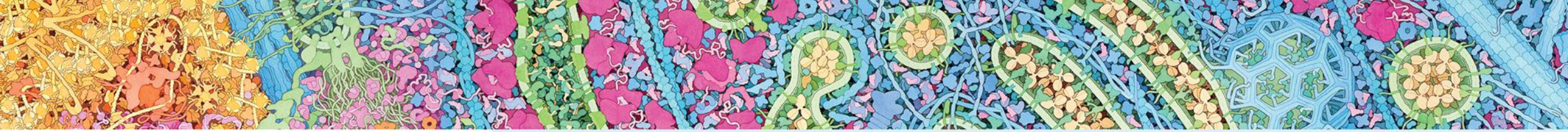


3d molecular designs
Transforming Science Learning

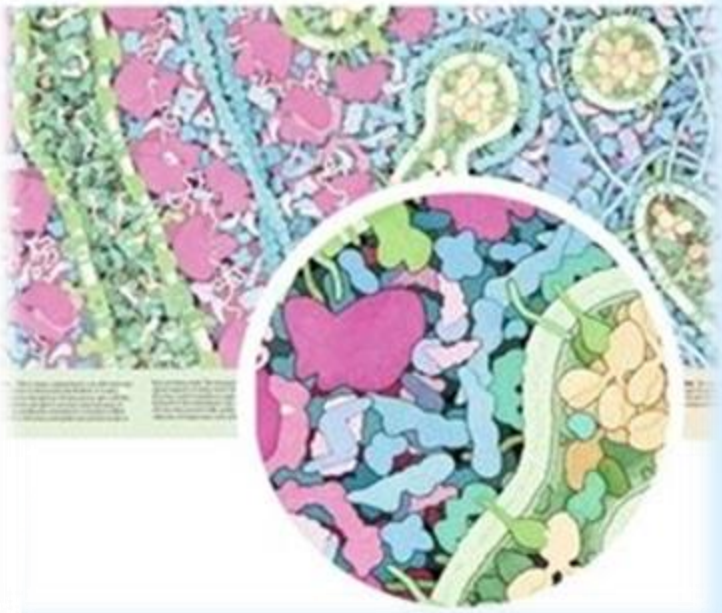
The view from 1,000,000X: a tour of the human cell

