

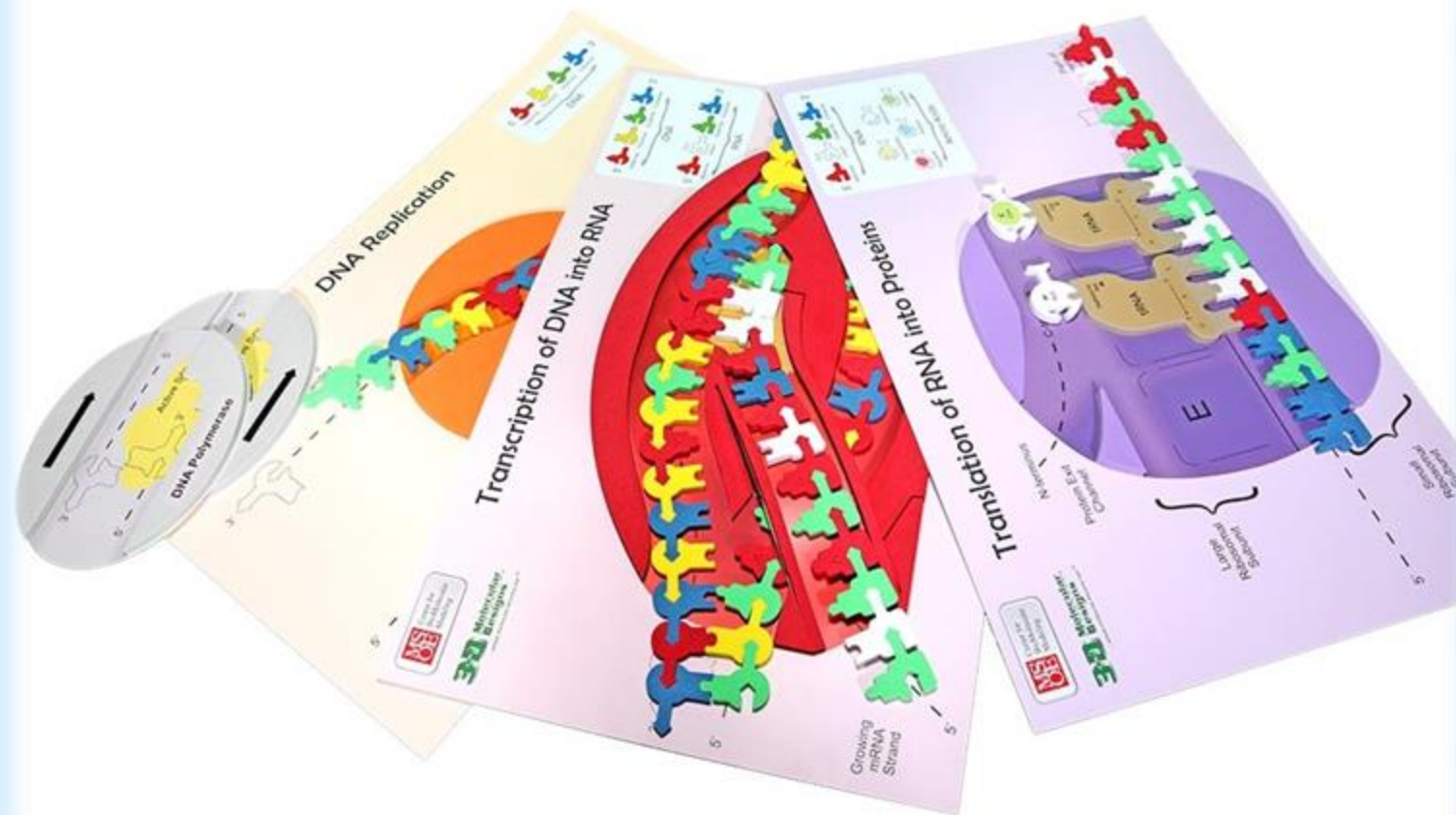
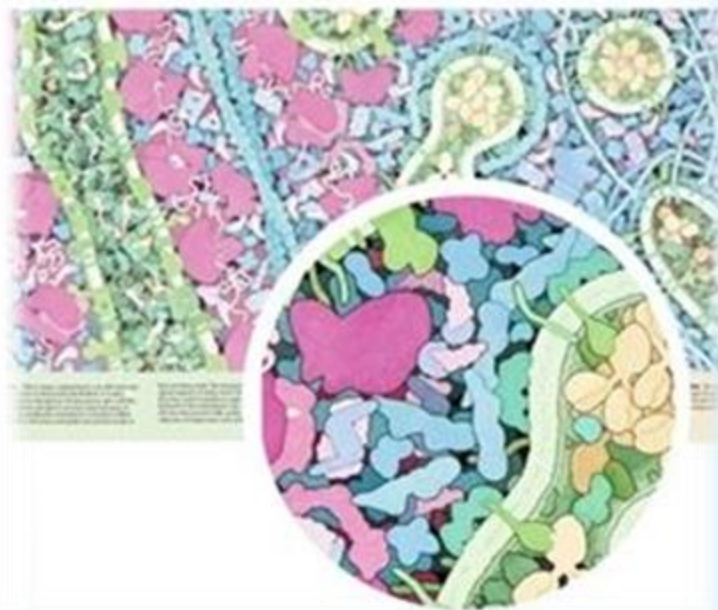


The view from 1,000,000X: a tour of the human cell

Ruth Hutson, MSSE

WSTA 2023

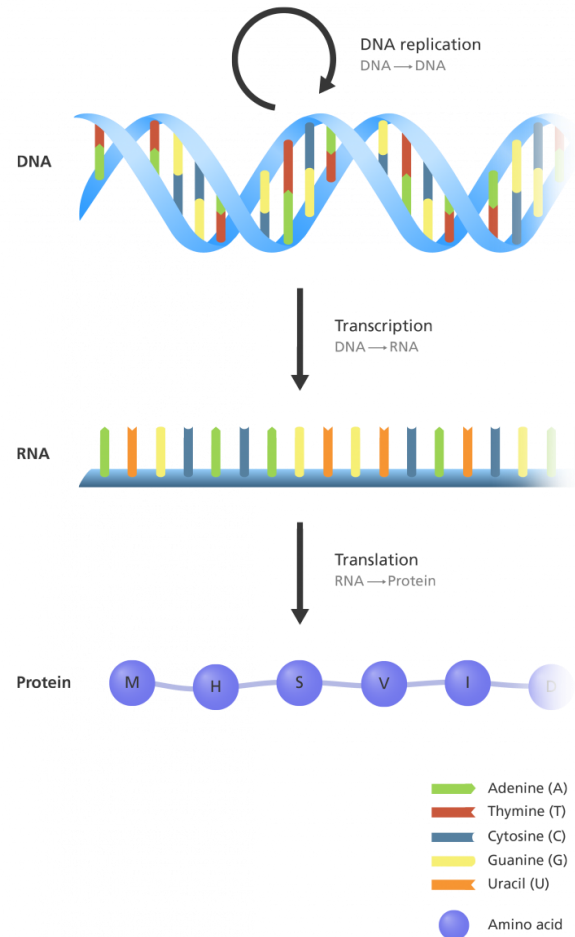




Workshop Outcomes

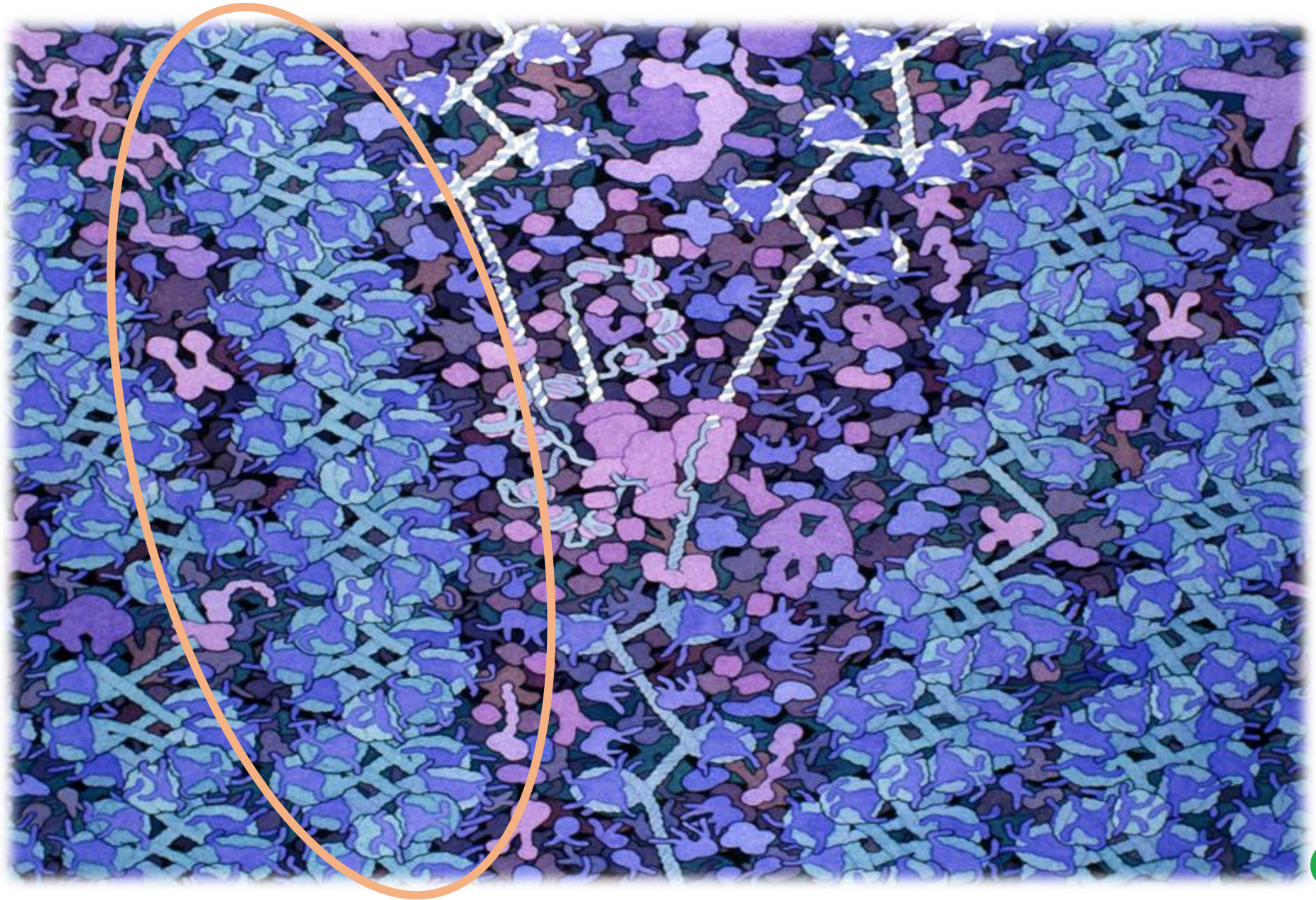
- Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells by explaining the purpose and process of replication, transcription, and translation using models of DNA and RNA.
- Examine patterns within and between side chains of amino acids.
- Model protein secondary and tertiary structure based on the primary structure of amino acid sequence.

What do your students find confusing about the central dogma?

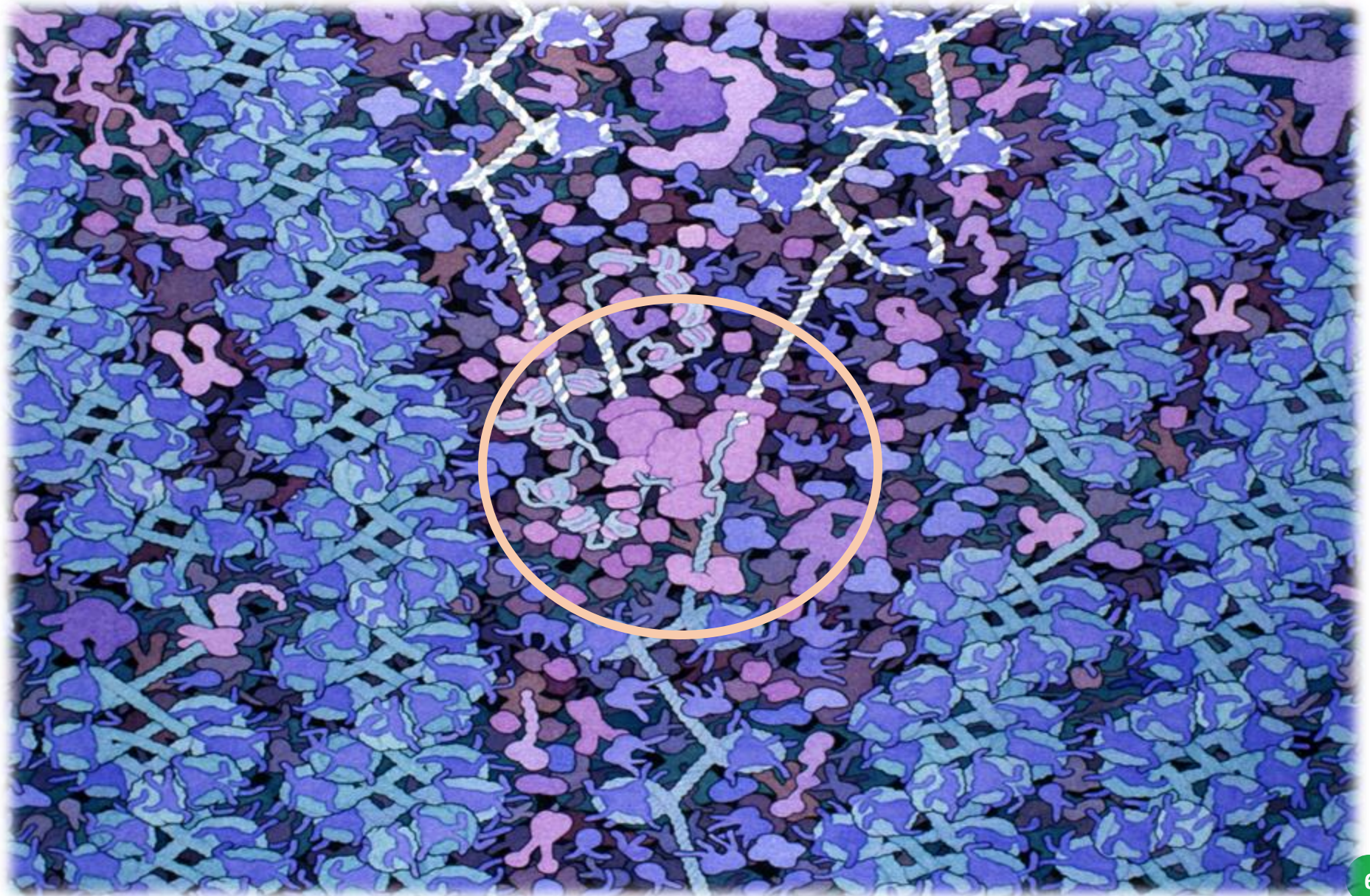


- Don't understand how the processes are related.
- Don't understand the relevance to their own body.
- All the vocabulary!

