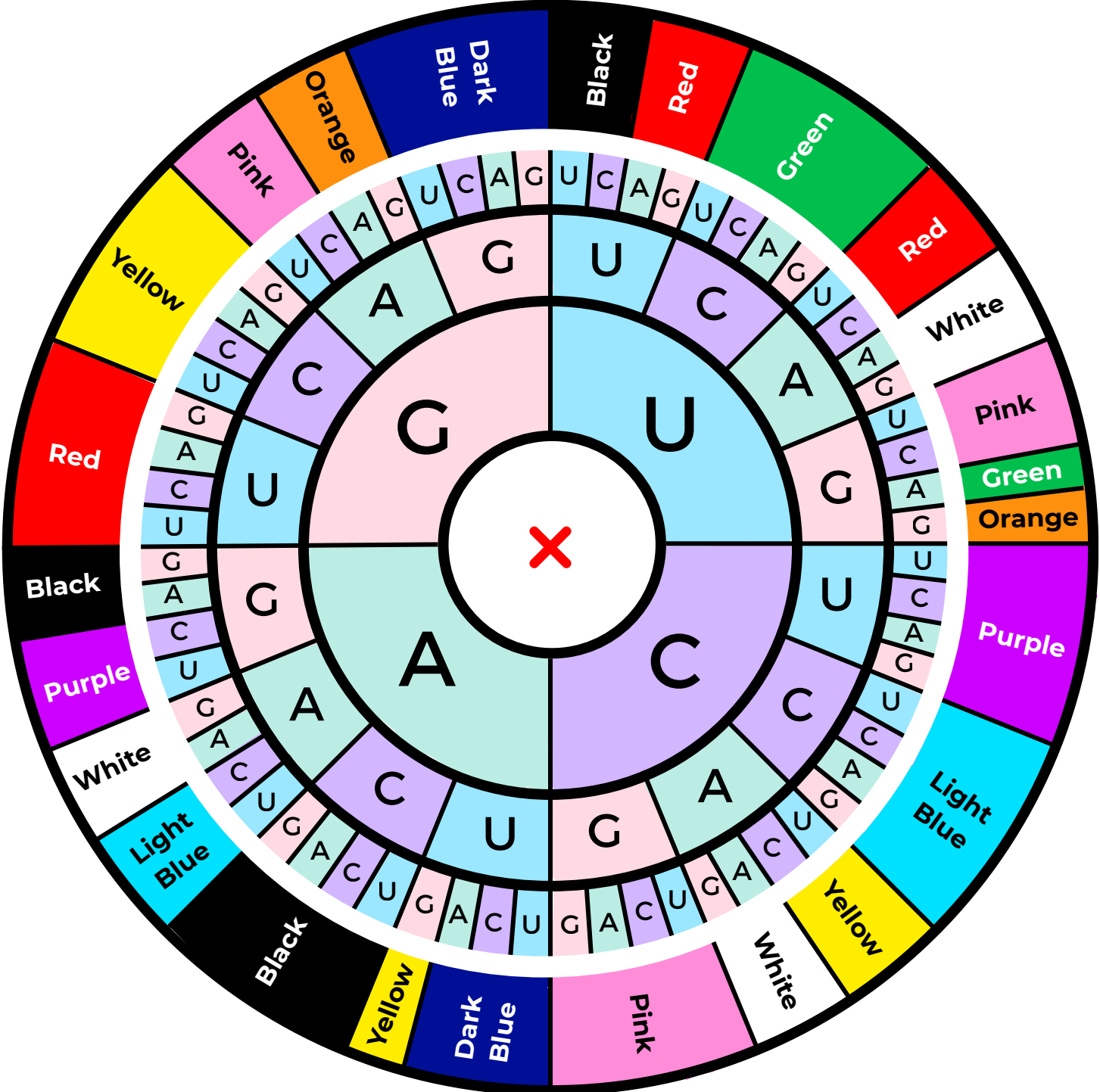


Puzzling Proteins

Codon Wheel



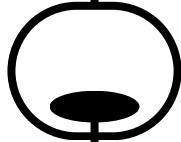
Codon Wheel



G U C



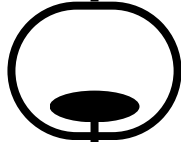
U G A



C C C



G A C



A A C



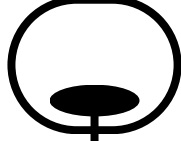
G A A



C U A



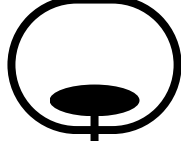
C G C



G C A

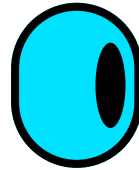


U A U



Match

Light Blue



+

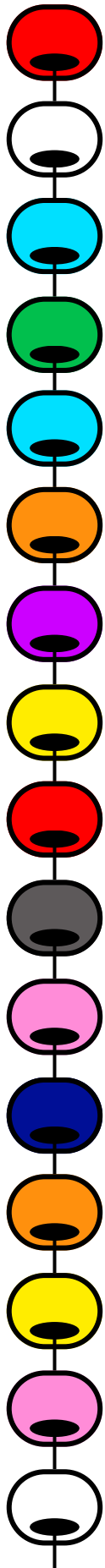


Pink

Puzzling Proteins

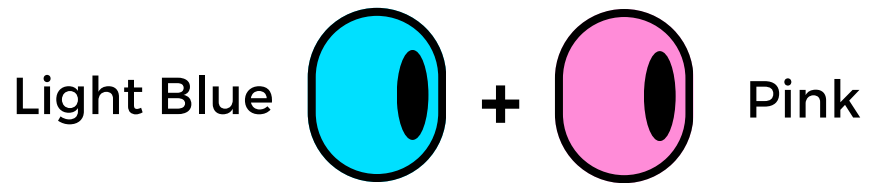
Codon Challenge





Extra Challenge

Match



AND