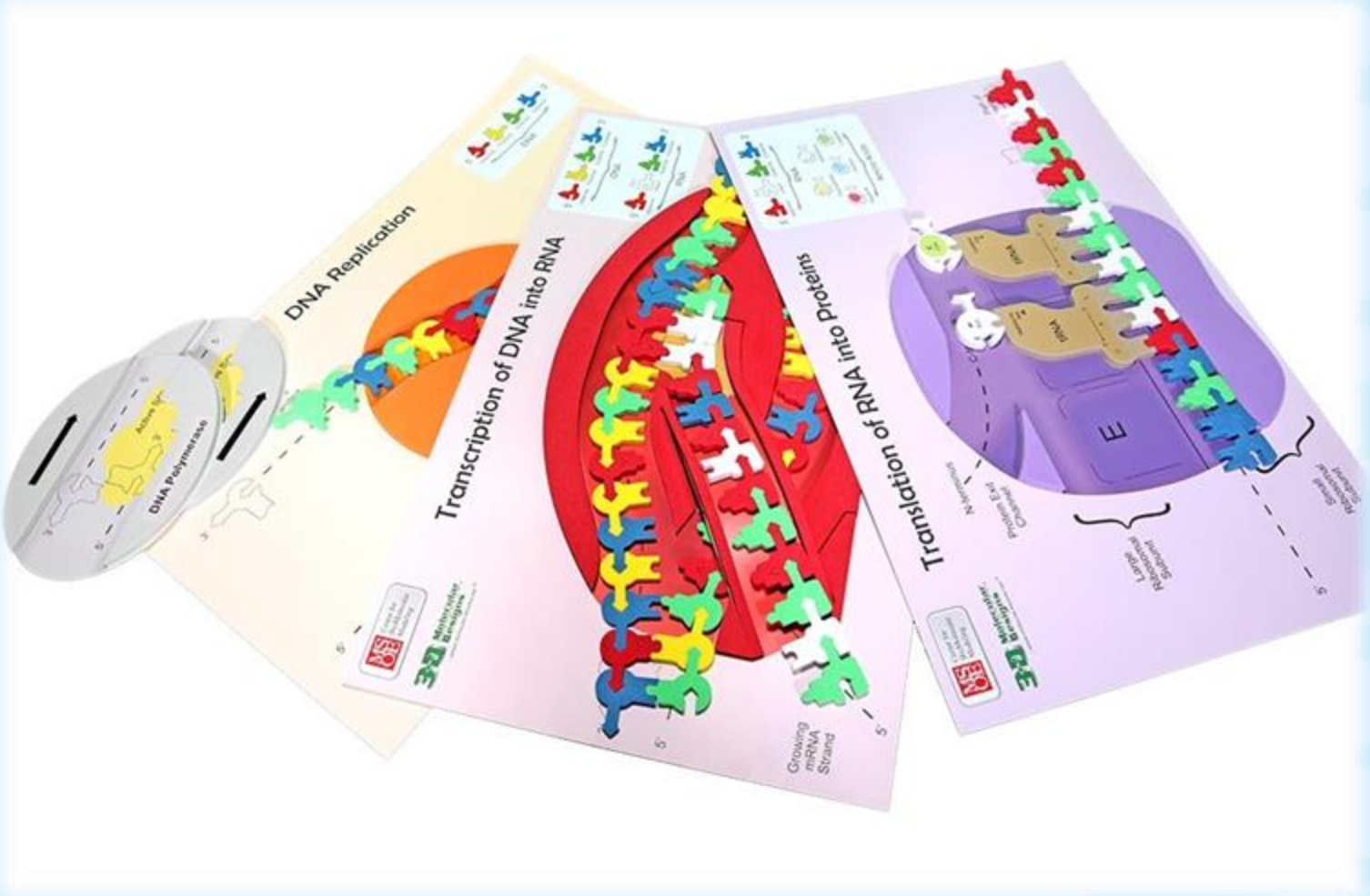
Ruth Hutson, MSSE

CAST-Houston 2023

3d molecular designs

Transforming Science Learning

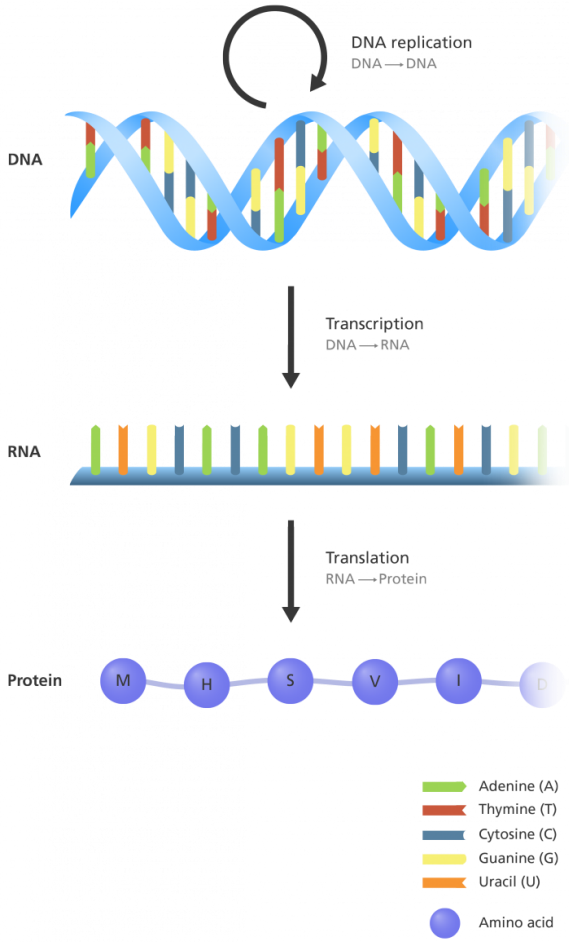




Workshop Outcomes

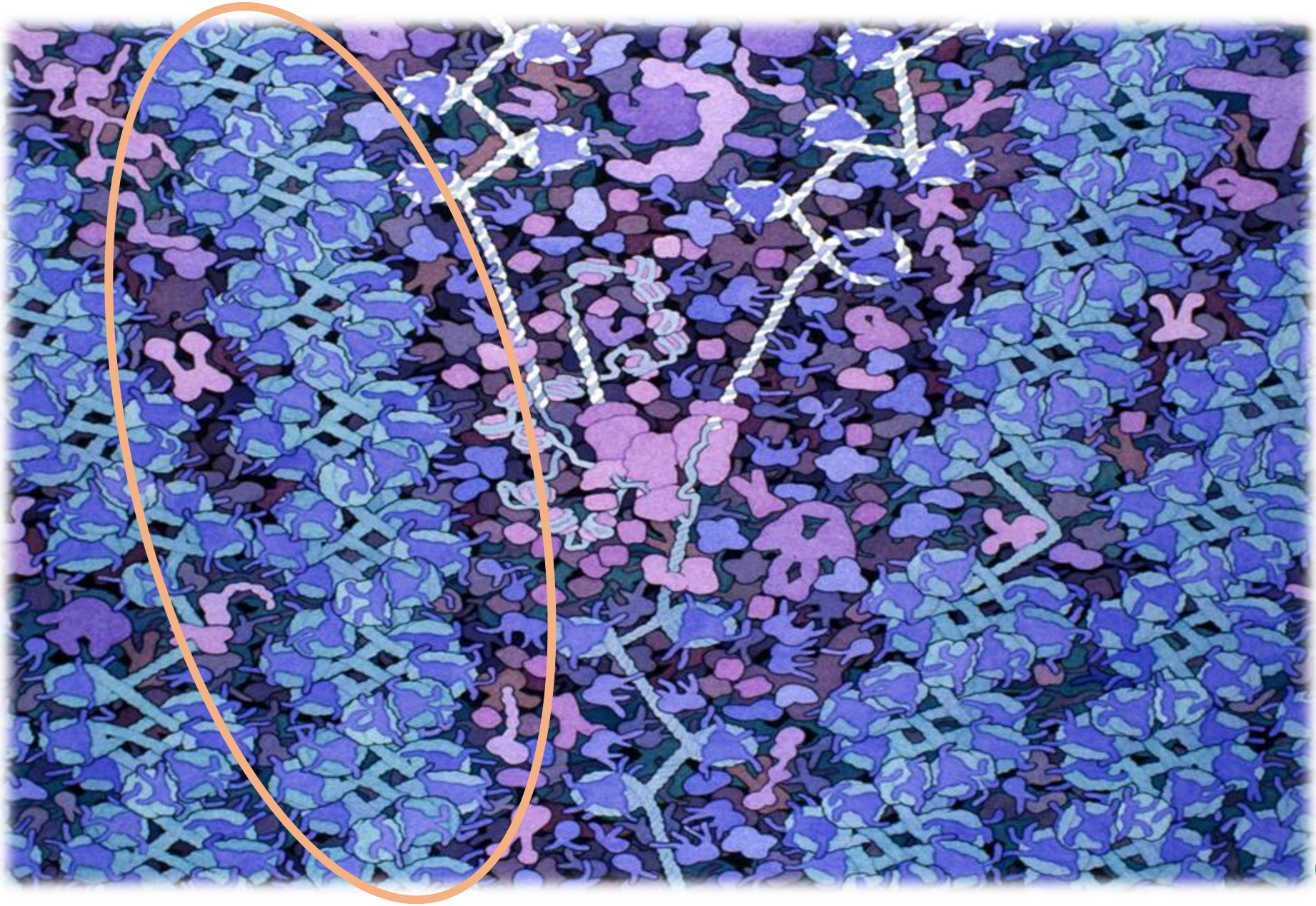
- Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins, which carry out the essential functions of life through systems of specialized cells by explaining the purpose and process of replication, transcription, and translation using models of DNA 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?

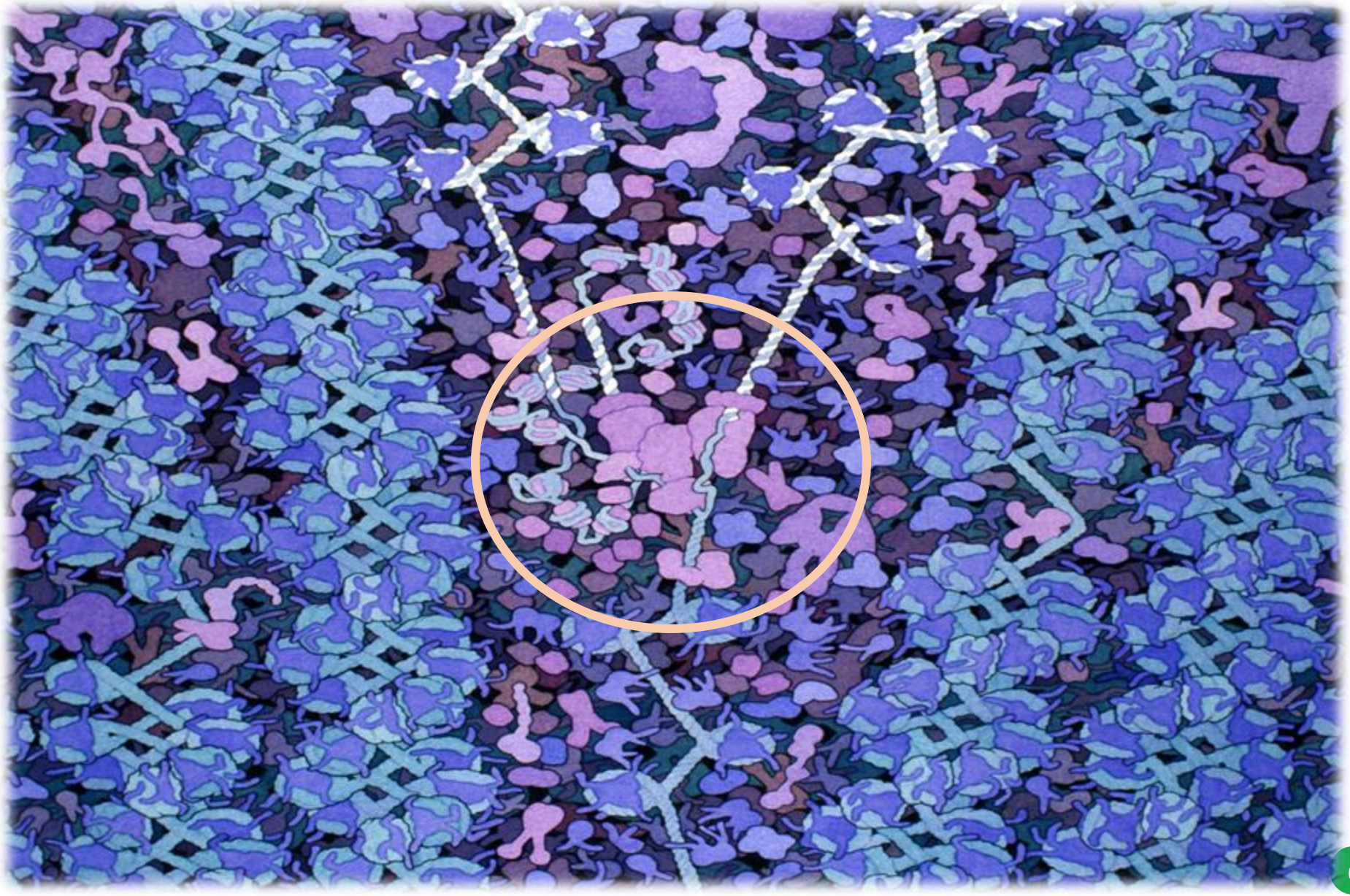


- Don’t understand how the processes are related.
- Don’t understand the relevance to their own body.
- All the vocabulary!