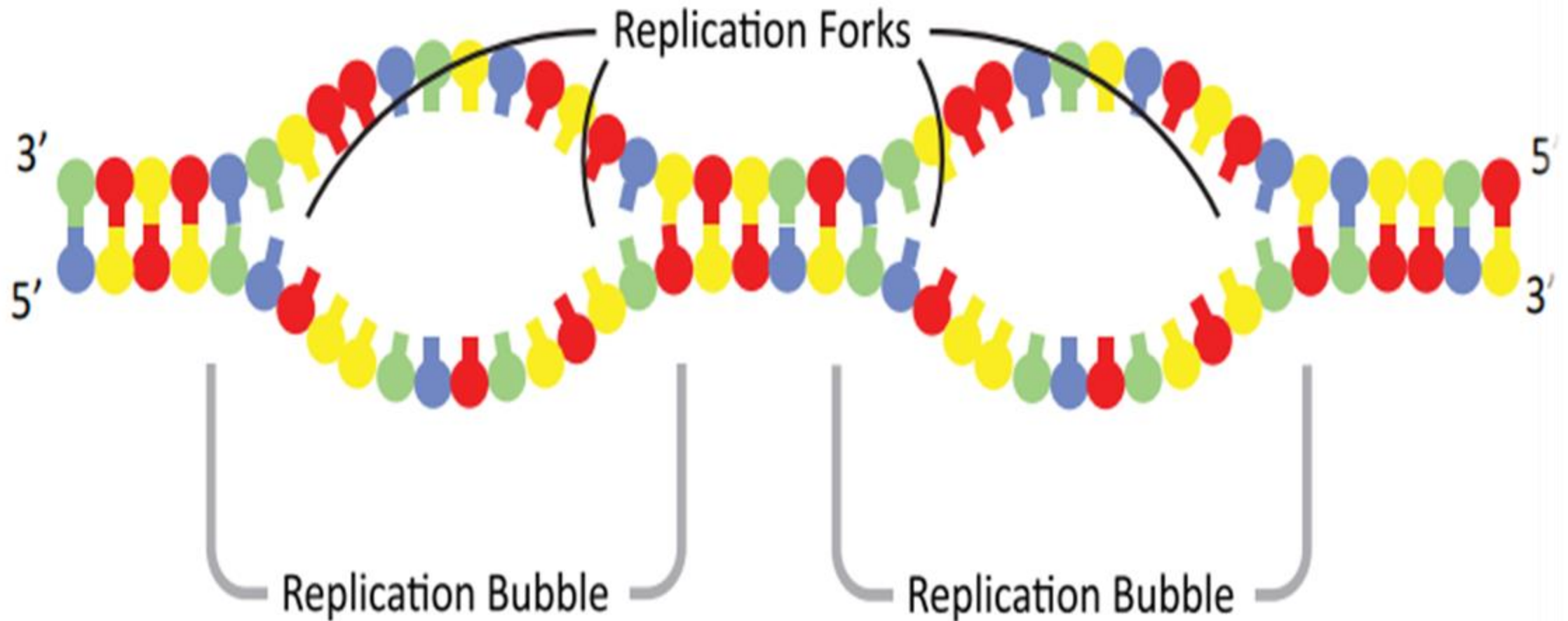
Replication in the Eukaryotic Nucleus



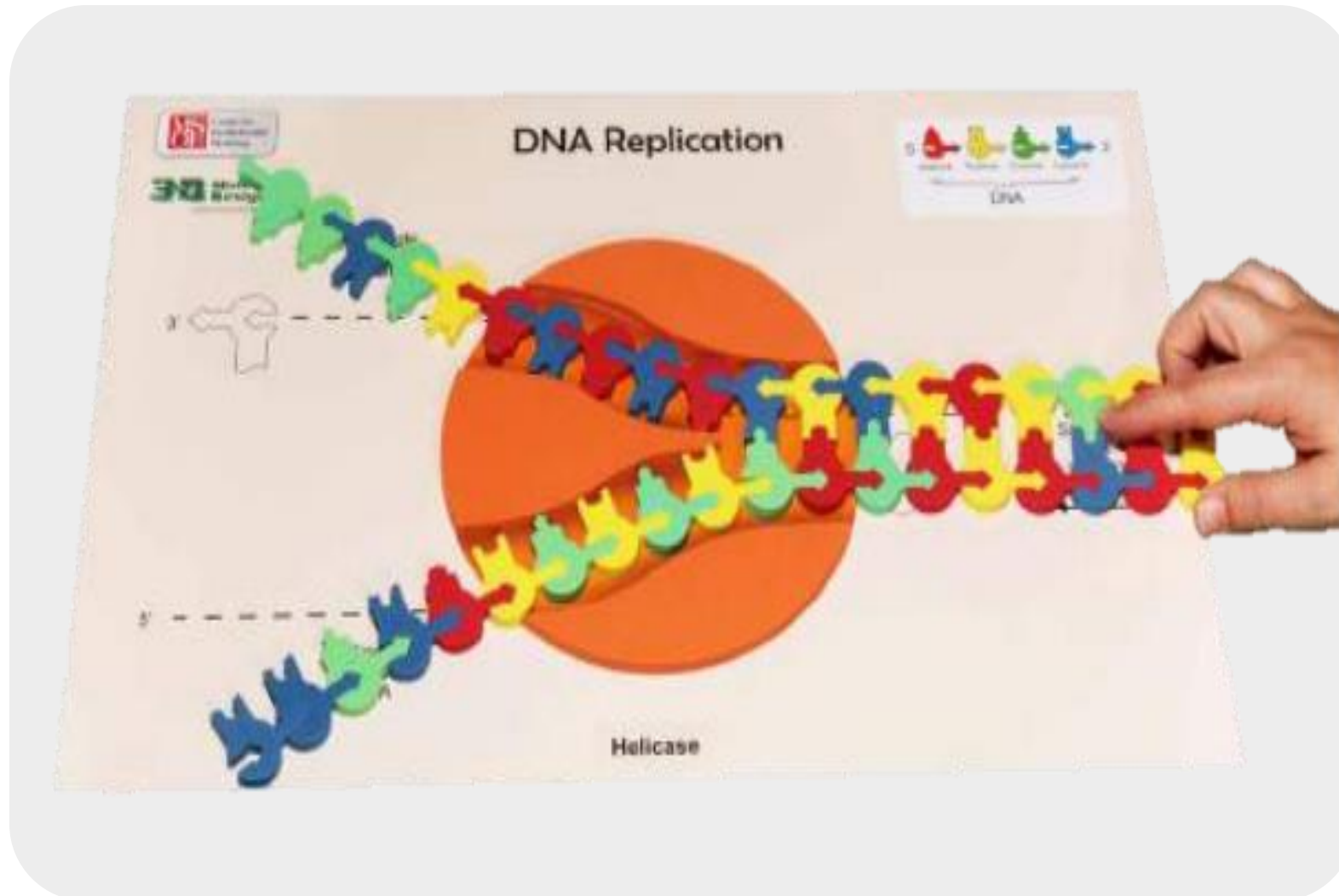
Replication in the Eukaryotic Nucleus



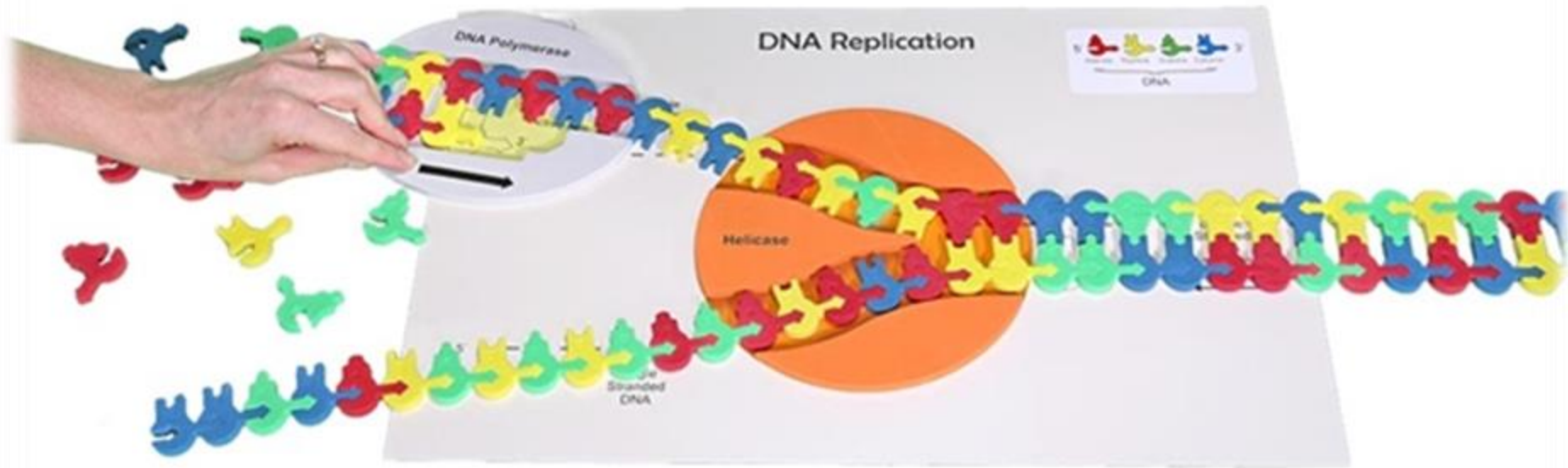
Replication Forks



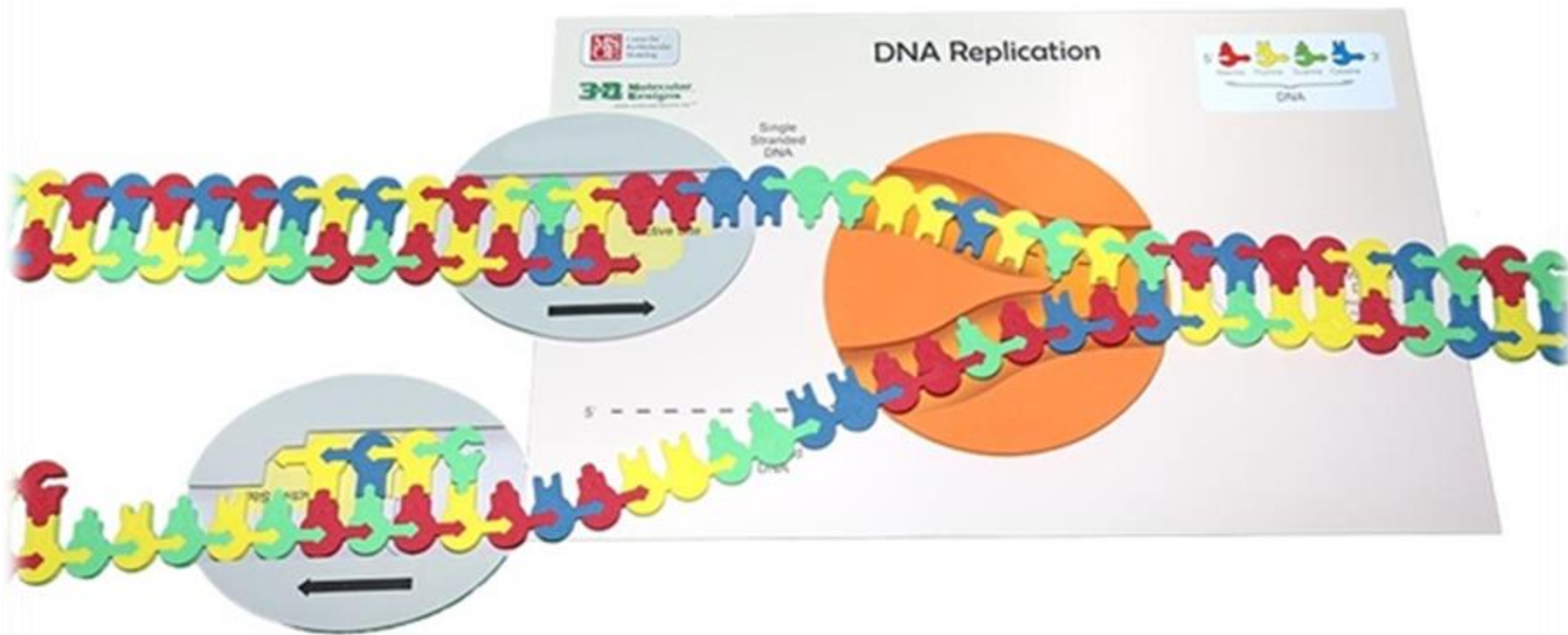
Replication



Continuous Replication



Discontinuous Replication



Comparing Leading and Lagging Strands



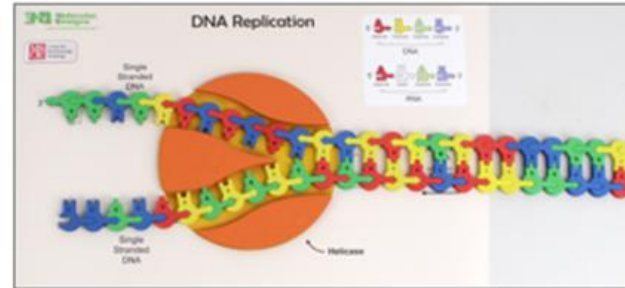


Template

Non-template



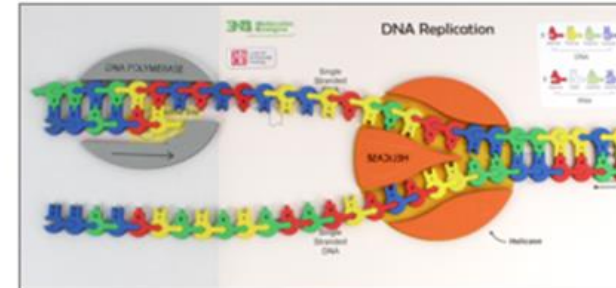
Diagram 1



Helicase unwinds the DNA at the replication fork

Helicases are enzymes that untwist the double helix and separate the two strands.

Diagram 2



DNA polymerase catalyzes the synthesis of new DNA

Leading Strand: New DNA can elongate only in the $5' \rightarrow 3'$ direction. The DNA strand that is made **continuously** is referred to as the leading strand. DNA polymerase moves toward the replication fork.

Diagram 3

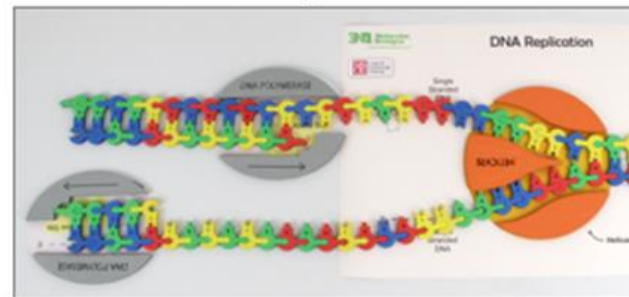
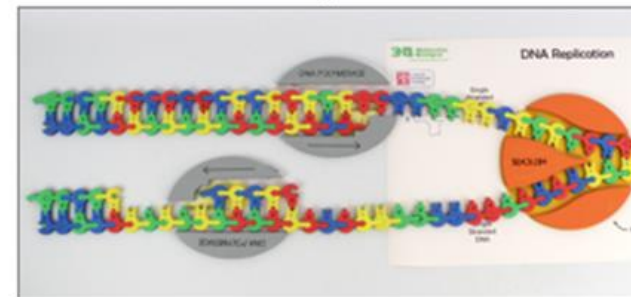
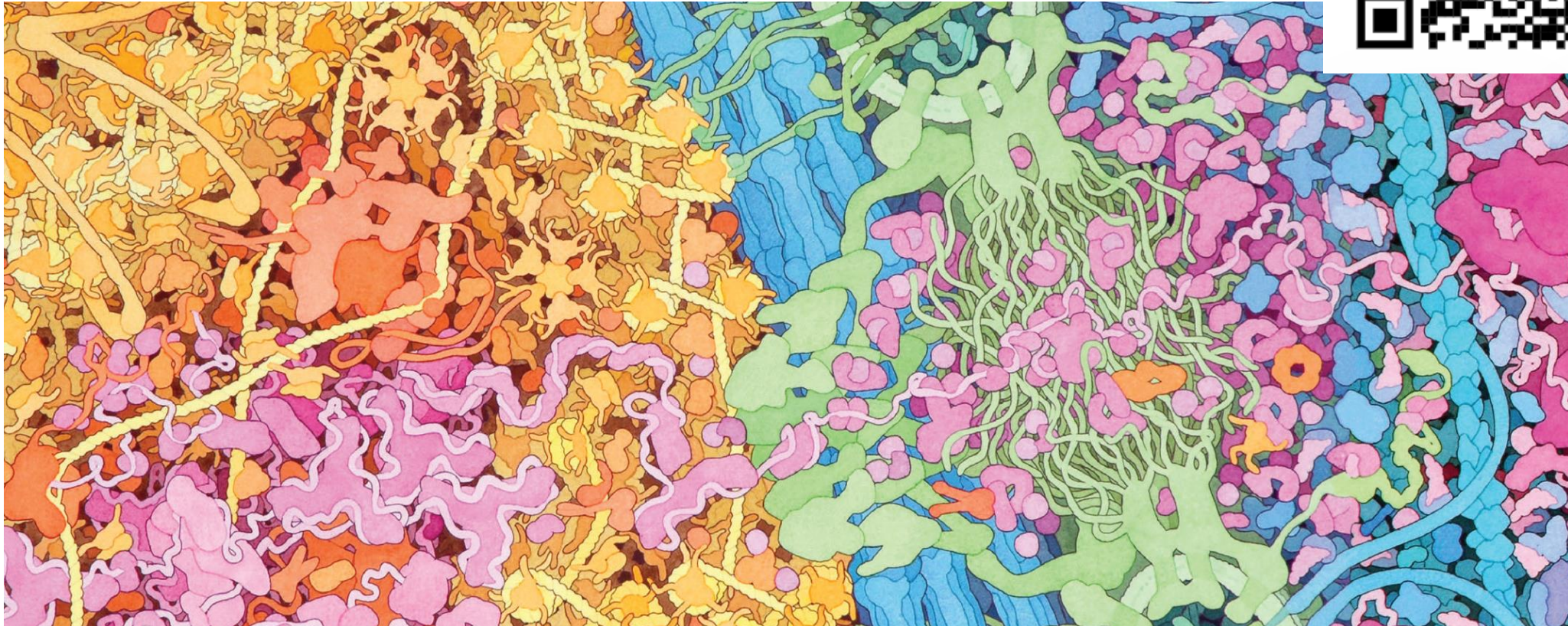


Diagram 4



Lagging Strand: DNA polymerase must move away from the fork instead of toward the fork as it did in the leading strand in order to maintain $5' \rightarrow 3'$ DNA synthesis (diagram 3). The lagging strand is synthesized in a series of **discontinuous** fragments referred to as Okazaki fragments (diagram 4).

A brief tour through the cell



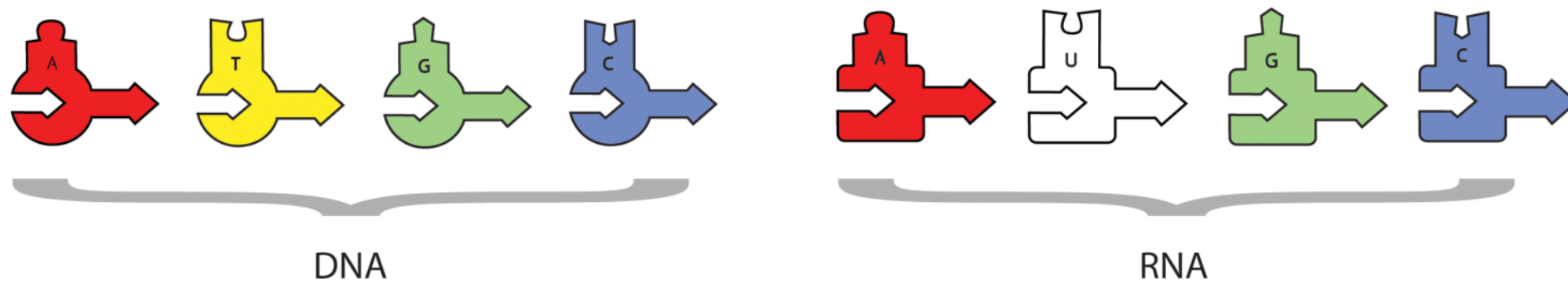
This image is an excerpt from Tour of a Human Cell by David Goodsell, as shown in 3D Molecular Designs' Tour of a Human Cell© poster and David Goodsell's book, *The Machinery of Life*.

A brief tour through the cell

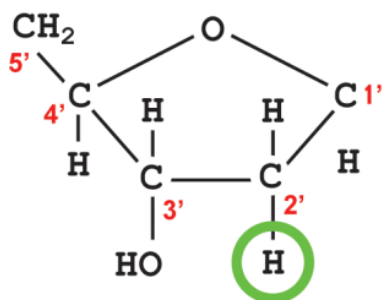


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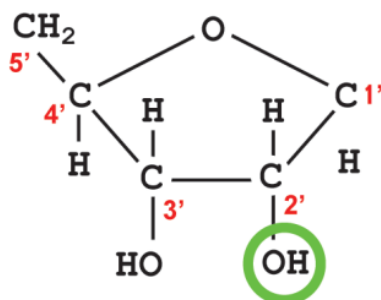
Transcription



Deoxyribose
found in DNA



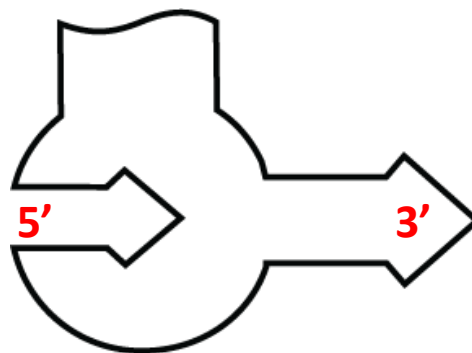
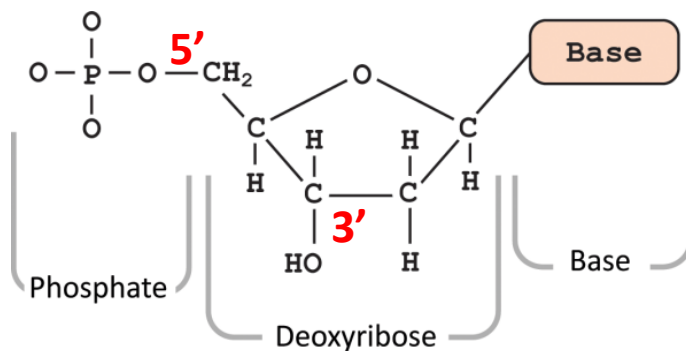
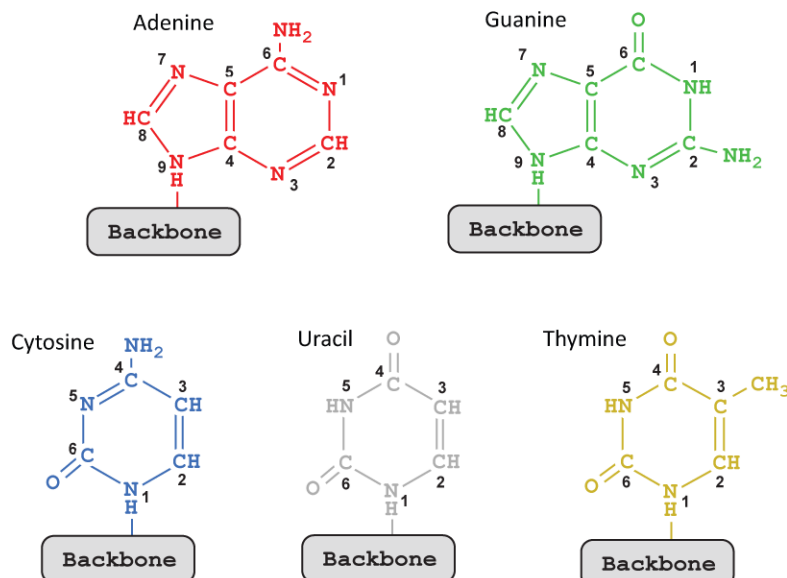
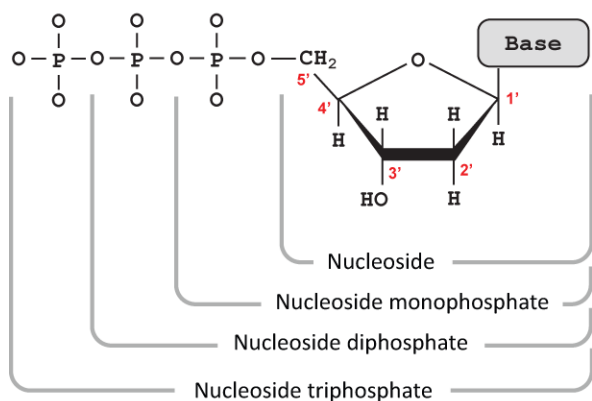
Ribose
found in RNA



Helpful Hint:

The DNA pieces are different than the RNA pieces!

Transcription

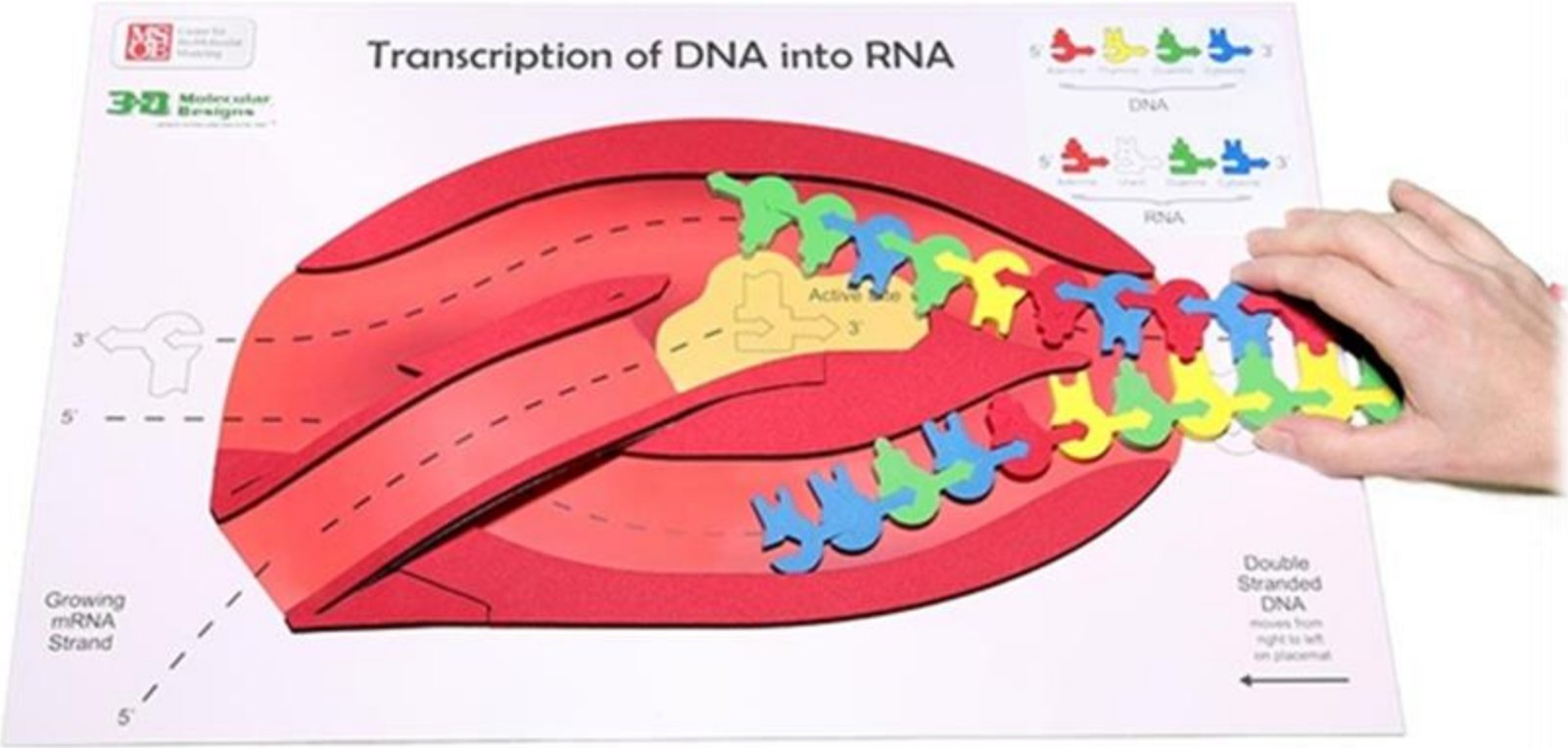


Helpful Hints:

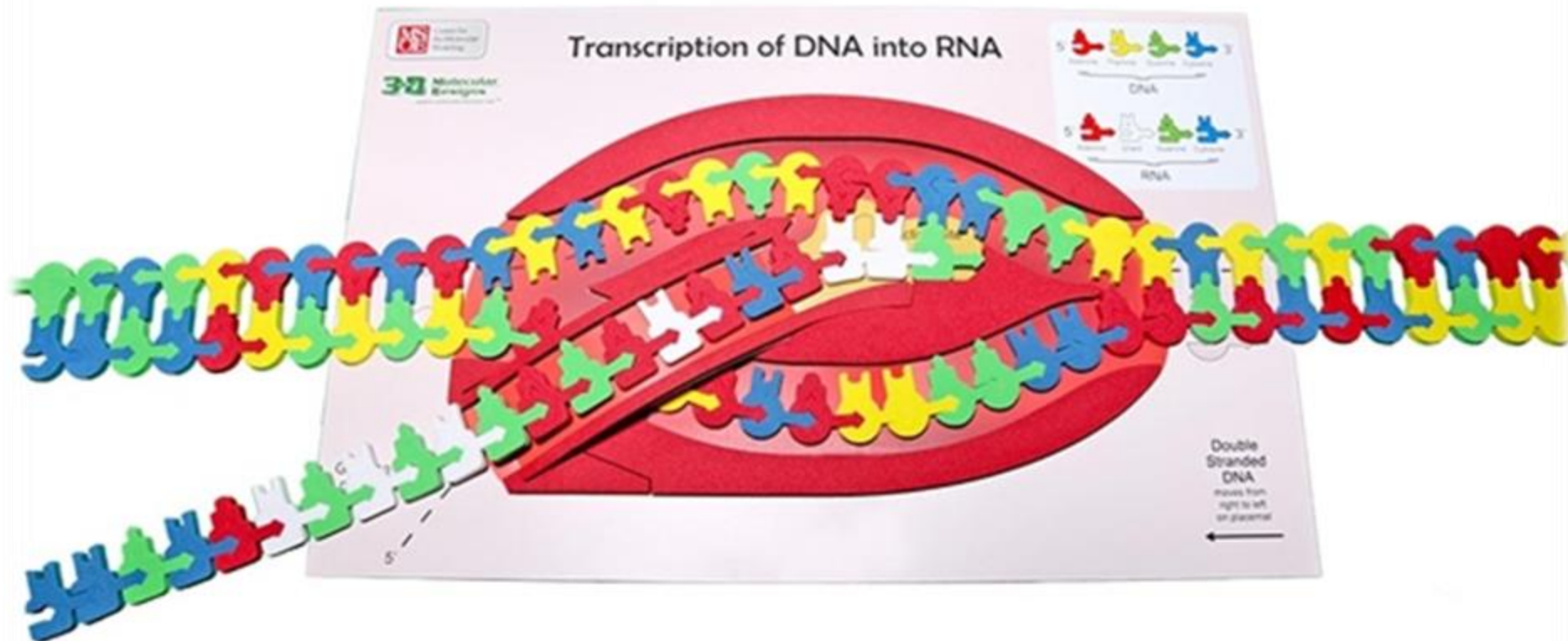
Take care in loading the DNA in the RNA polymerase.

Remember RNA is synthesized from the 5' to the 3' end.

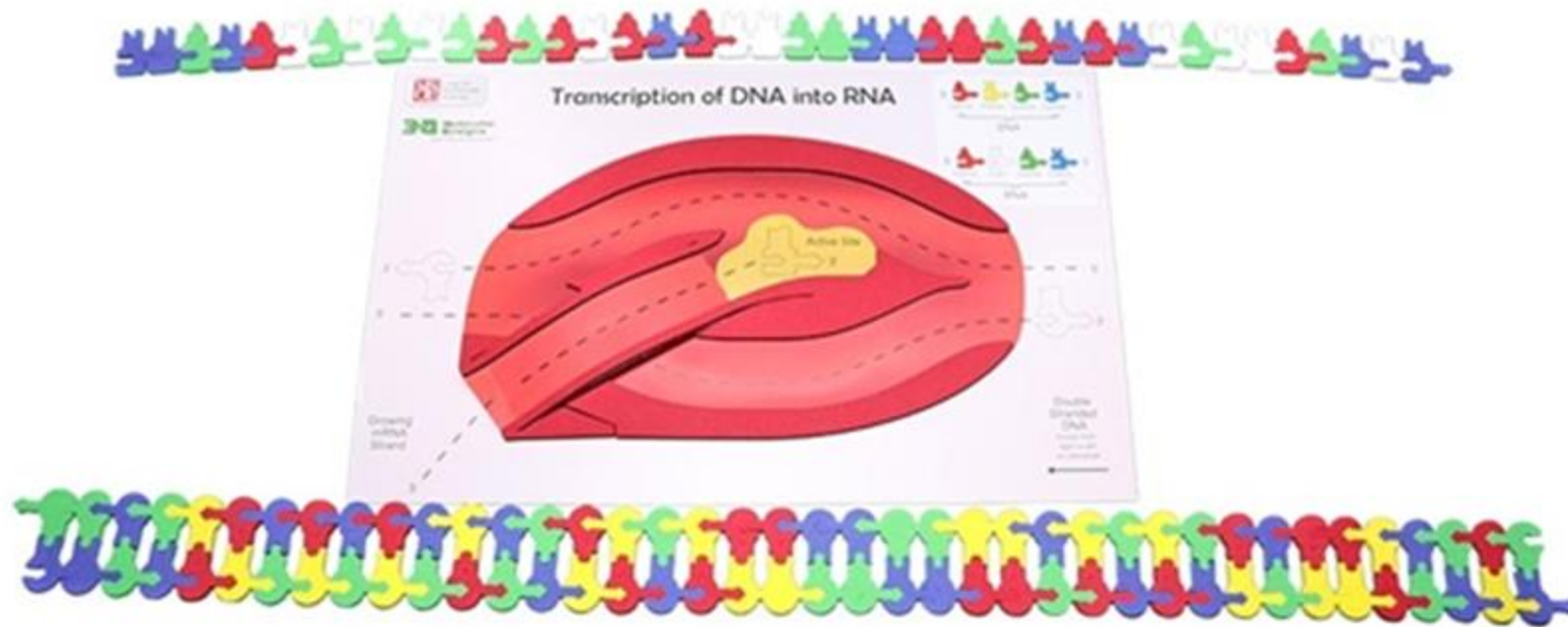
Transcription: Initiation



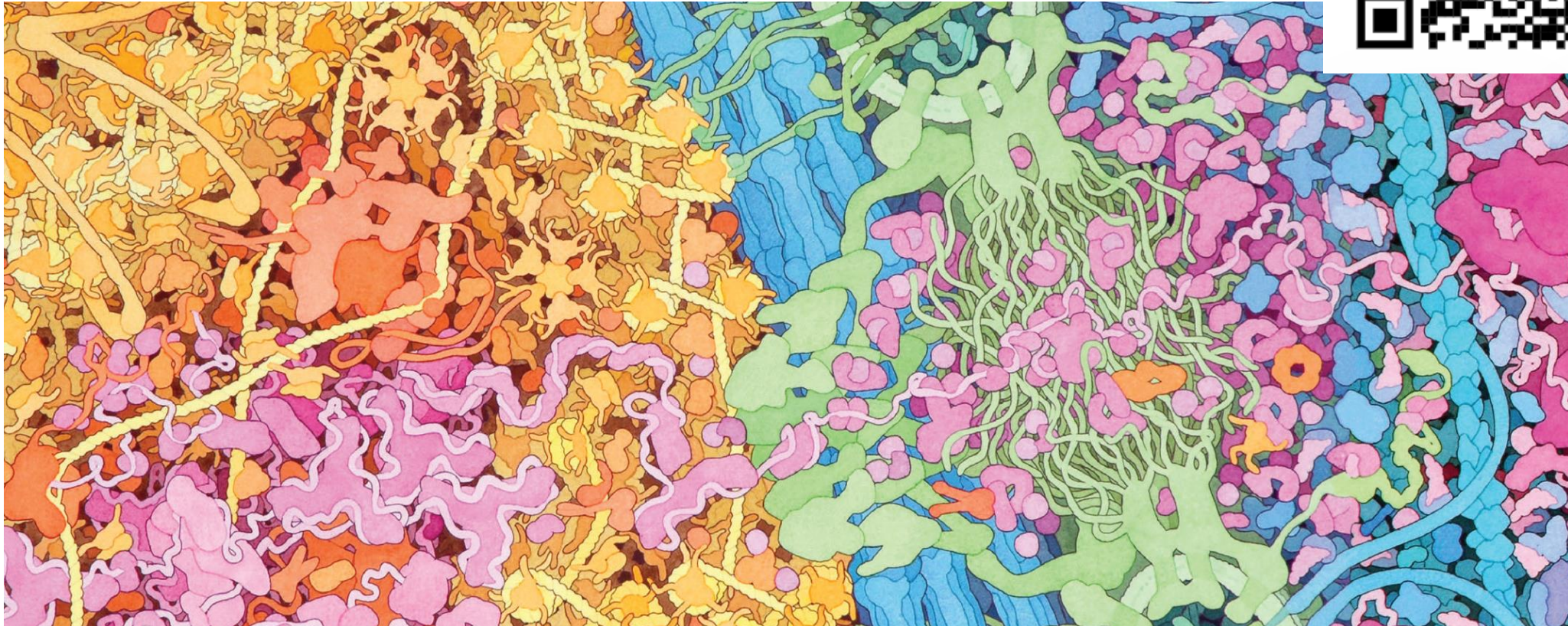
Transcription: Elongation



Transcription: Termination



A brief tour through the cell

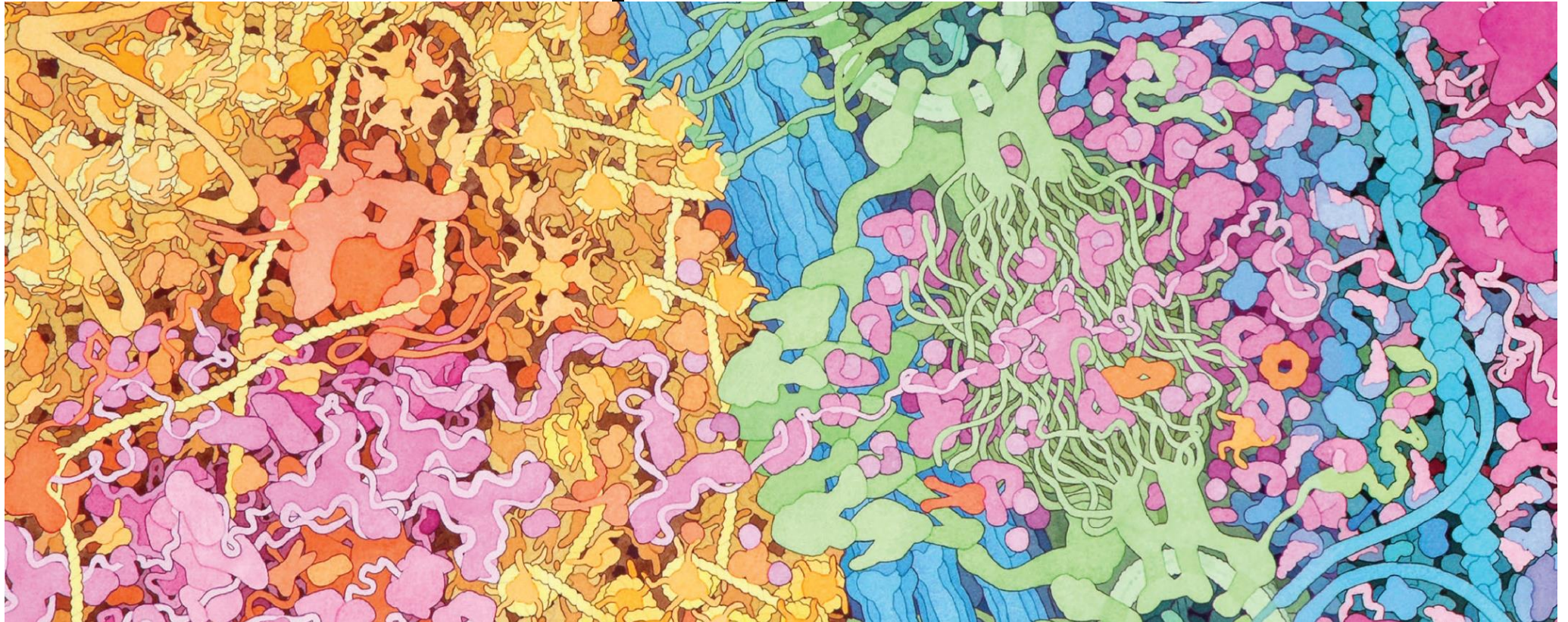


This image is an excerpt from Tour of a Human Cell by David Goodsell, as shown in 3D Molecular Designs' Tour of a Human Cell© poster and David Goodsell's book, *The Machinery of Life*.