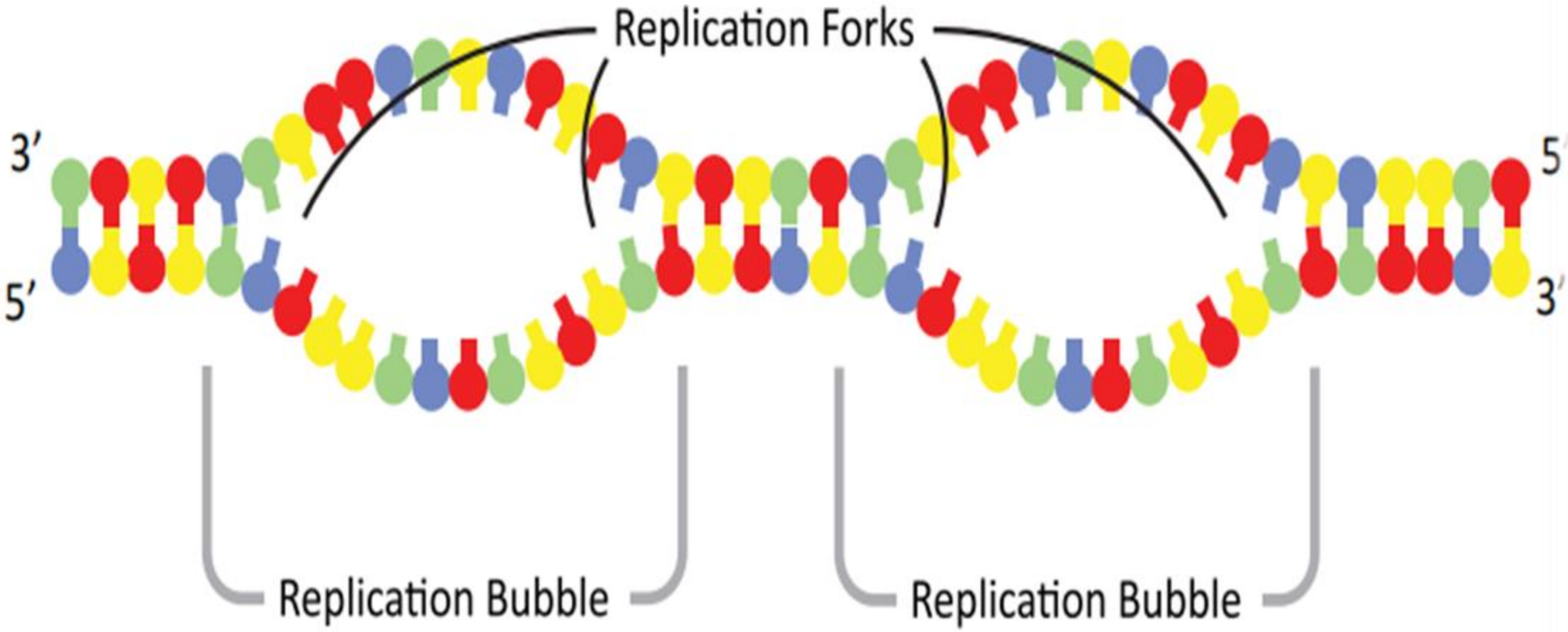
Replication in the Eukaryotic Nucleus



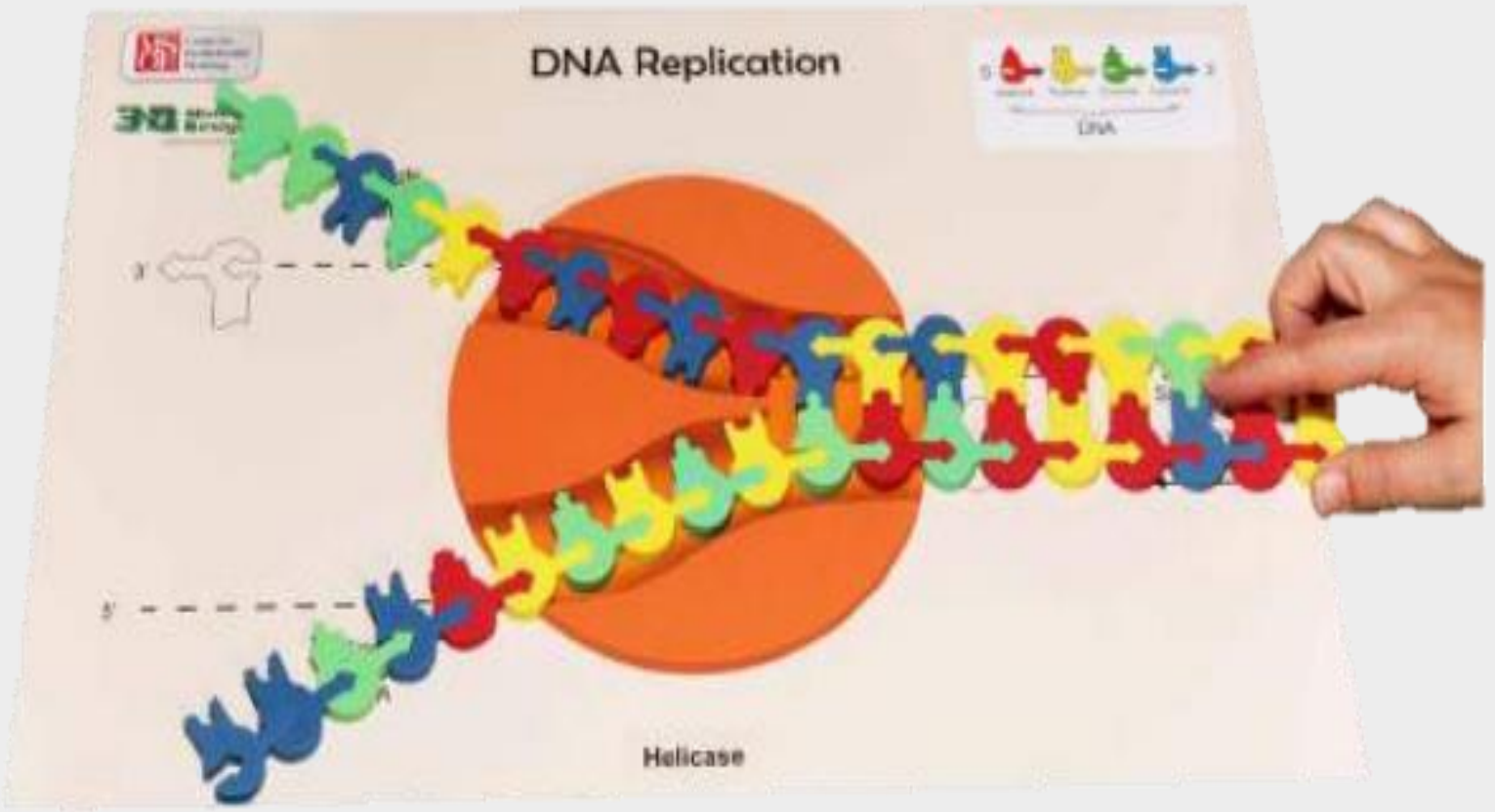
Replication in the Eukaryotic Nucleus



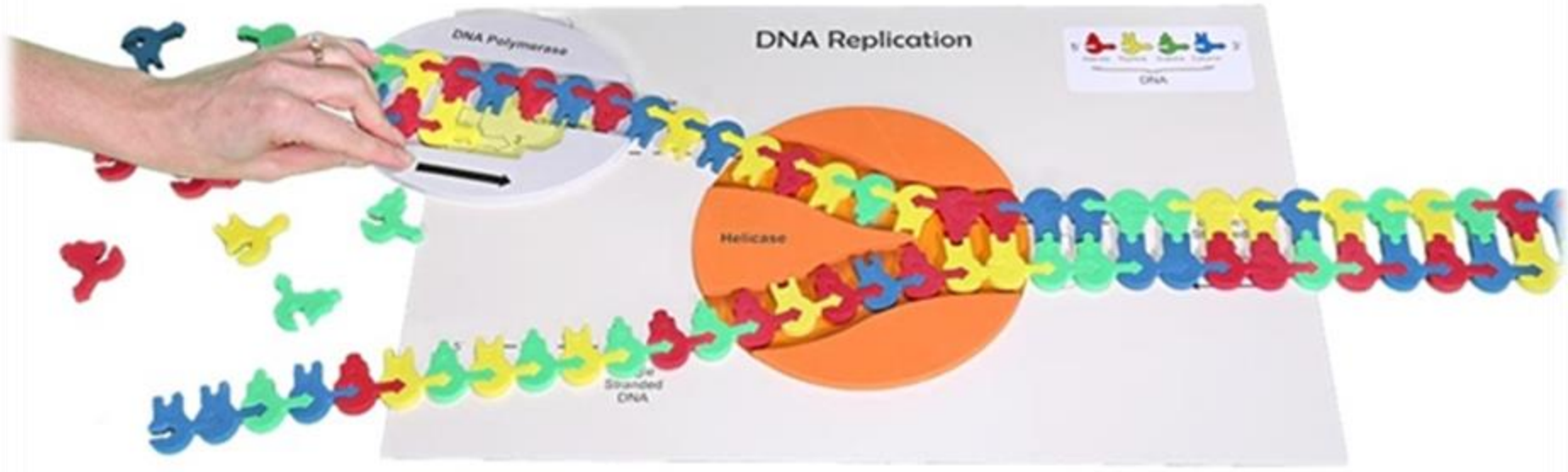
Replication Forks



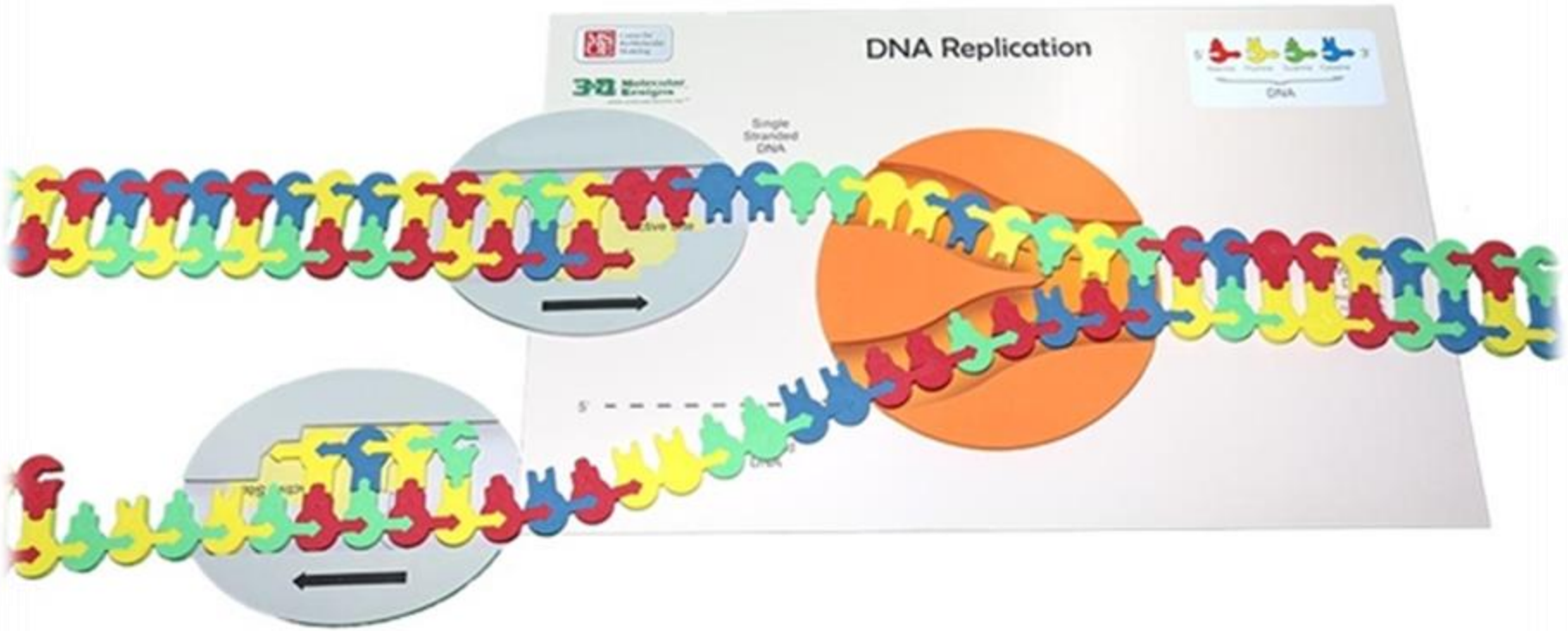
Replication



Continuous Replication



Discontinuous Replication



Comparing Leading and Lagging Strands

Template

Non-template

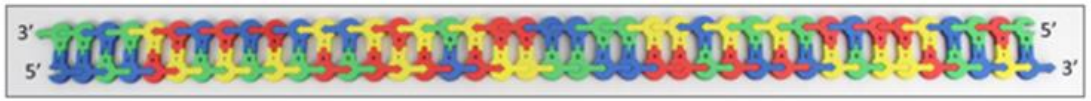
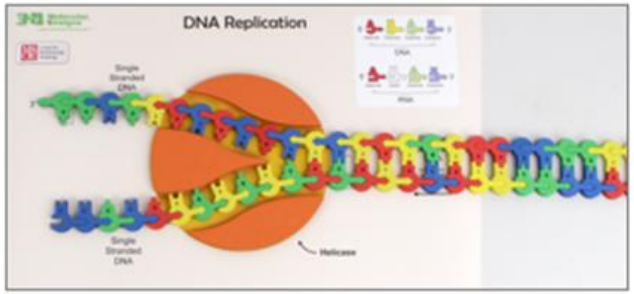


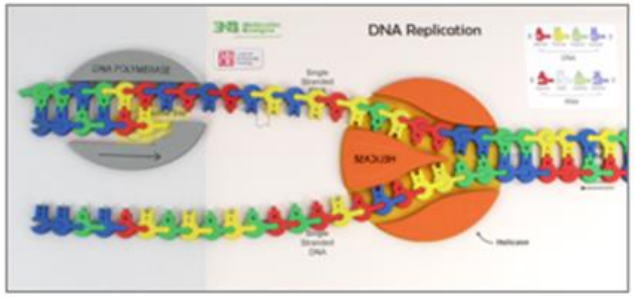
Diagram 1



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′ → 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

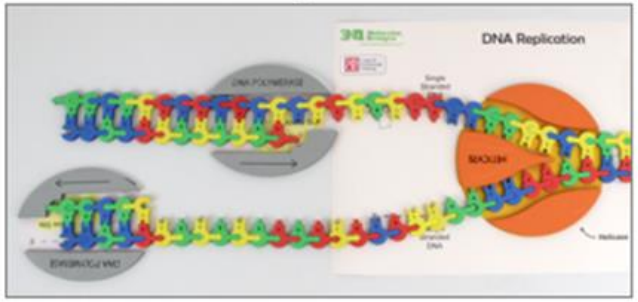
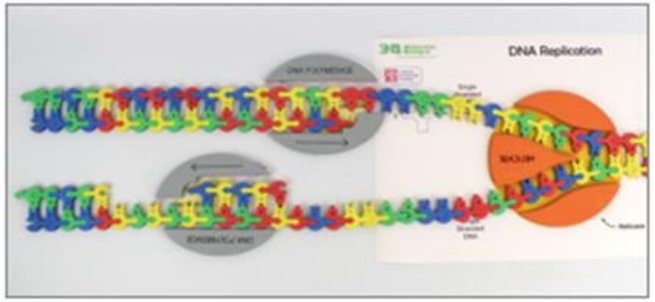