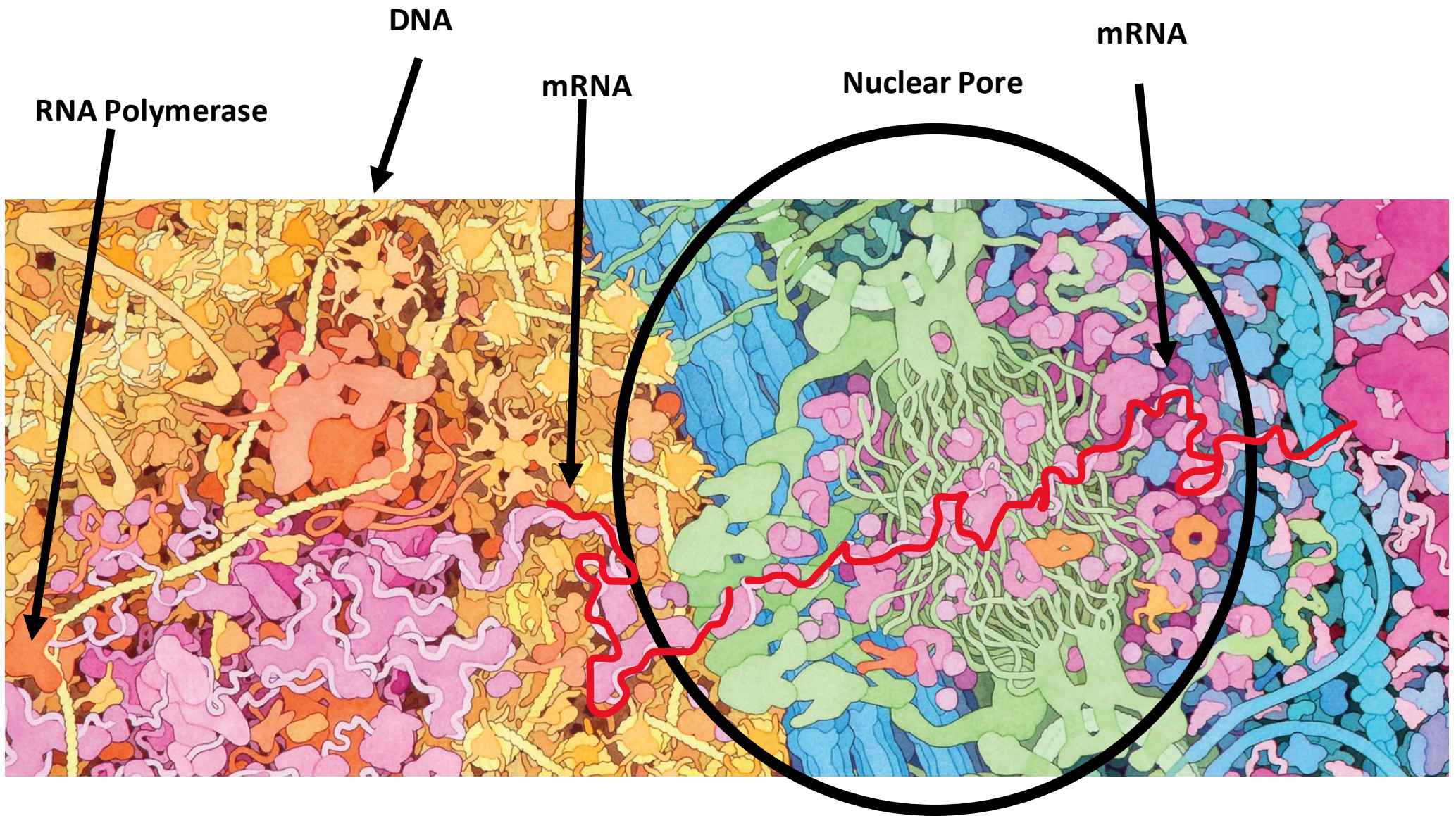
Nucleus

Nuclear
Membrane

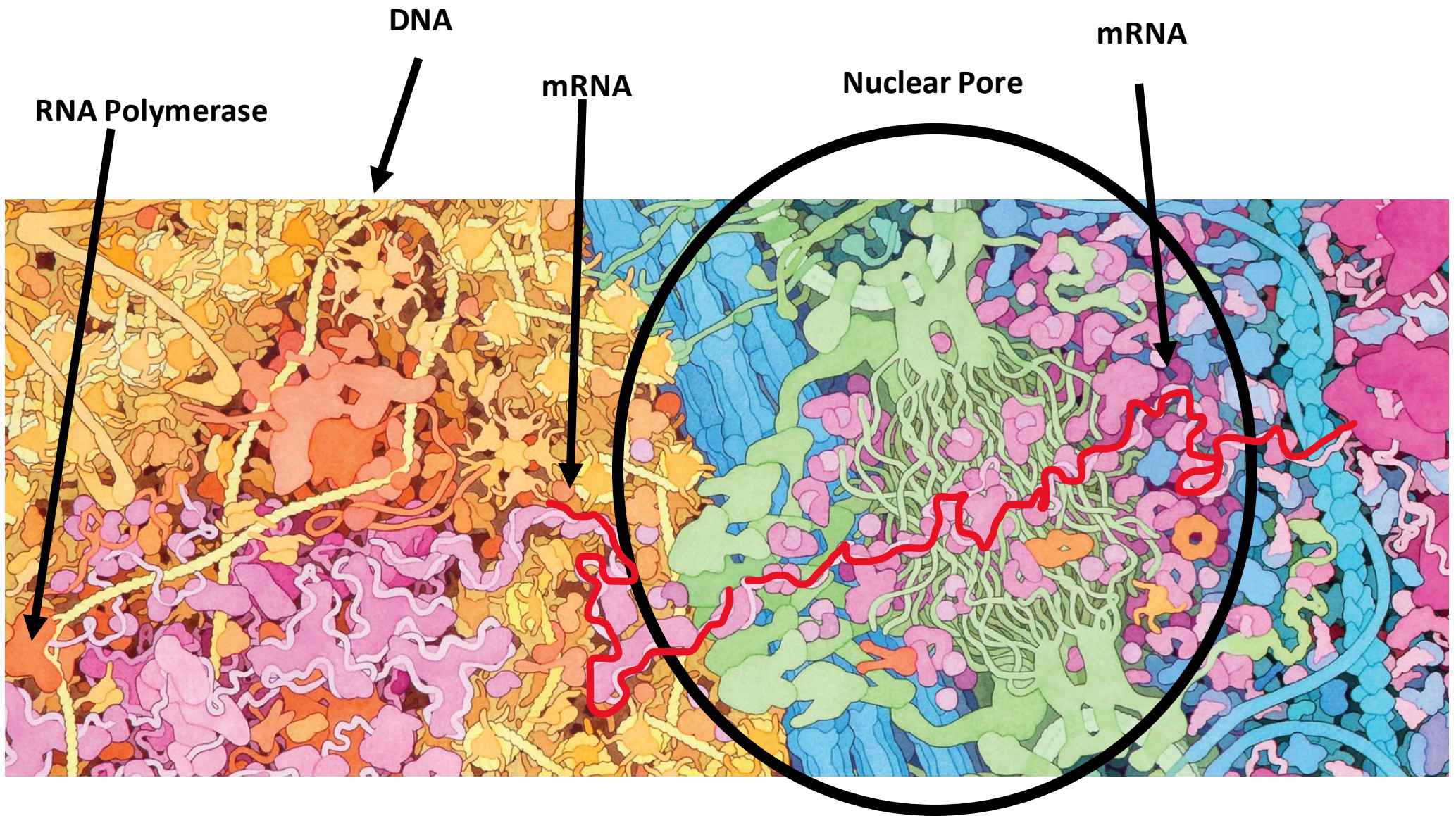
Cytoplasm



This image is an excerpt from Tour of a Human Cell by David Goodsell, as shown in 3D Molecular Designs' Tour of a Human Cell© poster and David Goodsell's book, *The Machinery of Life*.



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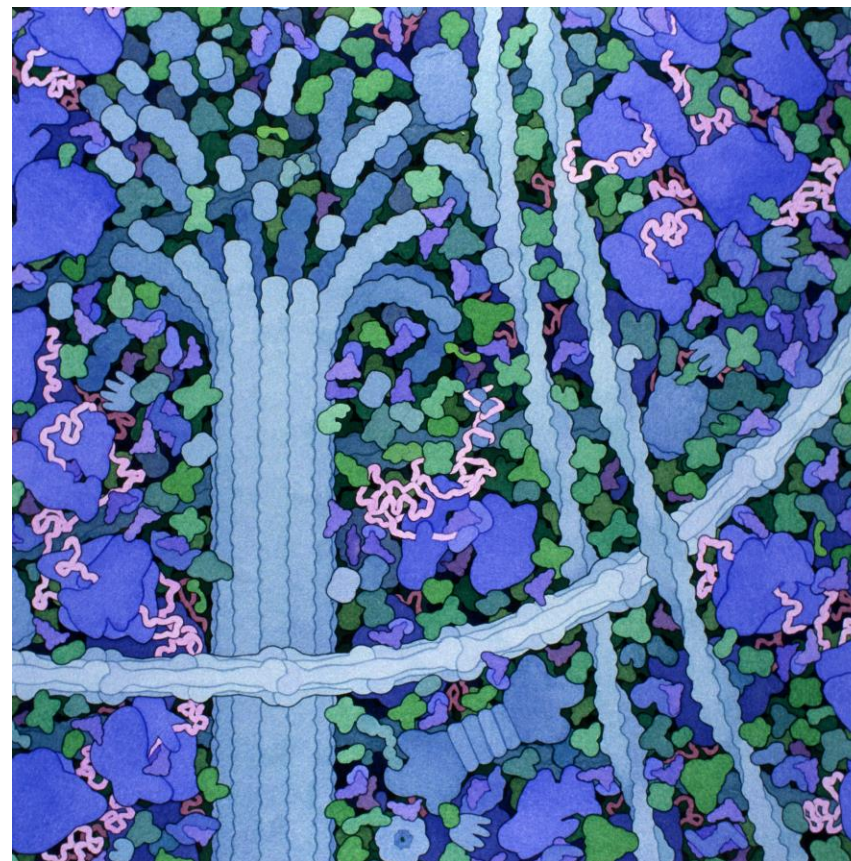
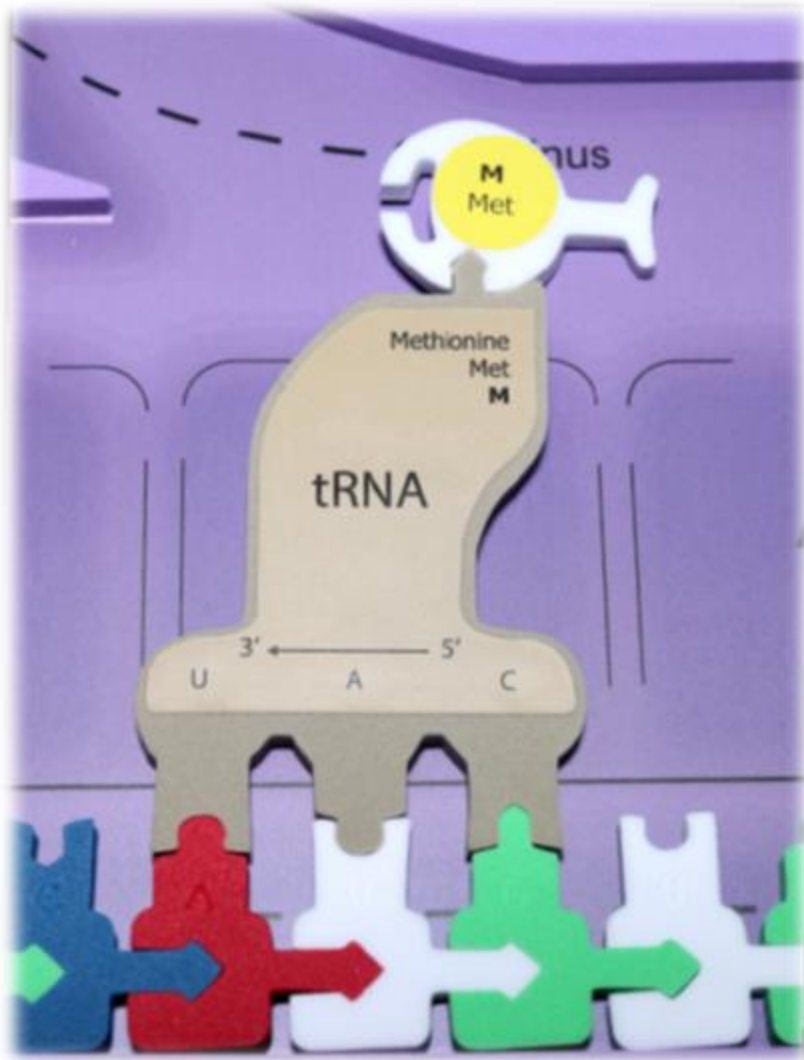


This image is an excerpt from Tour of a Human Cell by David Goodsell, as shown in 3D Molecular Designs' Tour of a Human Cell© poster and David Goodsell's book, *The Machinery of Life*.

See you back in five minutes.