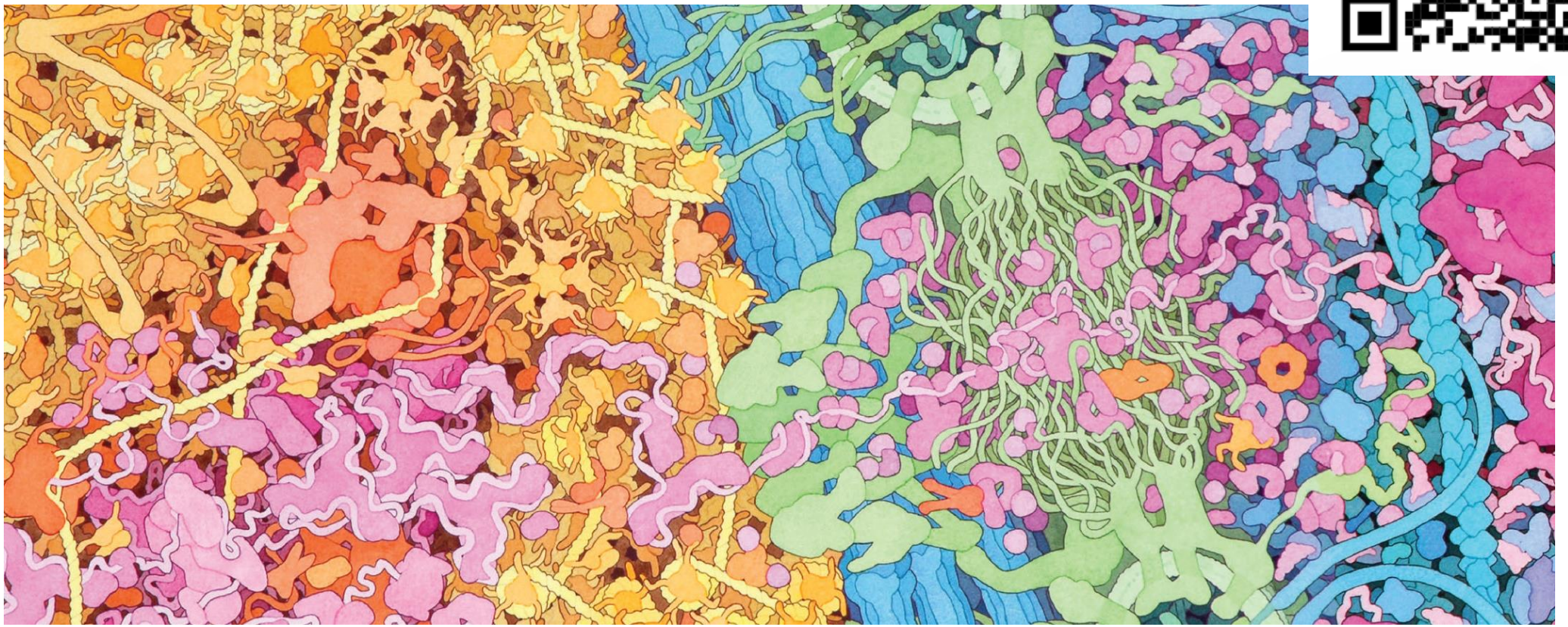


Diagram 4



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′ → 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



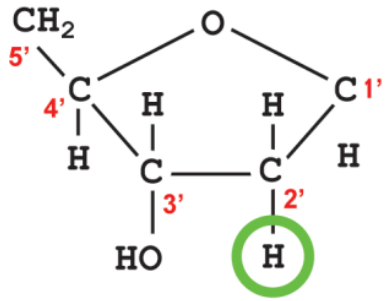
This image is an excerpt from Tour of a Human Cell by David Goodsell, as shown in 3D Molecular Designs' Tour of a Human Cell© poster and David Goodsell's book, ***The Machinery of Life.***

Transcription

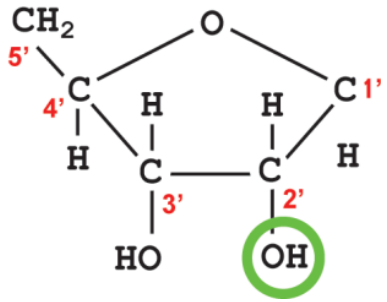
DNA

RNA

Deoxyribose
found in DNA



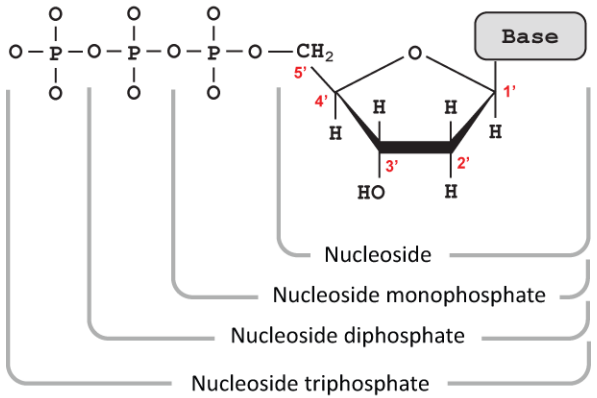
Ribose
found in RNA

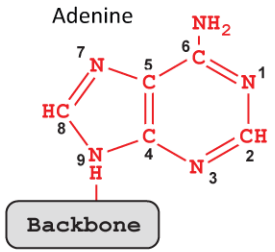


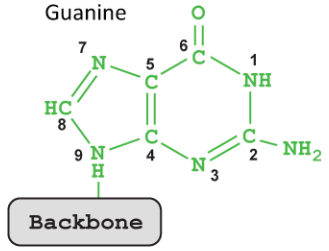
Helpful Hint:

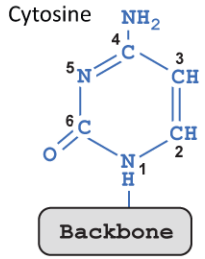
The DNA pieces are different than the RNA pieces!

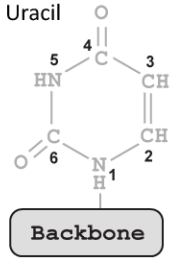
Transcription

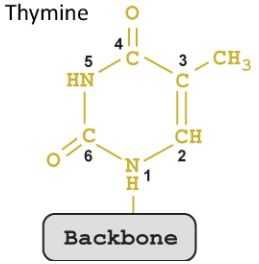


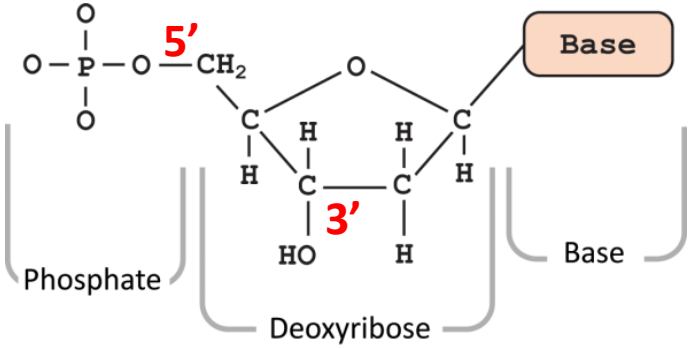


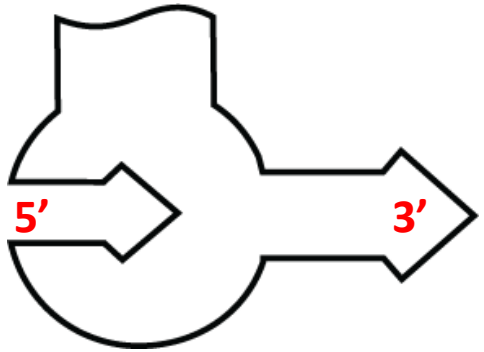










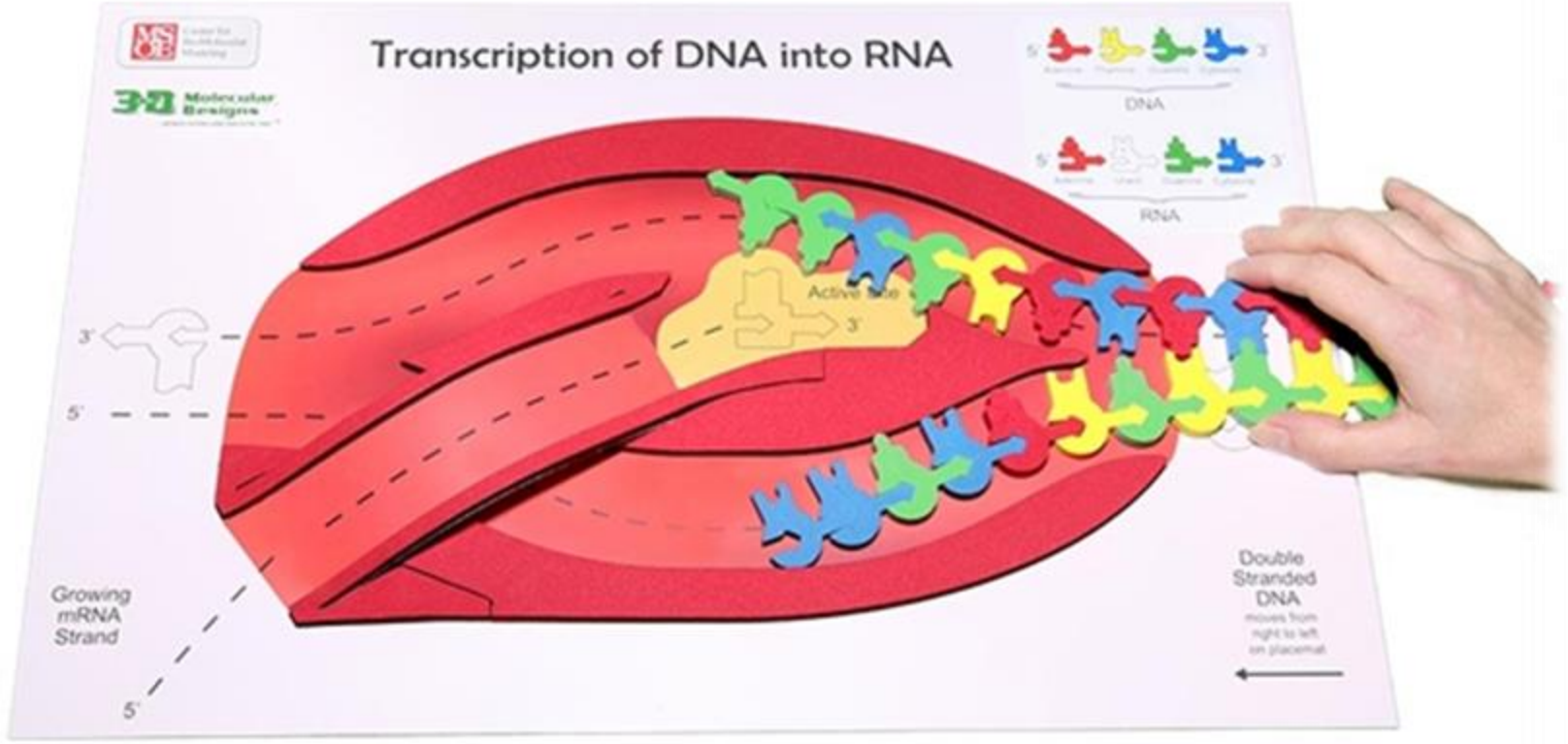


Helpful Hints:

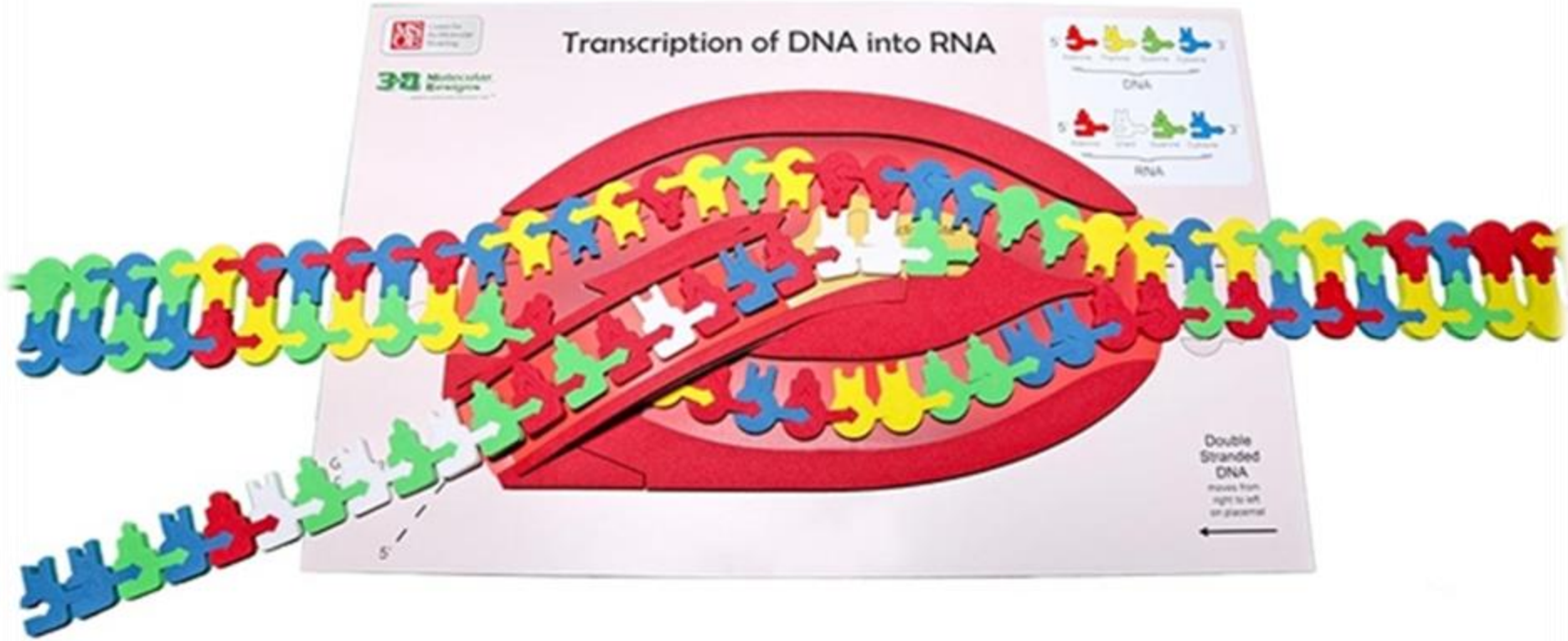
Take care in loading the DNA in the RNA polymerase.