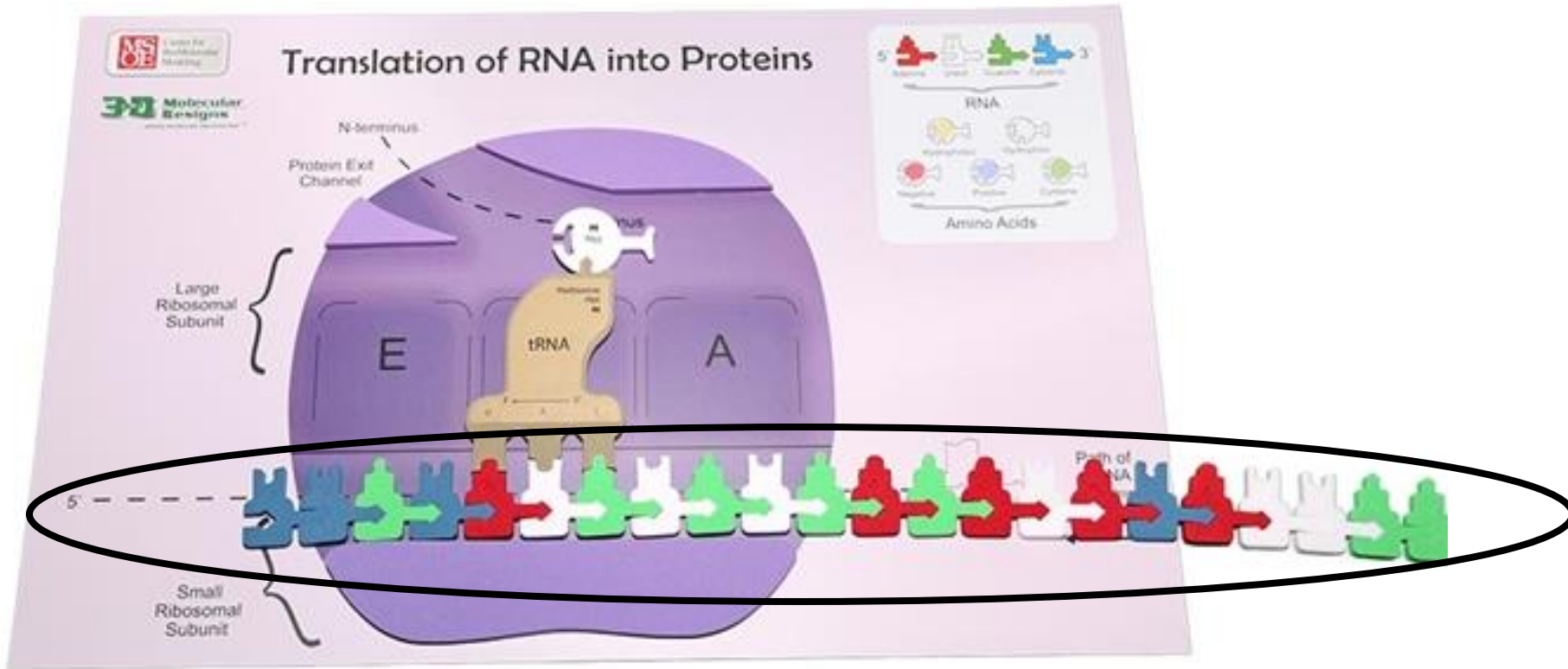


Translation

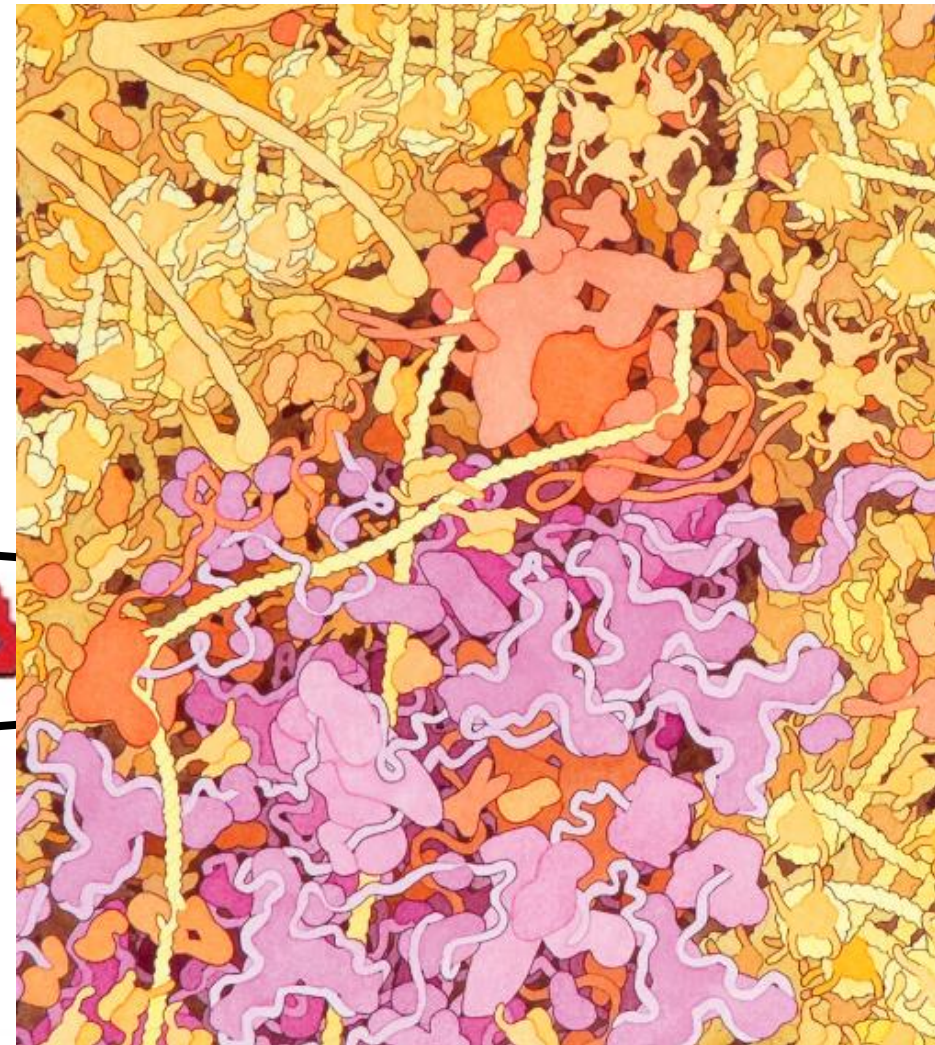
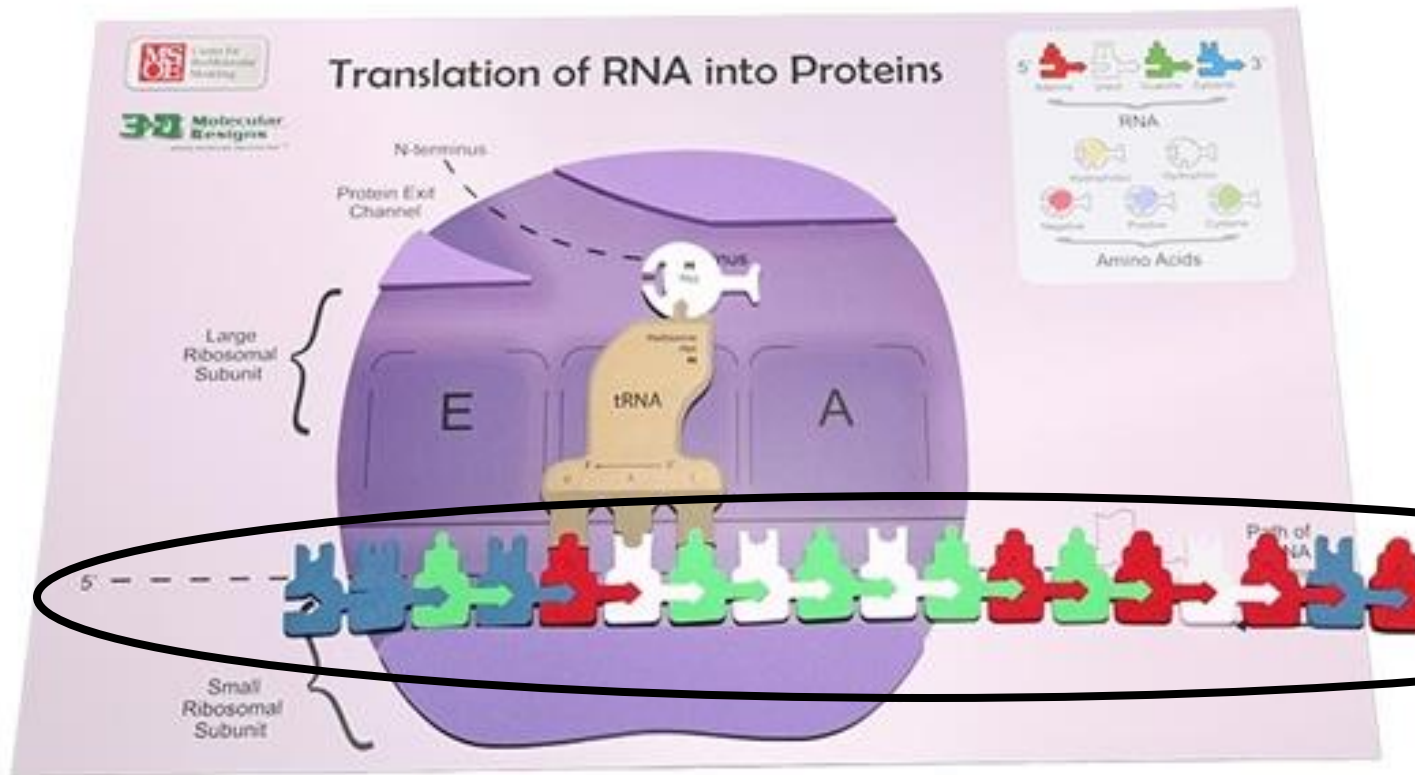


Acknowledgement: Illustration by David S. Goodsell. doi: 10.2210/rcsb_pdb/goodsell-gallery-006

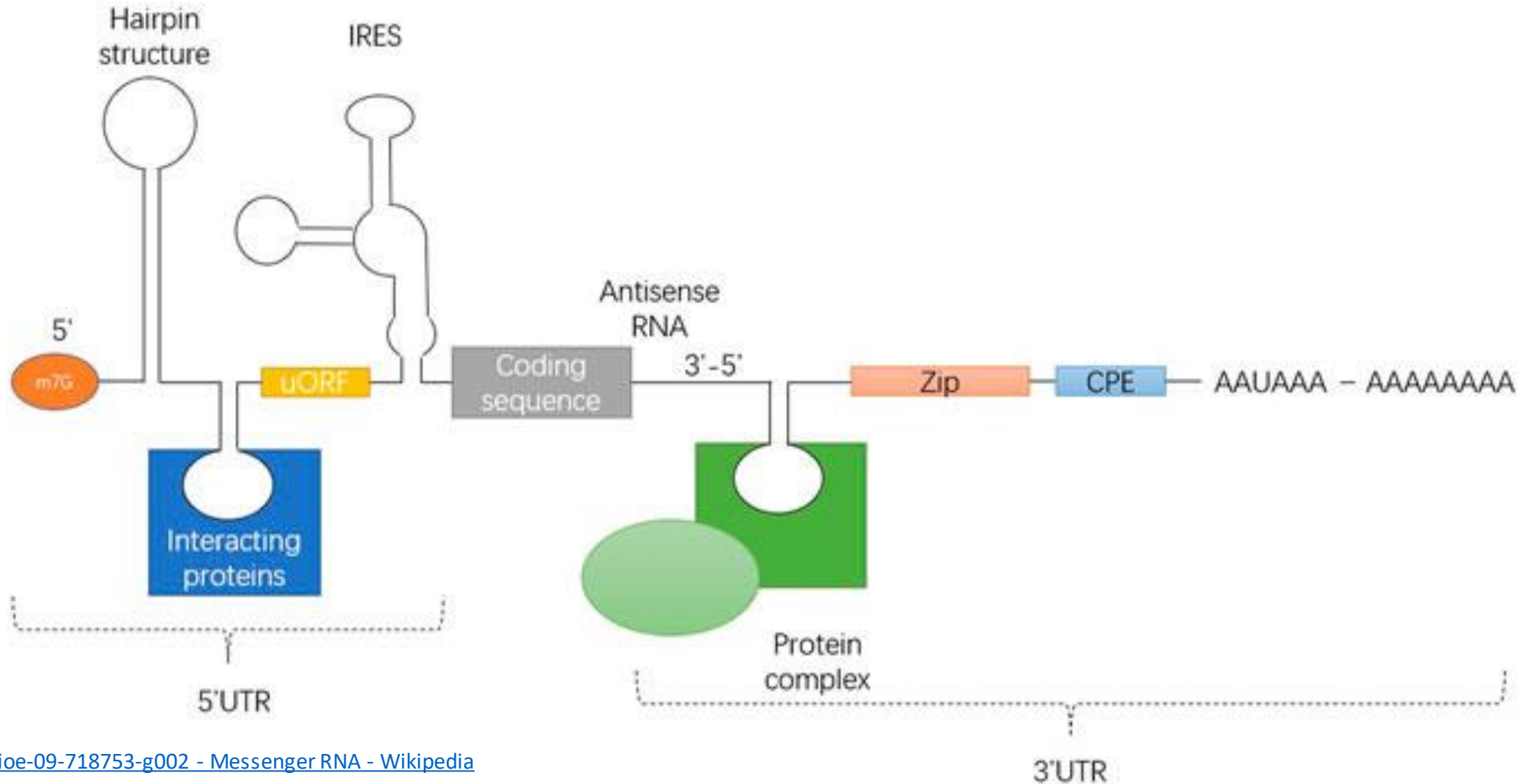
Messenger RNA—It's not limp spaghetti.



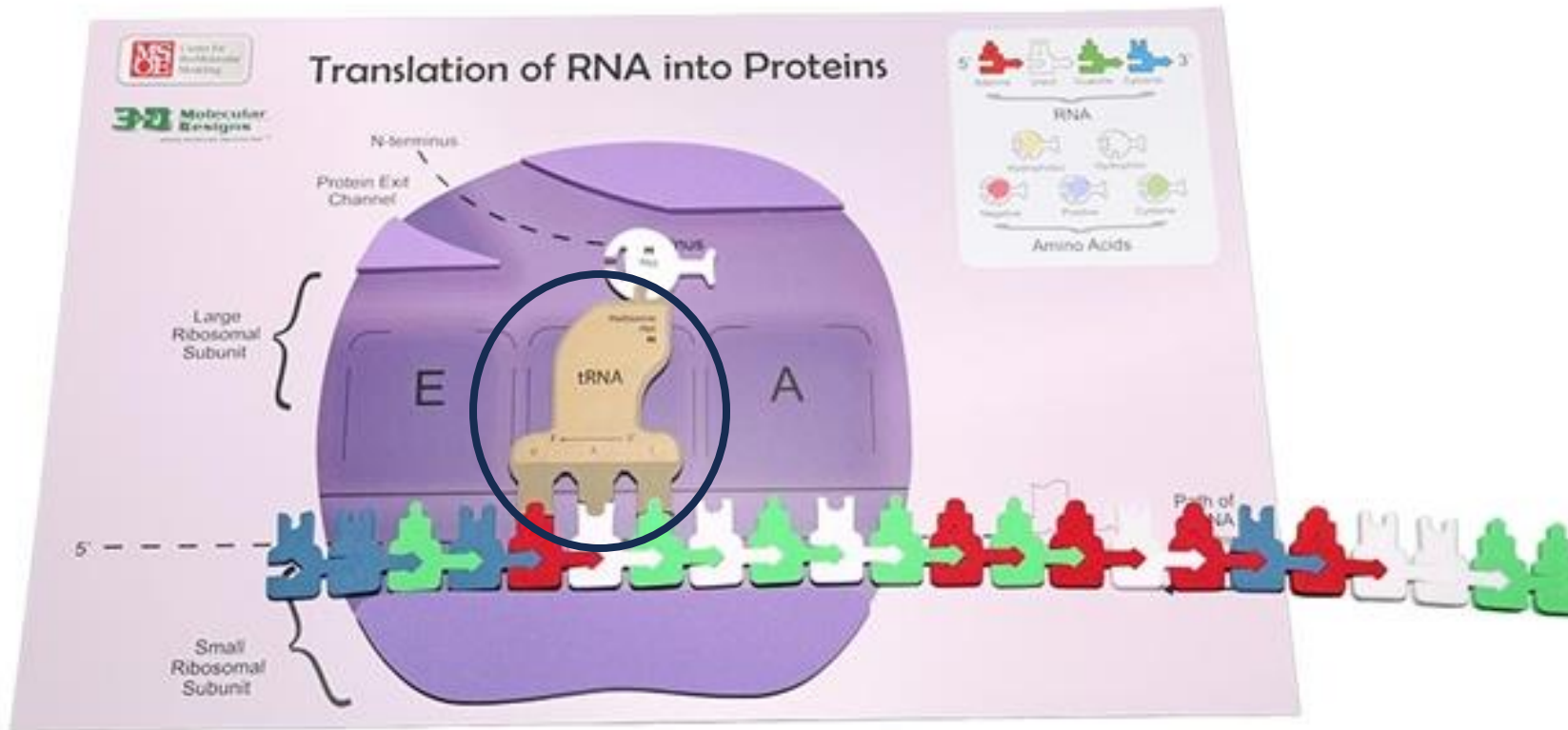
Messenger RNA—It's not limp spaghetti.



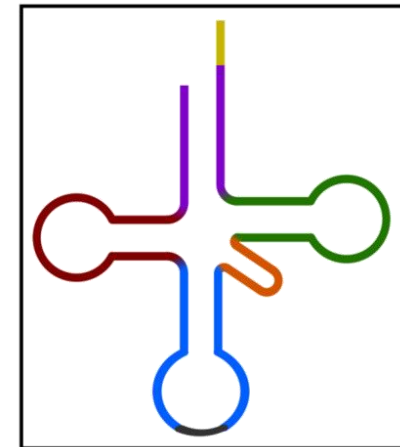
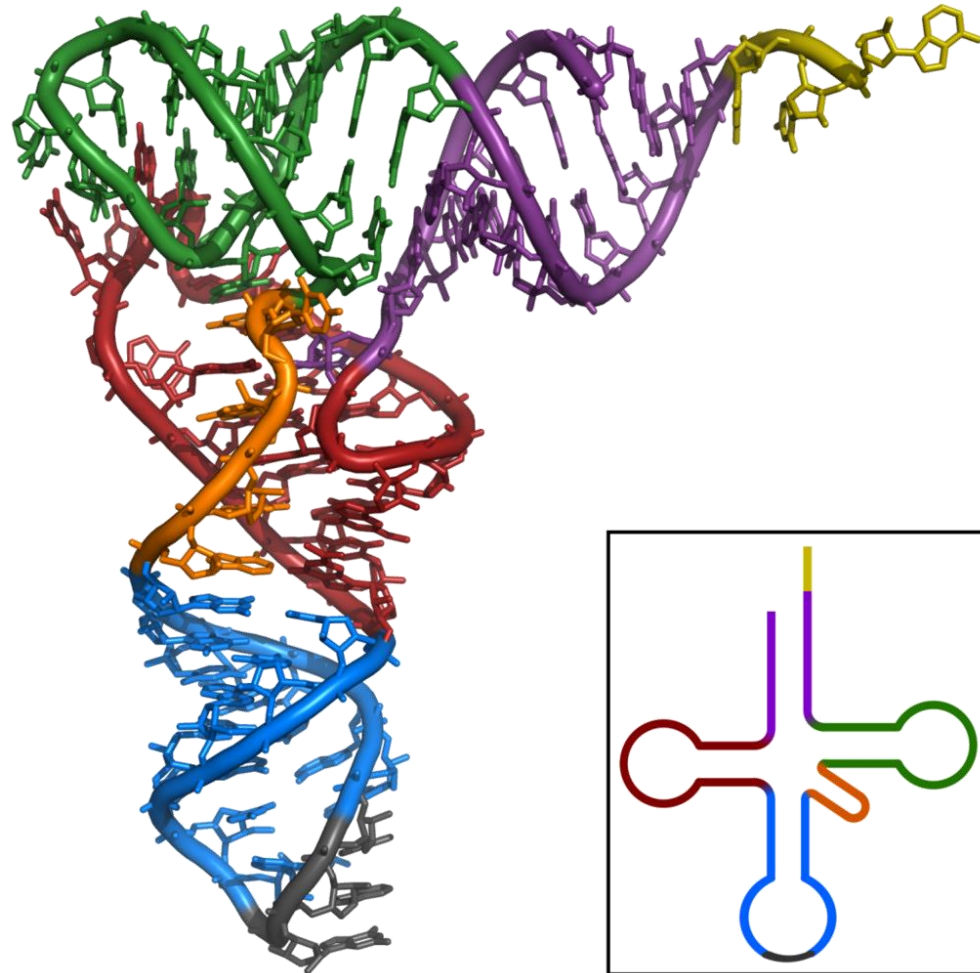
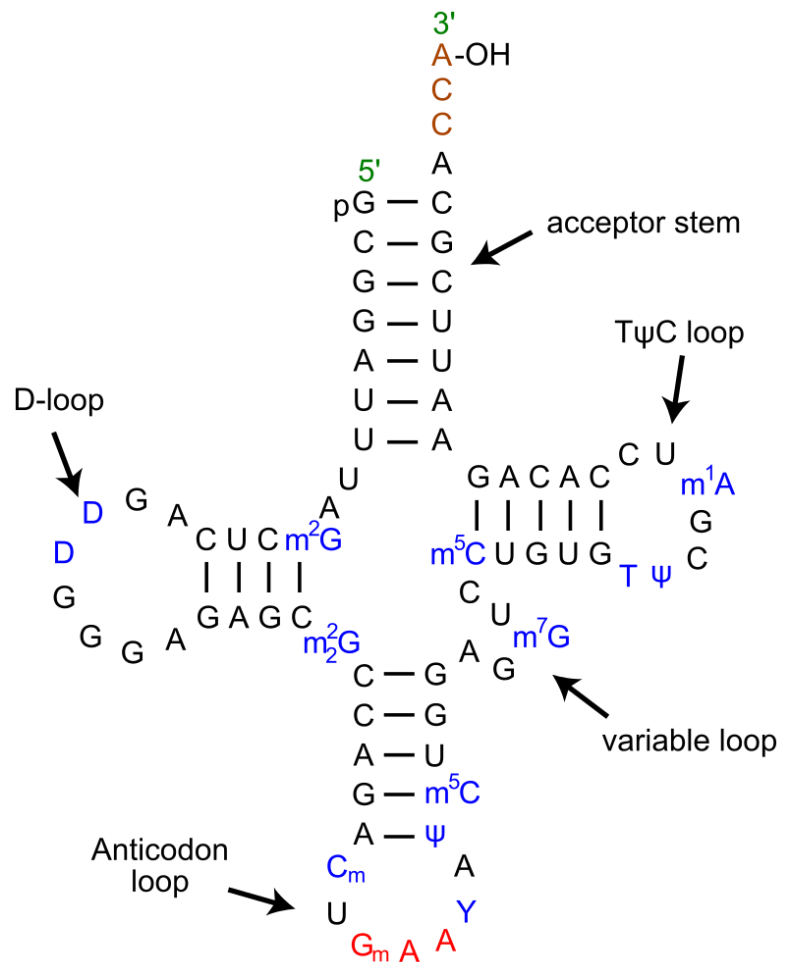
mRNA—Is this unstructured?



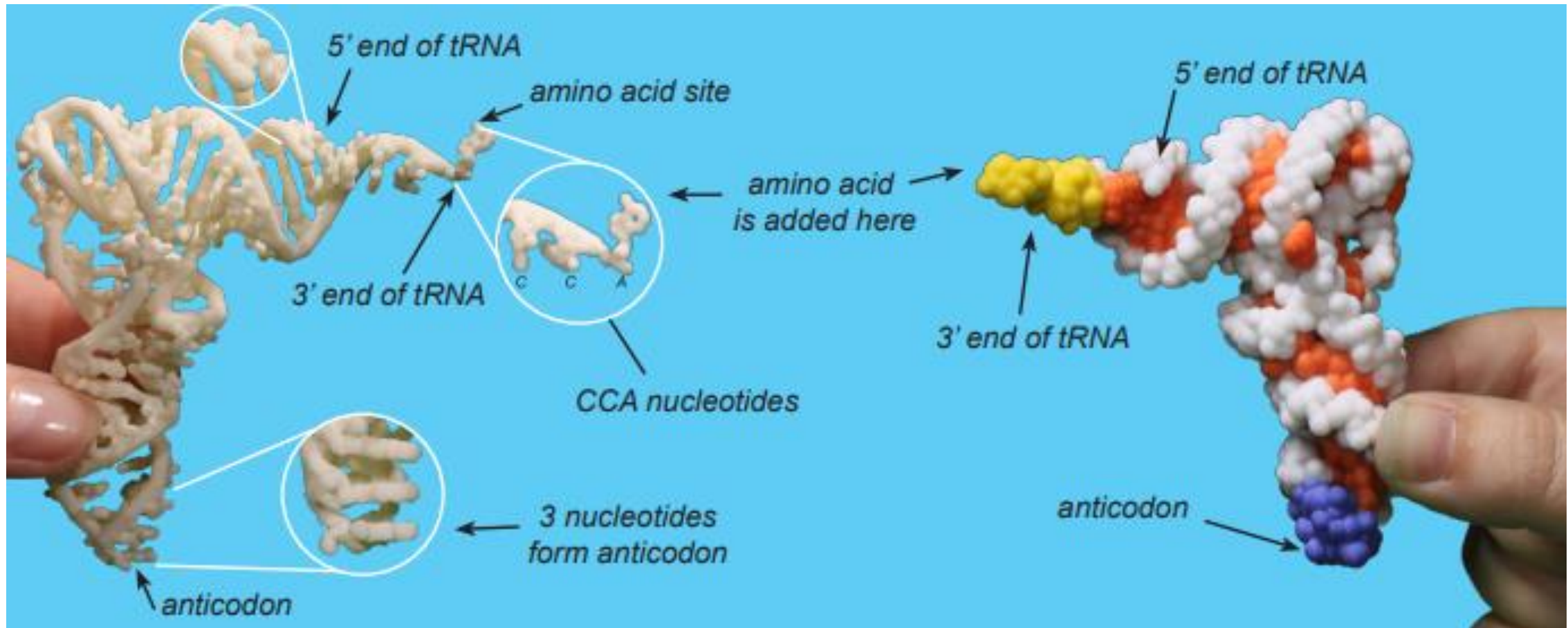
Transfer RNA



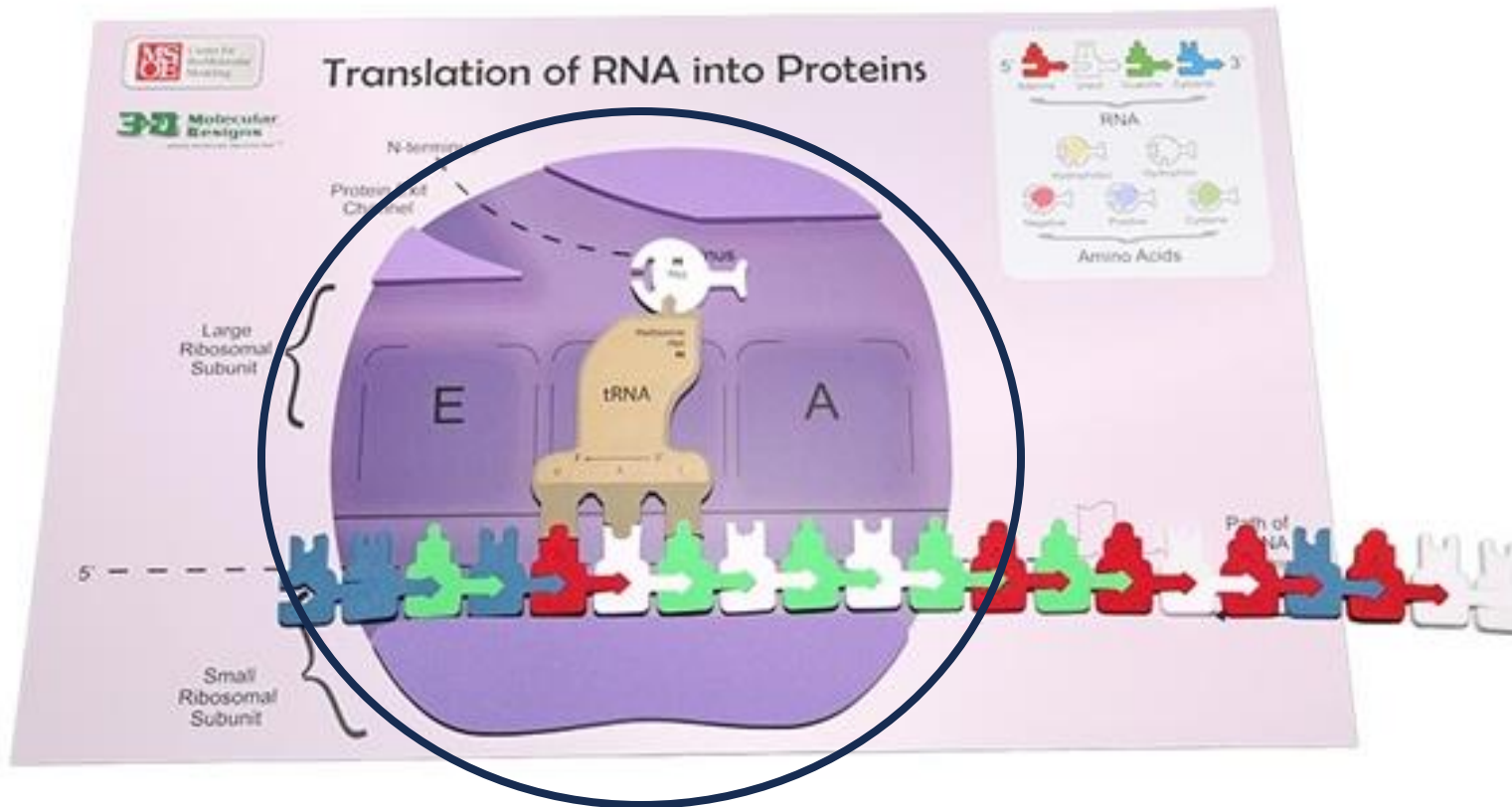
Comparing tRNA models



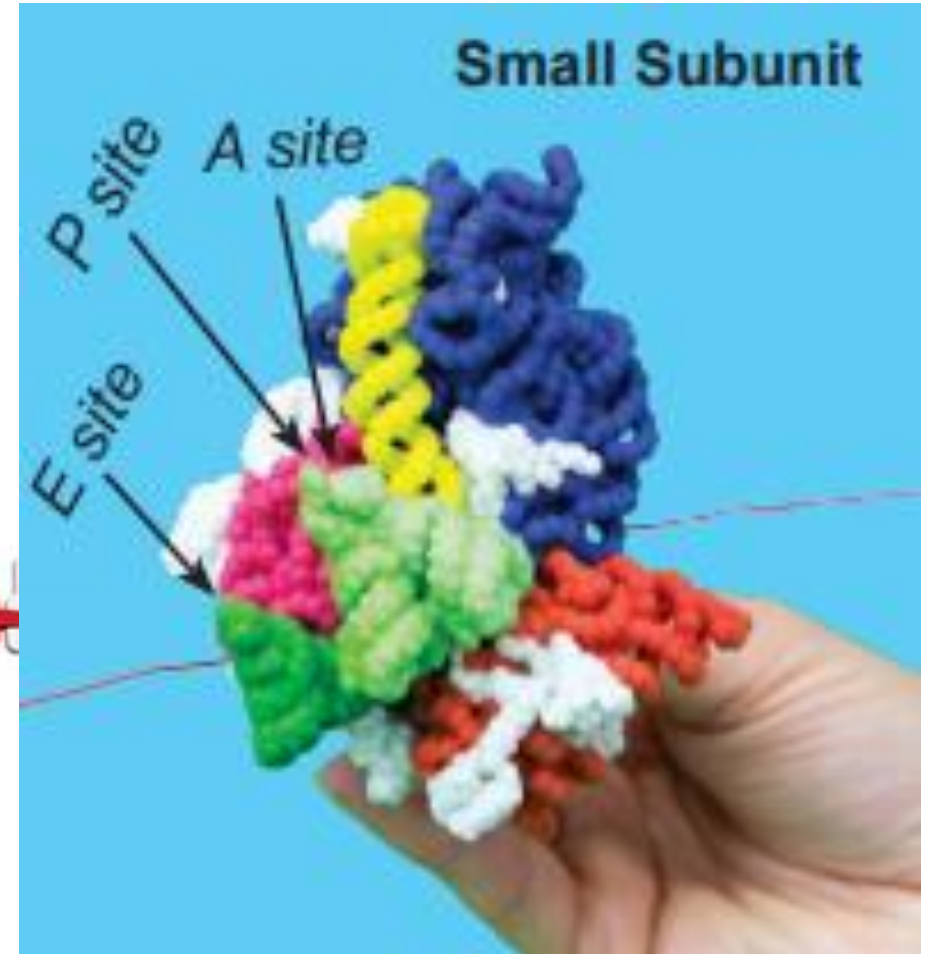
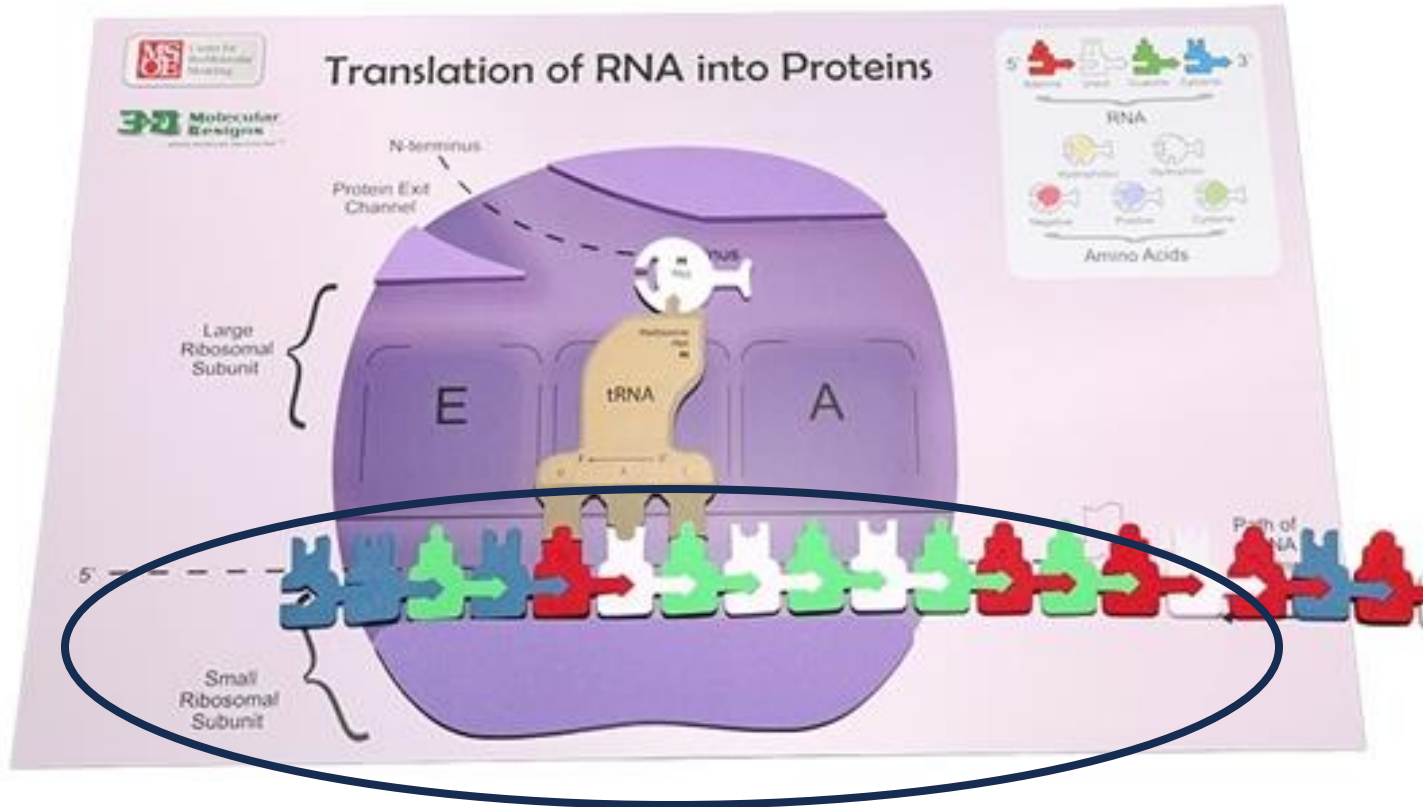
Comparing tRNA models



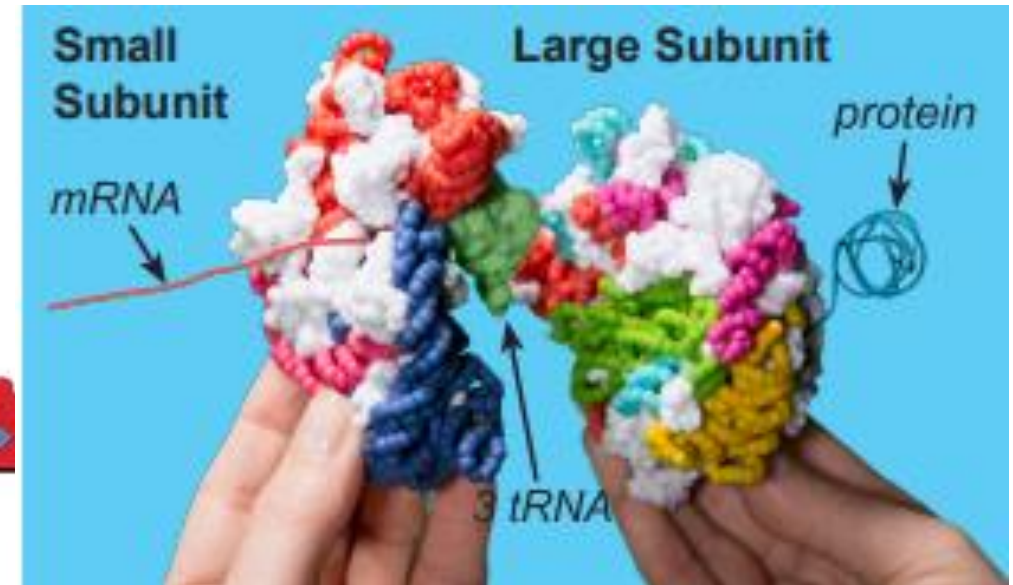
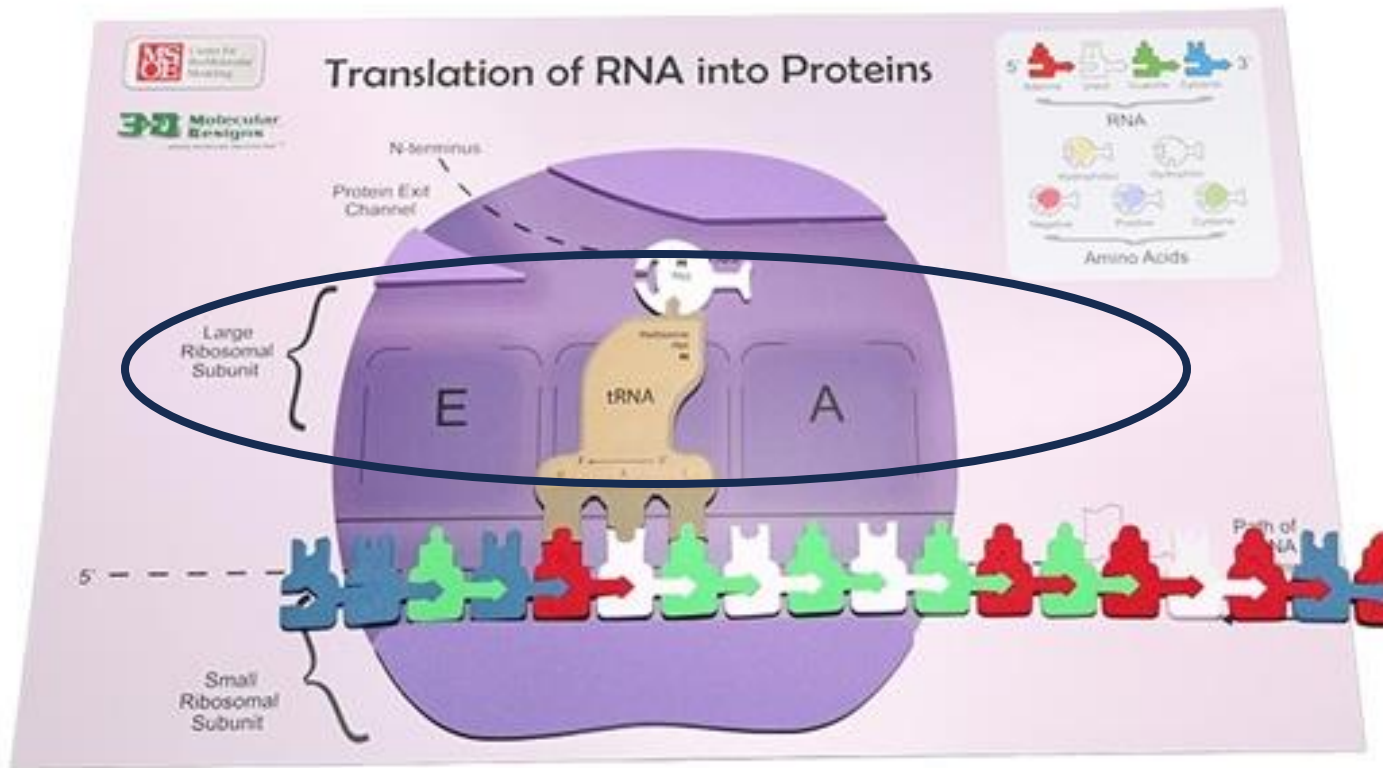
Ribosome-Ribosomal RNA and protein biological machine