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

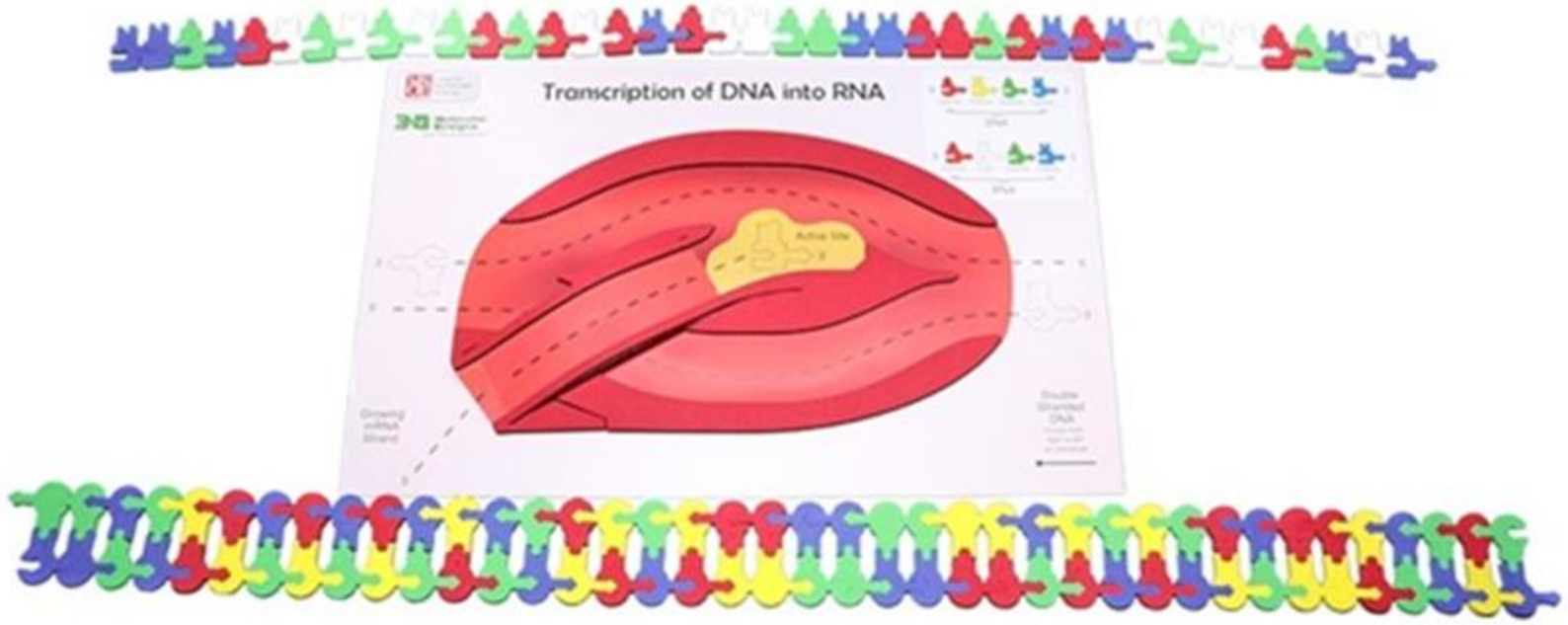
Transcription: Initiation



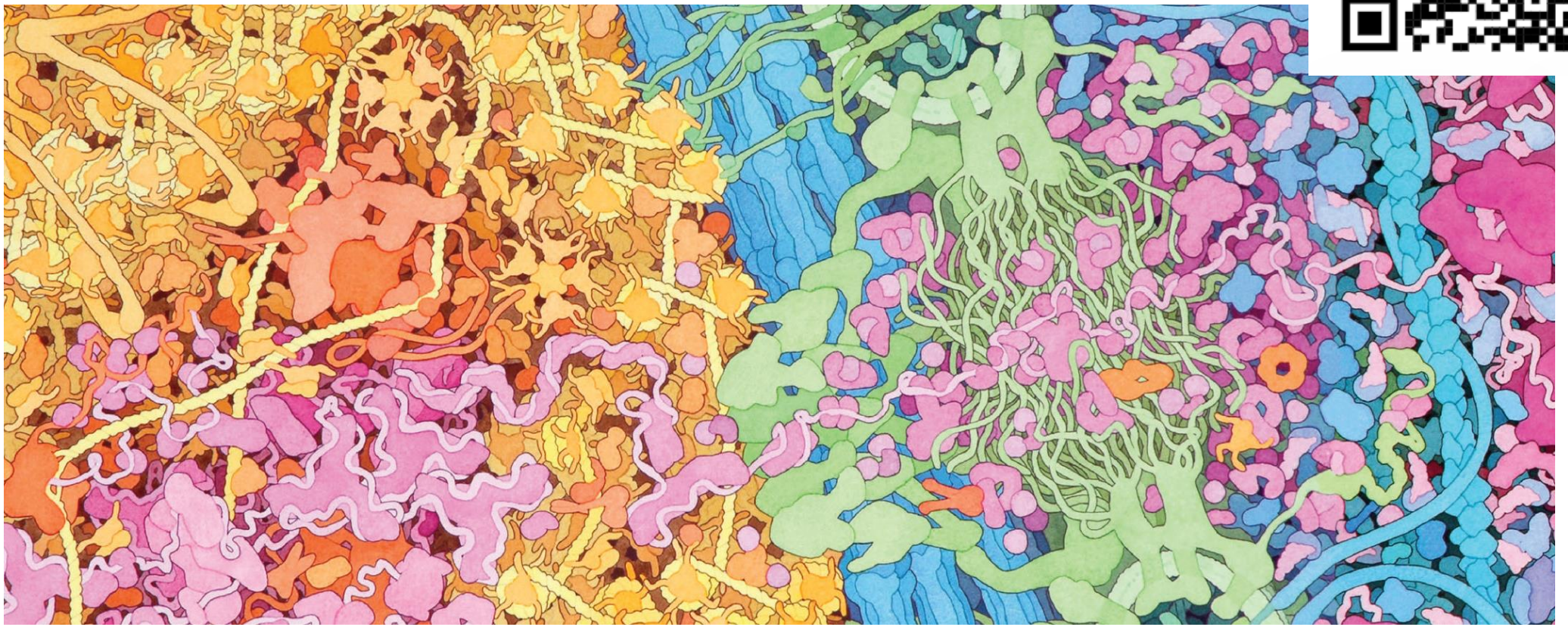
Transcription: Elongation



Transcription: Termination



A brief tour through the cell

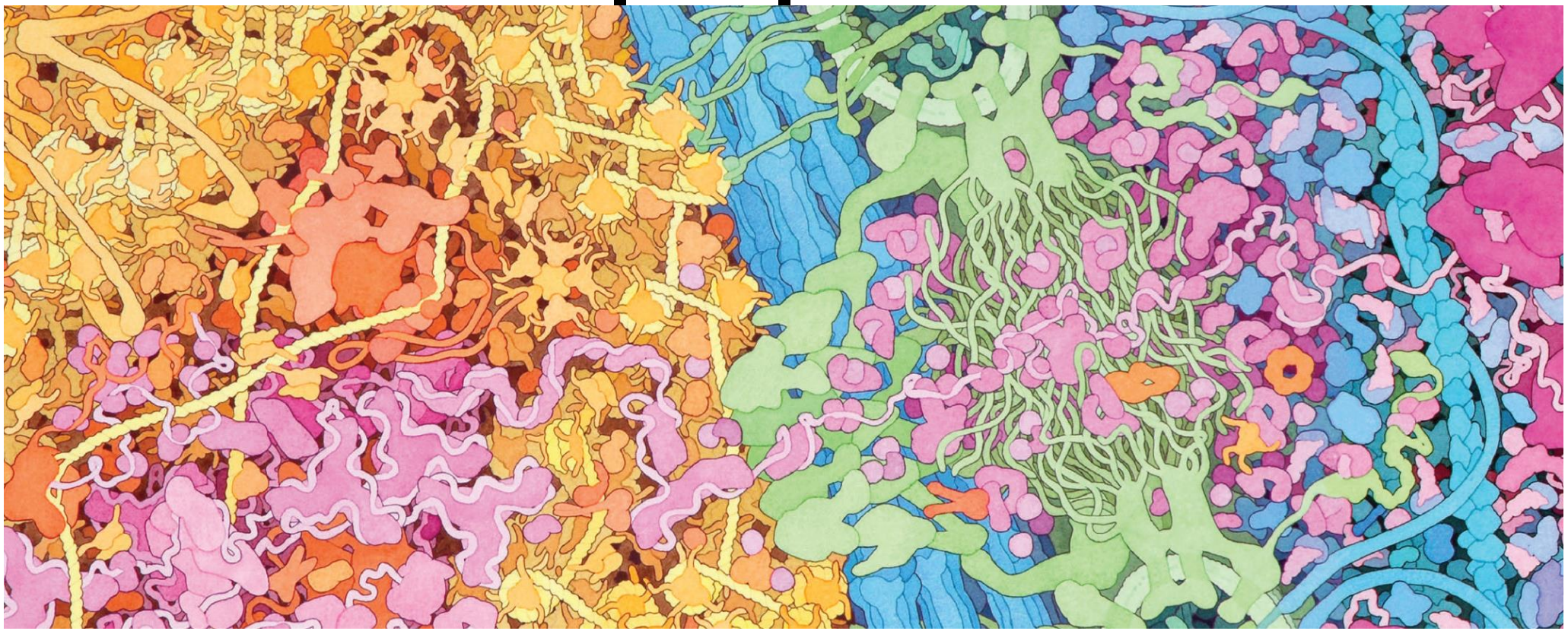


This image is an excerpt from Tour of a Human Cell by David Goodsell, as shown in 3D Molecular Designs' Tour of a Human Cell© poster and David Goodsell's book, ***The Machinery of Life.***

Nucleus

Nuclear Membrane

Cytoplasm



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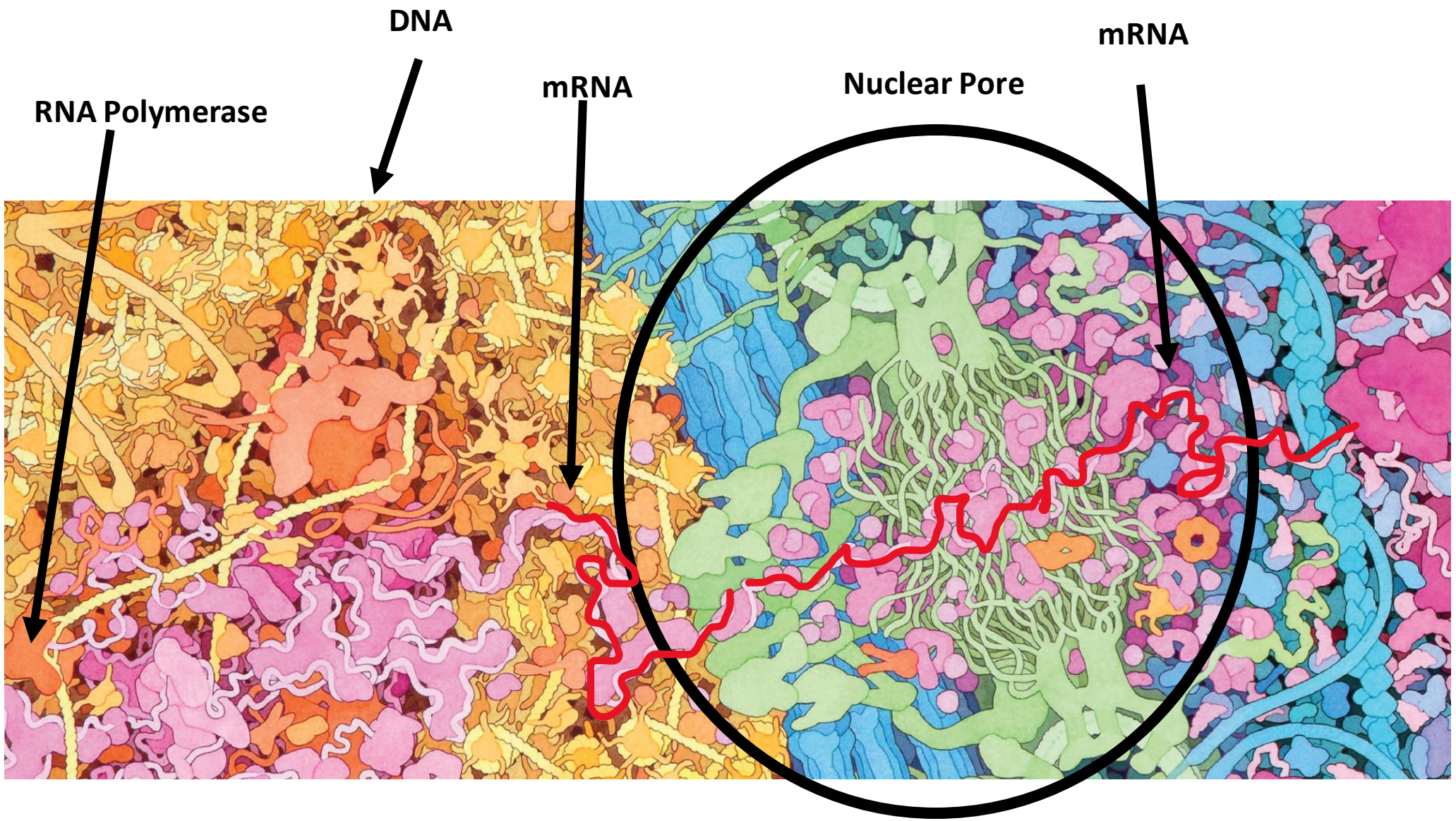

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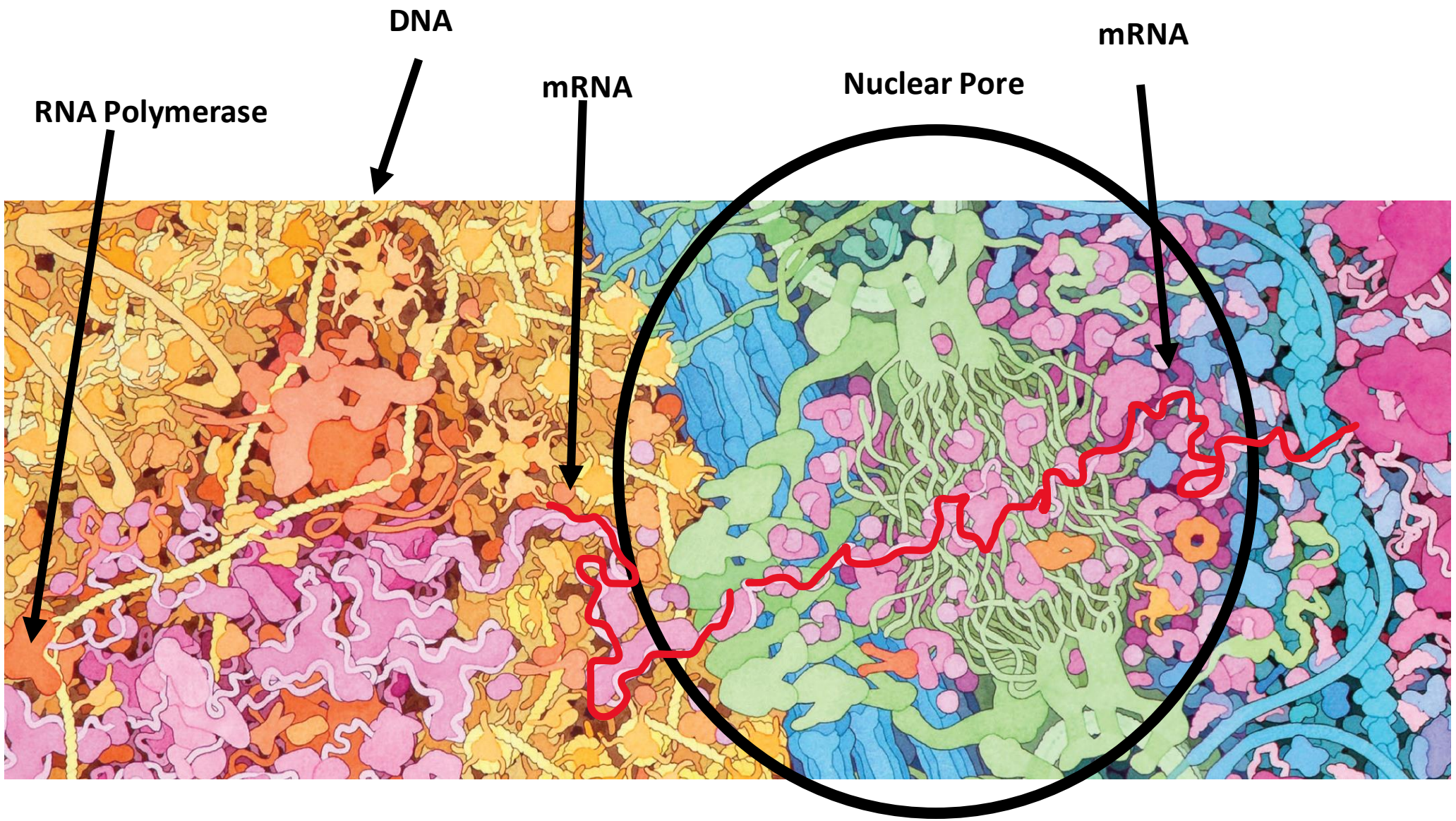