Ribosome-Ribosomal RNA and protein biological machine



Ribosome-Ribosomal RNA and protein biological machine



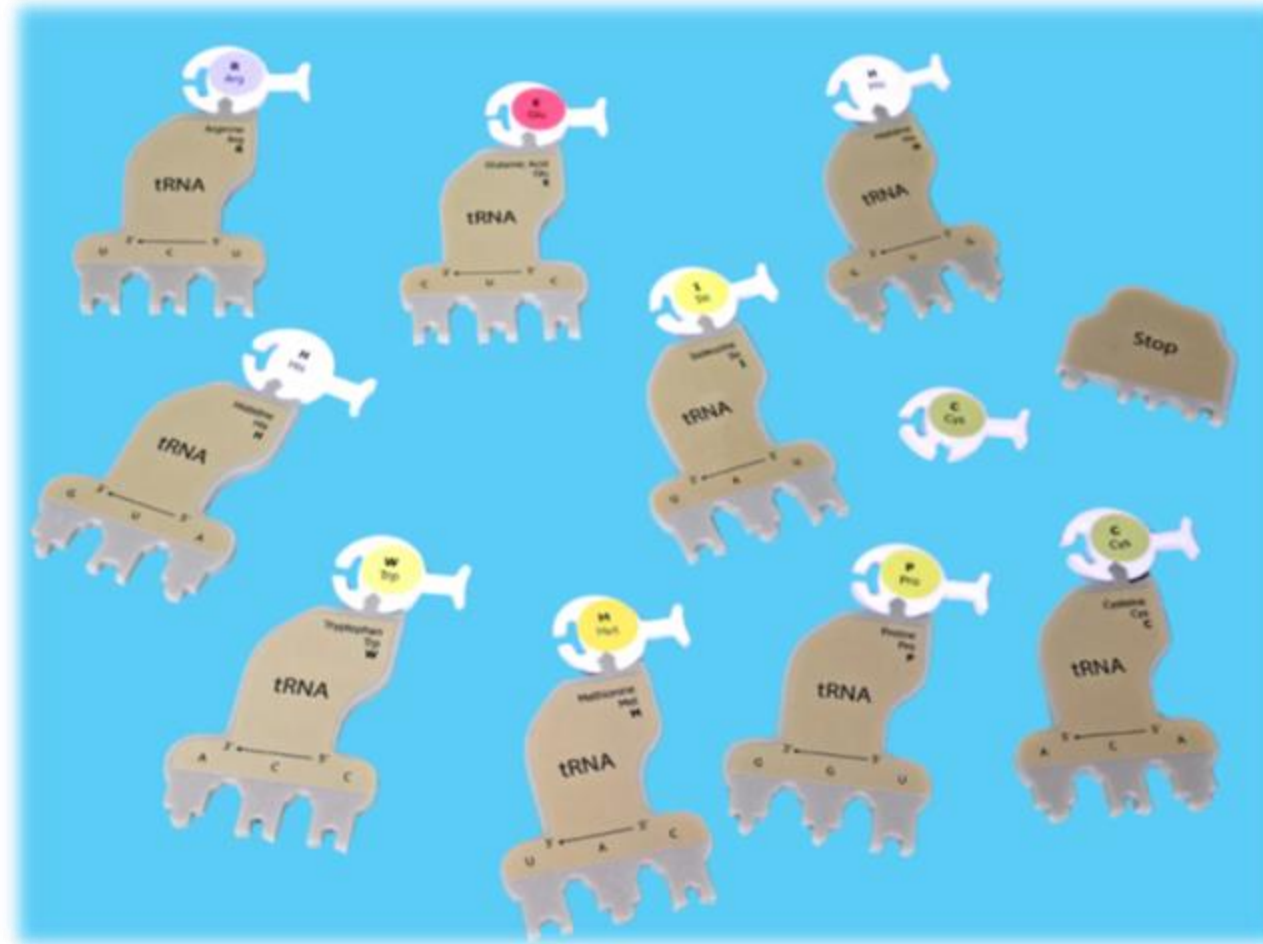
The Genetic Codon Chart®

	U	C	A	G	
U	UUU → Phe F UUC → Phe F UUA → Leu L UUG → Leu L	UCU → Ser S UCC → Ser S UCA → Ser S UCG → Ser S	UAU → Tyr Y UAC → Tyr Y UAA → Stop UAG → Stop	UGU → Cys C UGC → Cys C UGA → Stop UGG → Trp W	U C A G
C	CUU → Leu L CUC → Leu L CUA → Leu L CUG → Leu L	CCU → Pro P CCC → Pro P CCA → Pro P CCG → Pro P	CAU → His H CAC → His H CAA → Gln Q CAG → Gln Q	CGU → Arg R CGC → Arg R CGA → Arg R CGG → Arg R	U C A G
A	AUU → Ile I AUC → Ile I AUA → Ile I AUG → Met M	ACU → Thr T ACC → Thr T ACA → Thr T ACG → Thr T	AAU → Asn N AAC → Asn N AAA → Lys K AAG → Lys K	AGU → Ser S AGC → Ser S AGA → Arg R AGG → Arg R	U C A G
G	GUU → Val V GUC → Val V GUA → Val V GUG → Val V	GCU → Ala A GCC → Ala A GCA → Ala A GCG → Ala A	GAU → Asp D GAC → Asp D GAA → Glu E GAG → Glu E	GGU → Gly G GGC → Gly G GGA → Gly G GGG → Gly G	U C A G

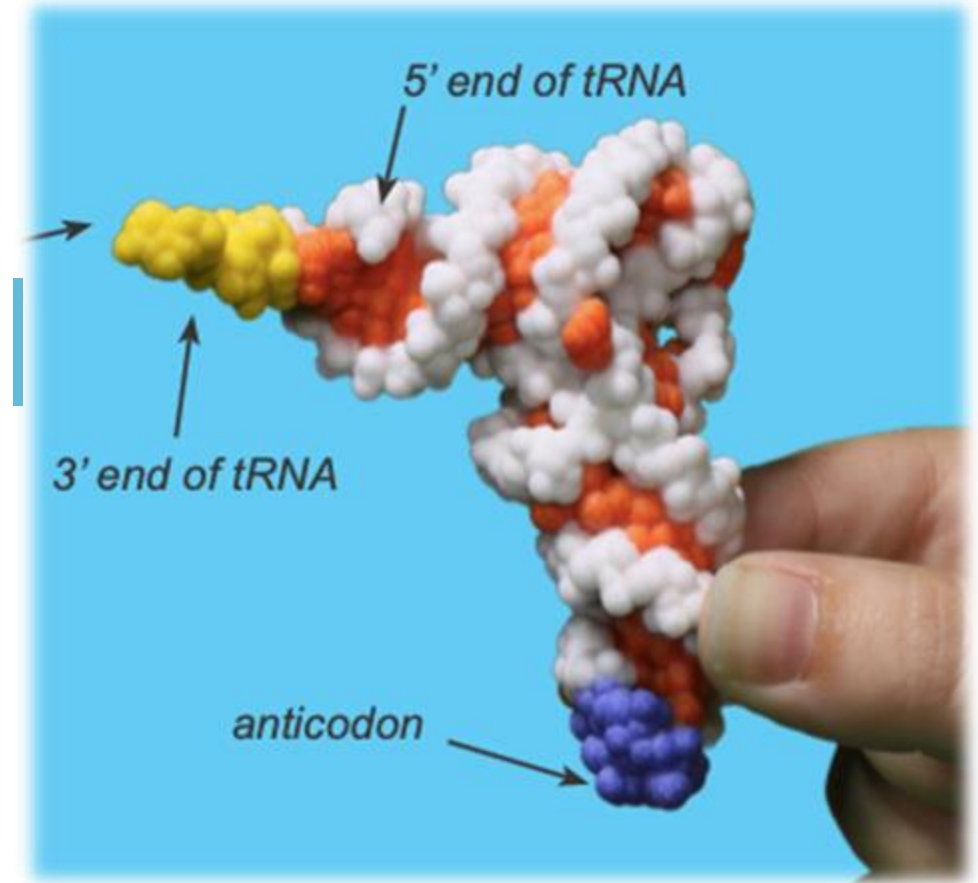
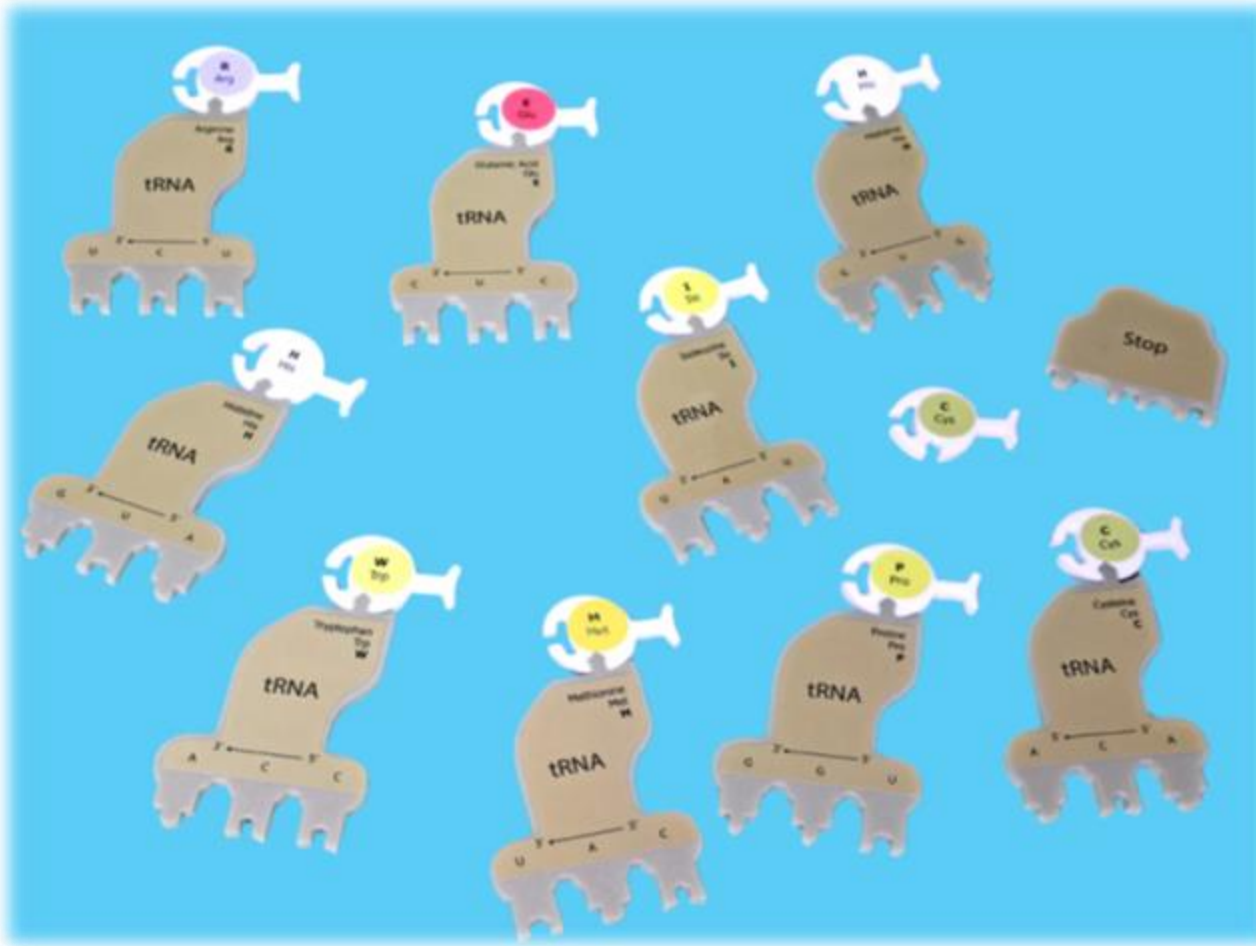
Amino Acid Properties

 Translation Start Codon	 Hydrophobic / Non-polar	 Negative Charge	 Cysteine
 Translation Stop Codon	 Hydrophilic / Polar	 Positive Charge	

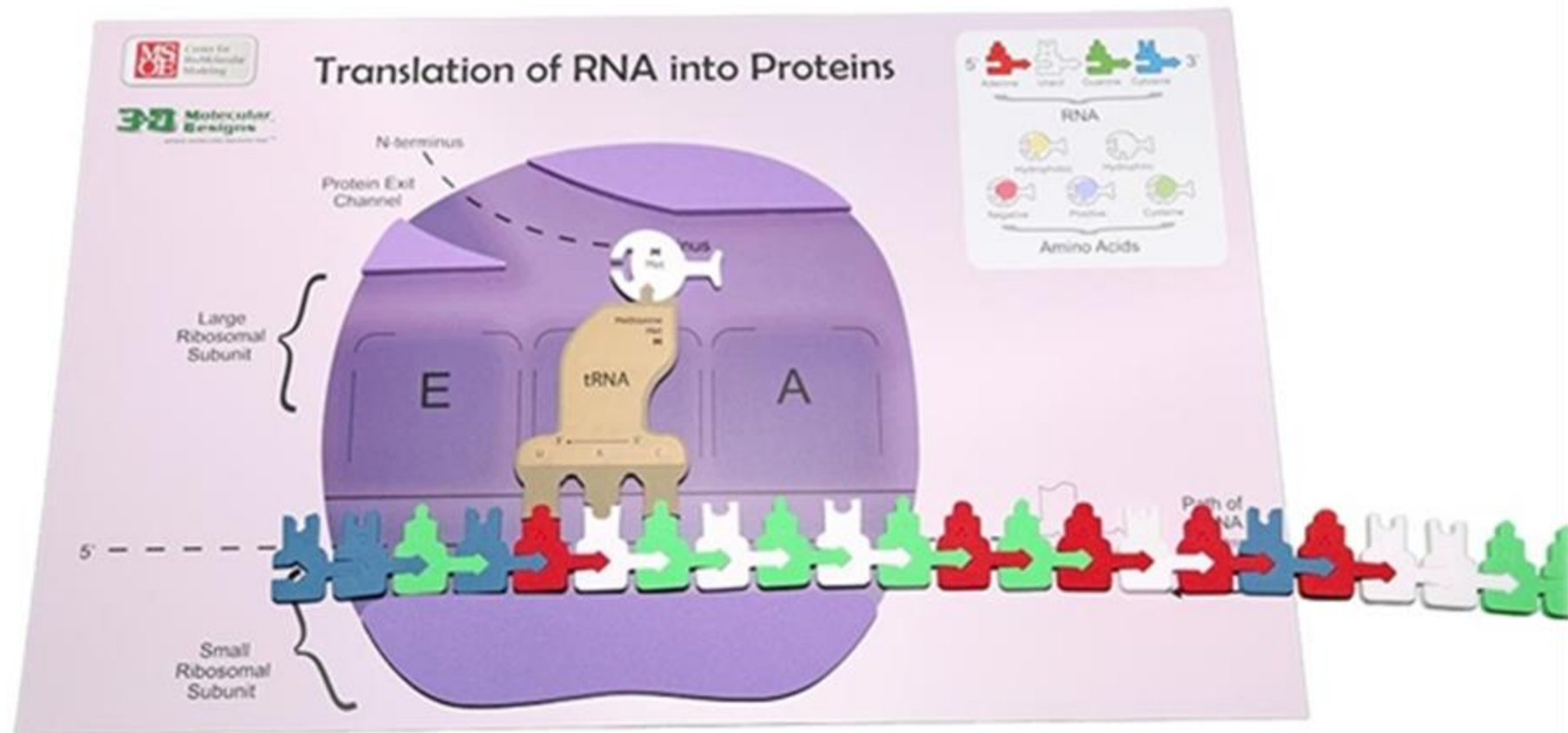
Pair the tRNA with the amino acids



A closer look at tRNAs



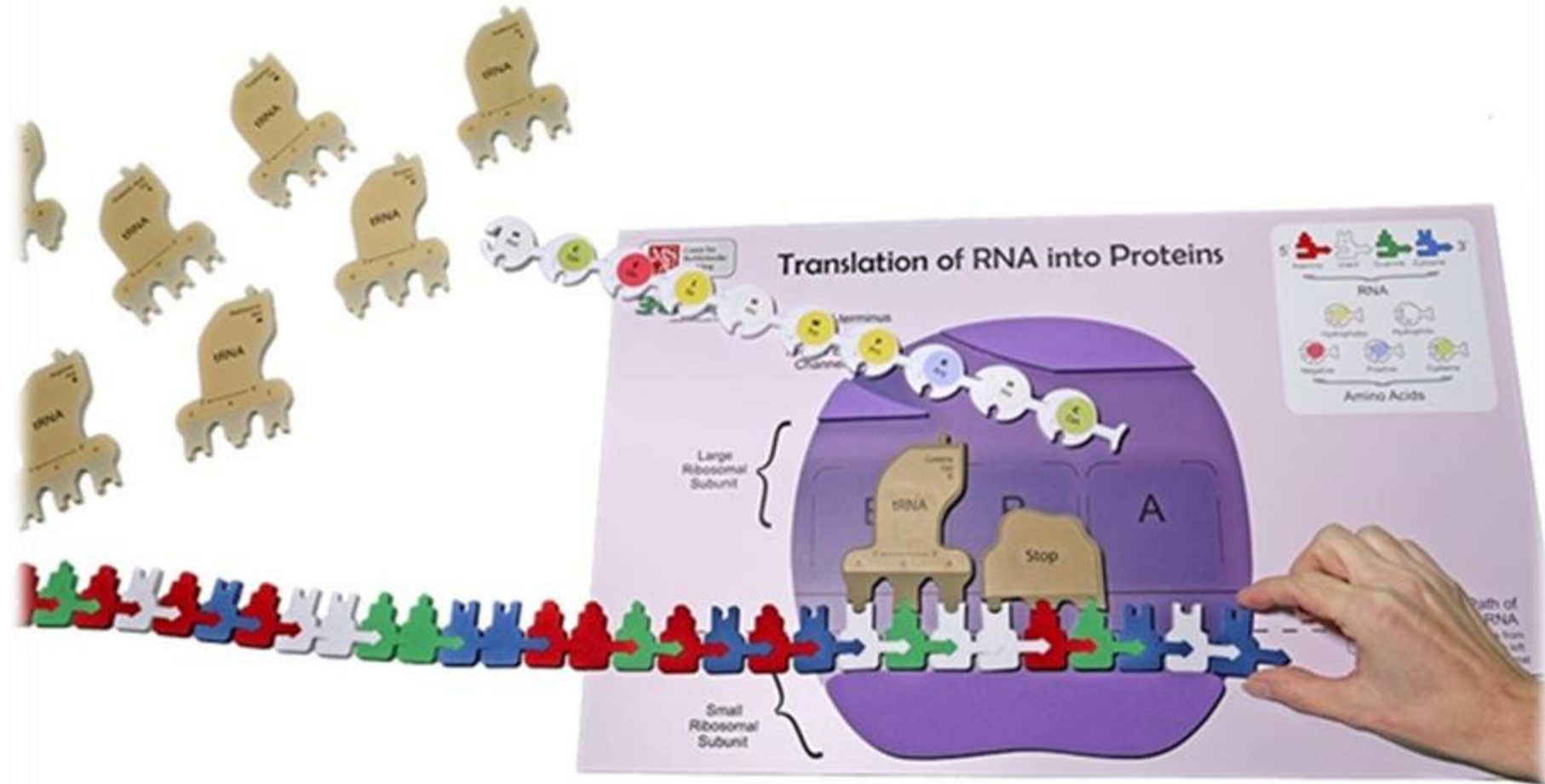
Translation: Initiation



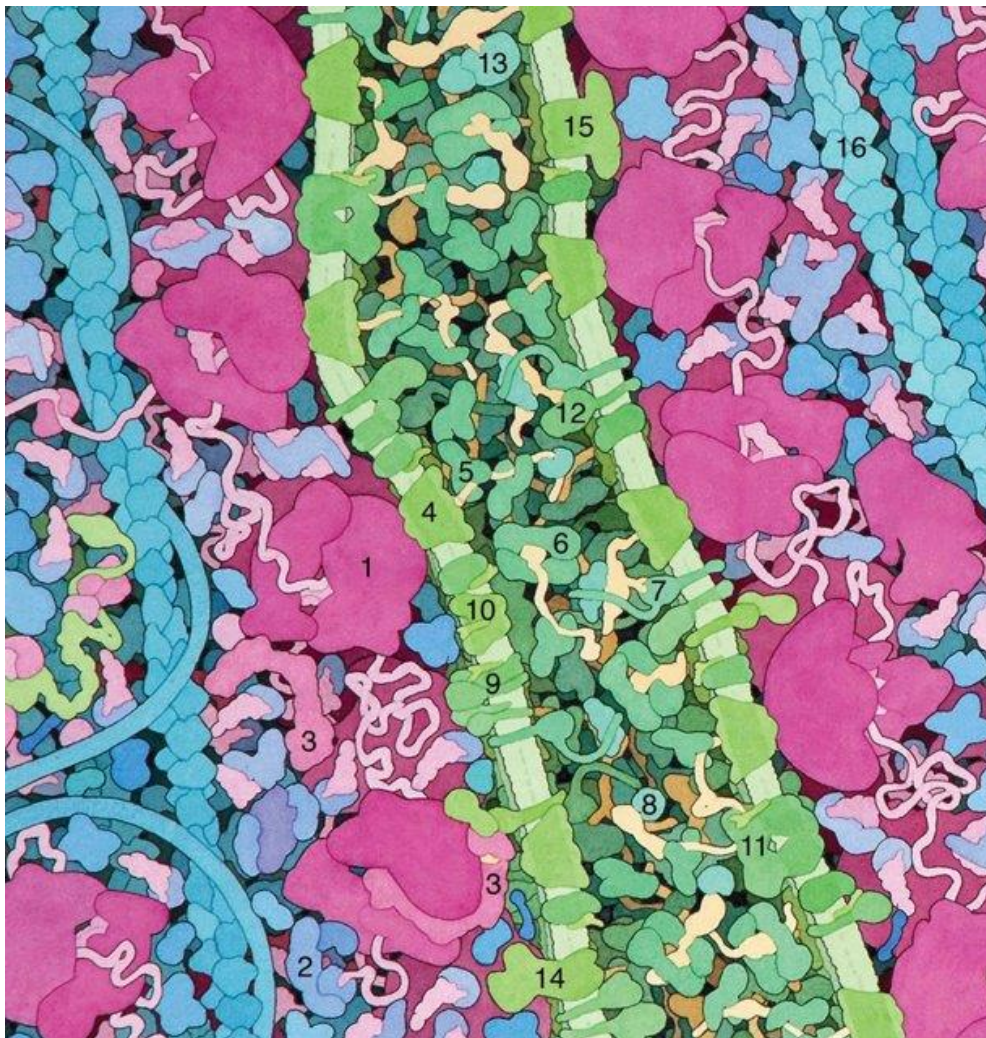
Translation: Elongation

The diagram illustrates the process of translation elongation. A large purple ribosome is shown with a small ribosomal subunit (bottom) and a large ribosomal subunit (top). The mRNA strand is threaded through the ribosome, with the 5' end on the left and the 3' end on the right. The mRNA is labeled with 5' and 3' ends. The ribosome is labeled with 'Large Ribosomal Subunit' and 'Small Ribosomal Subunit'. The mRNA is labeled with '5'' and '3'' ends. The ribosome is shown with a 'Protein Exit Channel' at the top. The growing polypeptide chain is shown as a string of colored beads (amino acids) emerging from the ribosome. The chain is labeled 'N-terminus' at the beginning and 'C-terminus' at the end. The amino acids are labeled with their names: Methionine (Met), Cysteine (Cys), Alanine (Ala), Glycine (Gly), Serine (Ser), Valine (Val), Leucine (Leu), Isoleucine (Ile), Threonine (Thr), Proline (Pro), Aspartic Acid (Asp), Glutamic Acid (Glu), Lysine (Lys), Arginine (Arg), Histidine (His), Phenylalanine (Phe), Tyrosine (Tyr), and Tryptophan (Trp). The amino acids are shown in various colors: red, green, blue, yellow, orange, and purple. The ribosome is shown with a 'tRNA' molecule (transfer RNA) carrying the growing polypeptide chain. The tRNA is labeled with 'tRNA' and 'A' (acceptor stem). The tRNA is shown with a '3'' end. The ribosome is shown with a 'Protein Exit Channel' at the top. The growing polypeptide chain is shown as a string of colored beads (amino acids) emerging from the ribosome. The chain is labeled 'N-terminus' at the beginning and 'C-terminus' at the end. The amino acids are labeled with their names: Methionine (Met), Cysteine (Cys), Alanine (Ala), Glycine (Gly), Serine (Ser), Valine (Val), Leucine (Leu), Isoleucine (Ile), Threonine (Thr), Proline (Pro), Aspartic Acid (Asp), Glutamic Acid (Glu), Lysine (Lys), Arginine (Arg), Histidine (His), Phenylalanine (Phe), Tyrosine (Tyr), and Tryptophan (Trp). The amino acids are shown in various colors: red, green, blue, yellow, orange, and purple.

Translation: Termination



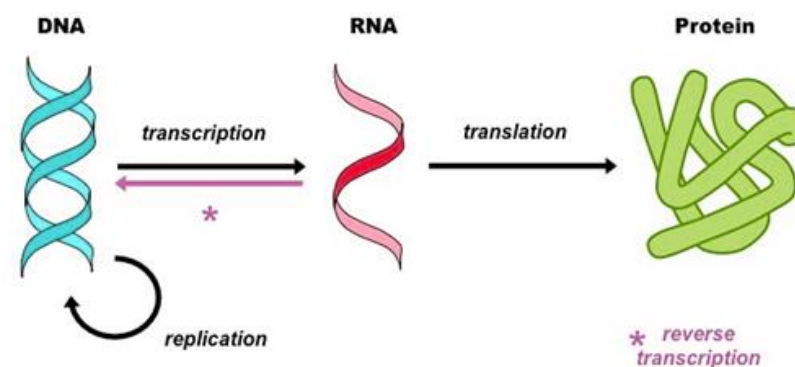
Revisit the panorama



Let's review

DNA Base	RNA Base
T	A
G	C
C	G
A	U
C	G
A	U

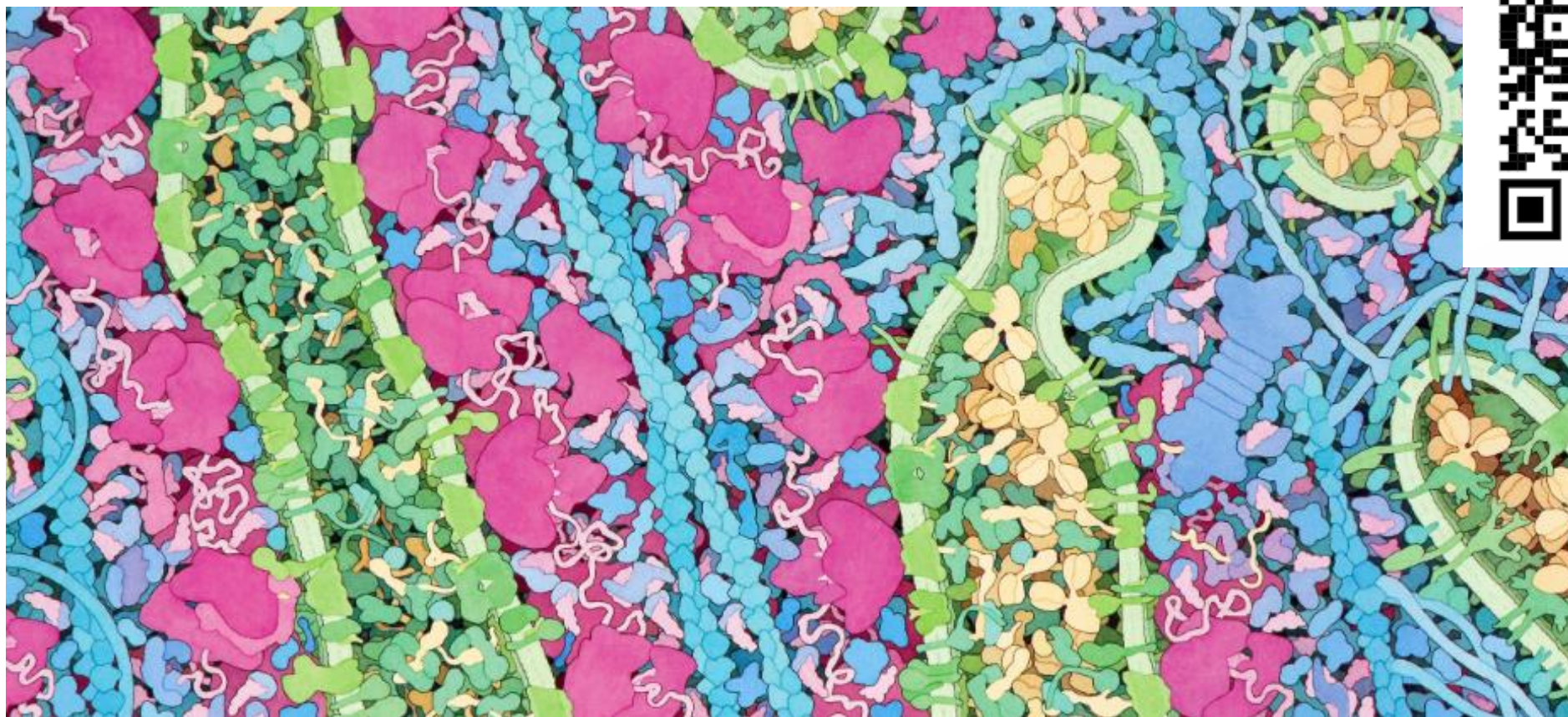
CENTRAL DOGMA



DNA and RNA



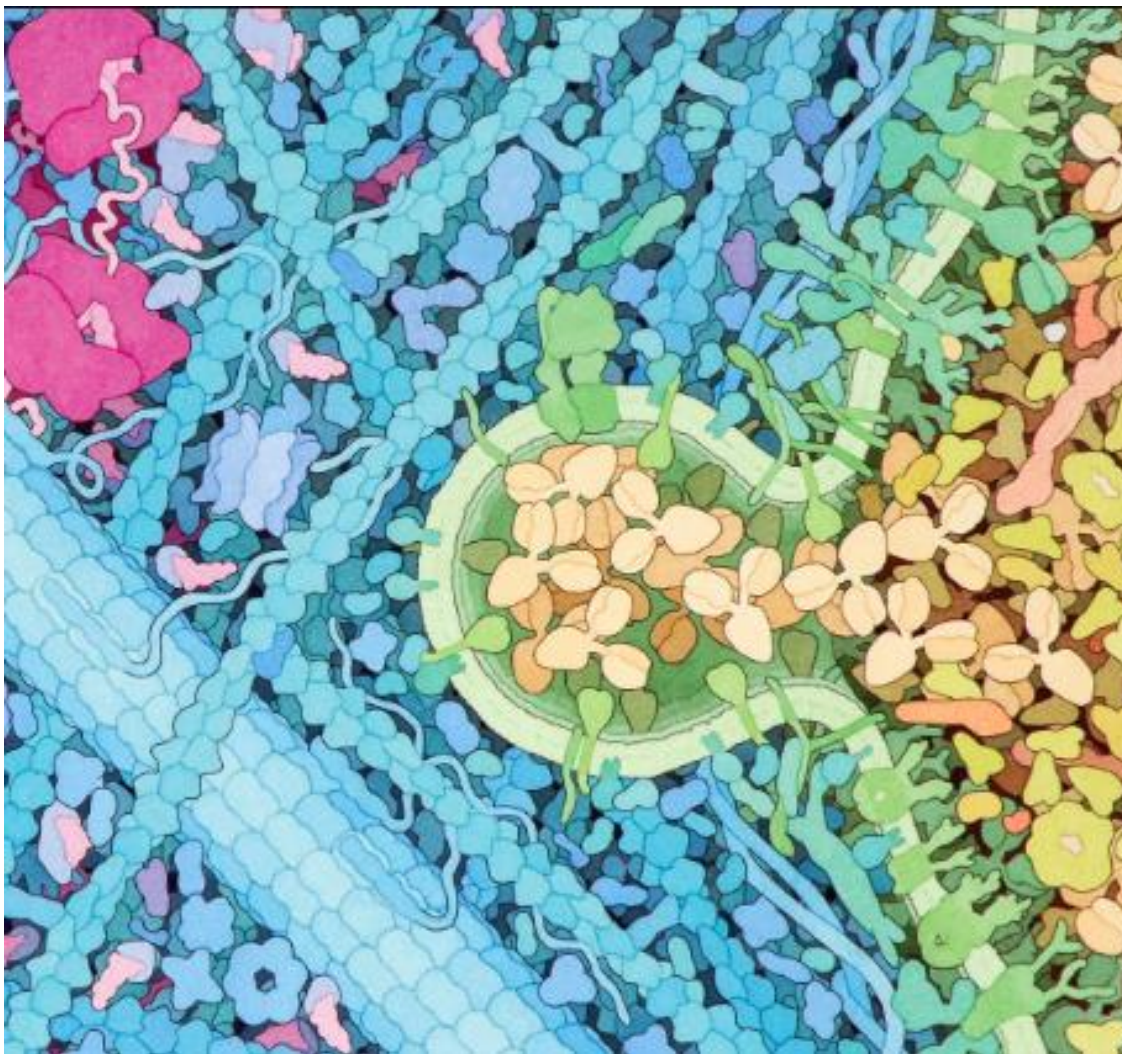
Revisit the panorama



Revisit the panorama



Revisit the panorama



Helpful resources

- [Tracking the Resolution of Student Misconceptions about the Central Dogma of Molecular Biology - PubMed \(nih.gov\)](#)
- [DNA → RNA: What Do Students Think the Arrow Means? - PMC \(nih.gov\)](#)
- [What's in a cell? — young people's understanding of the genetic relationship between cells, within an individual: Journal of Biological Education: Vol 34, No 3 \(tandfonline.com\)](#)
- [Teaching More by Lecturing Less | CBE—Life Sciences Education \(lifescied.org\)](#)



Additional Resources

- [Quentin Vicens and Jeffrey S. Kieft. 2022. PNAS. Thoughts on how to think \(and talk\) about RNA structure.](#)
- [Anna Marie Pyle \(Yale U./HHMI\) Part 1: RNA Structure – YouTube.](#)
- [Eukaryotic cell panorama - Goodsell - 2011 - Biochemistry and Molecular Biology Education - Wiley Online Library](#)

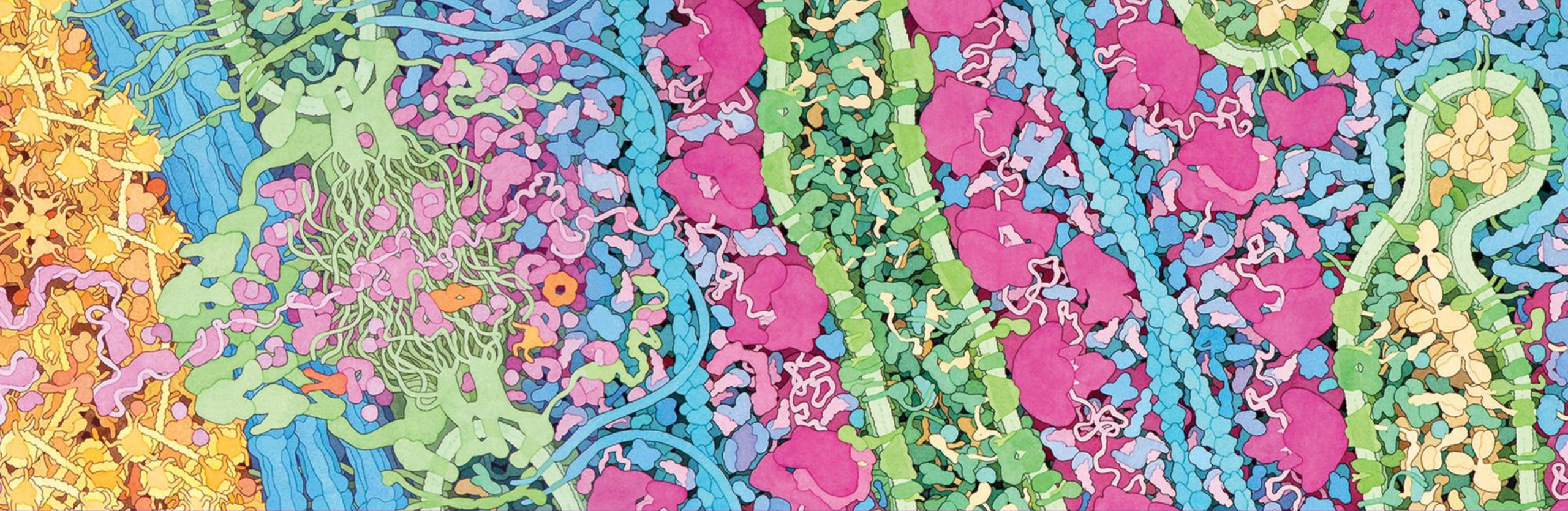
Workshop NGSS Connections

SEPs	CCCs	DCIs
Using Mathematics and Computational Thinking	Scale, Proportion, and Quantity	5-PS1-2
Developing and Using Models	Patterns	MS-PS1-1
Planning and Carrying Out Investigations		HS-PS1-3

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Let us know what you
think.

Scan the QR
Code and
complete this
short survey.





3d molecular
designs

Transforming Science Learning