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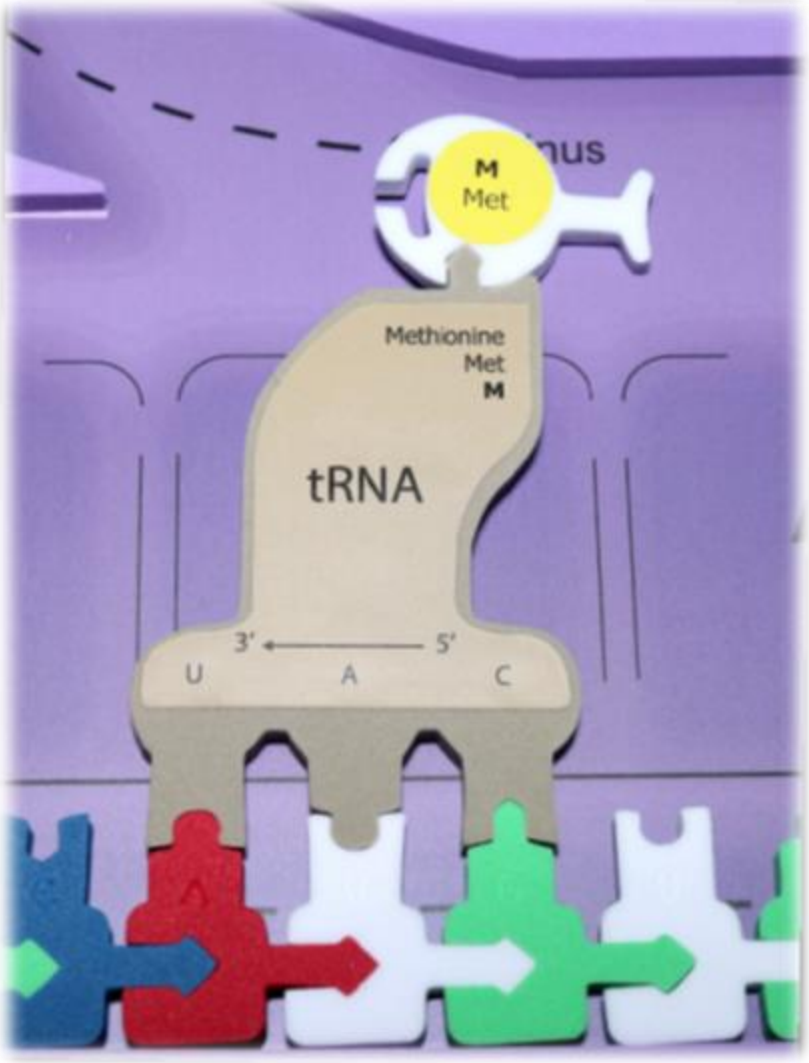
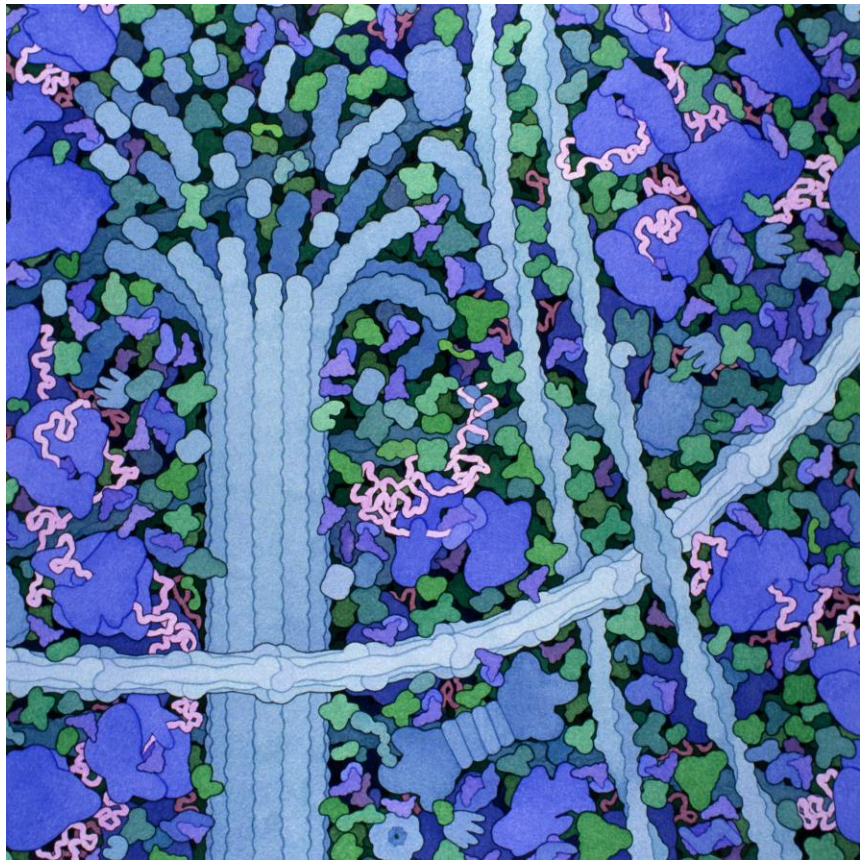
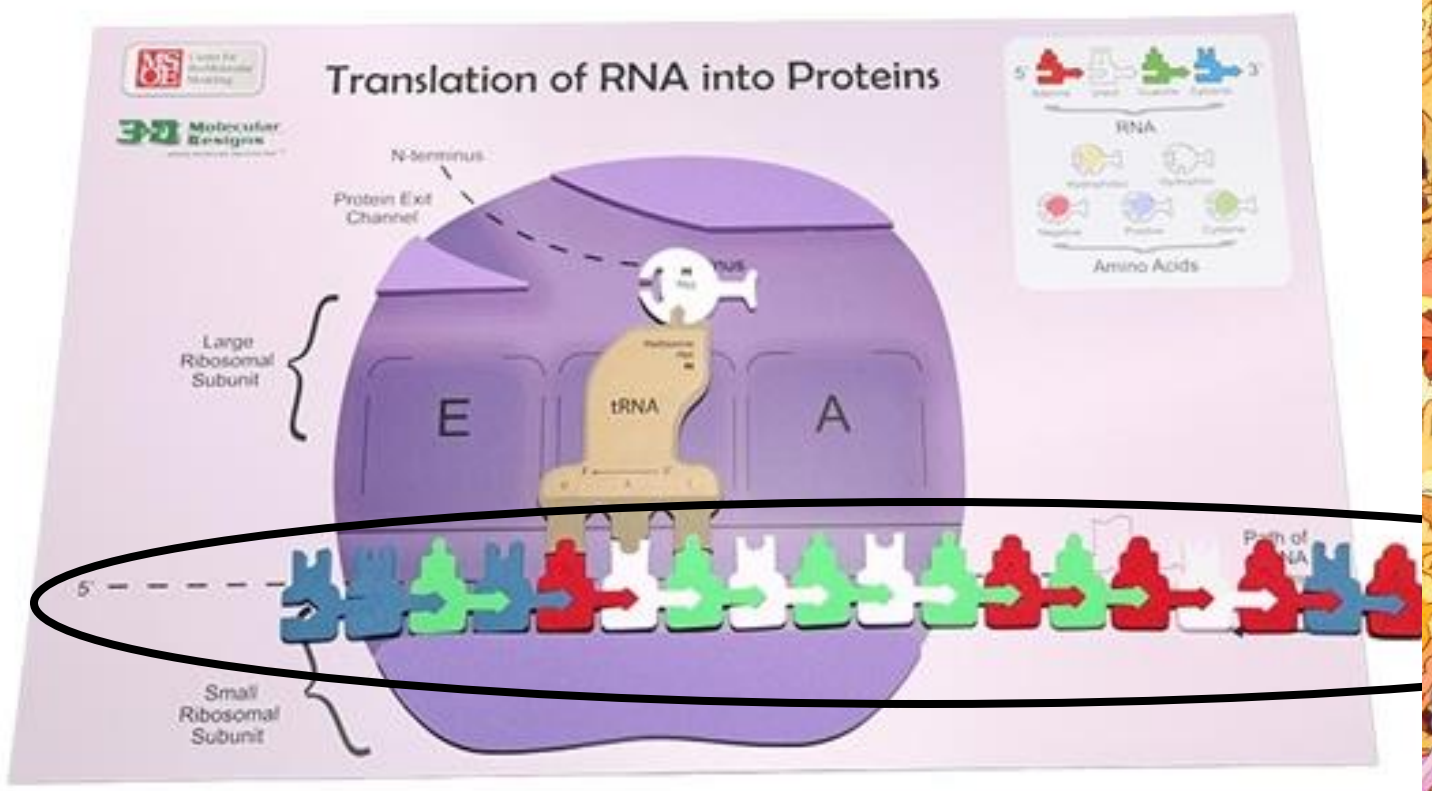
Translation

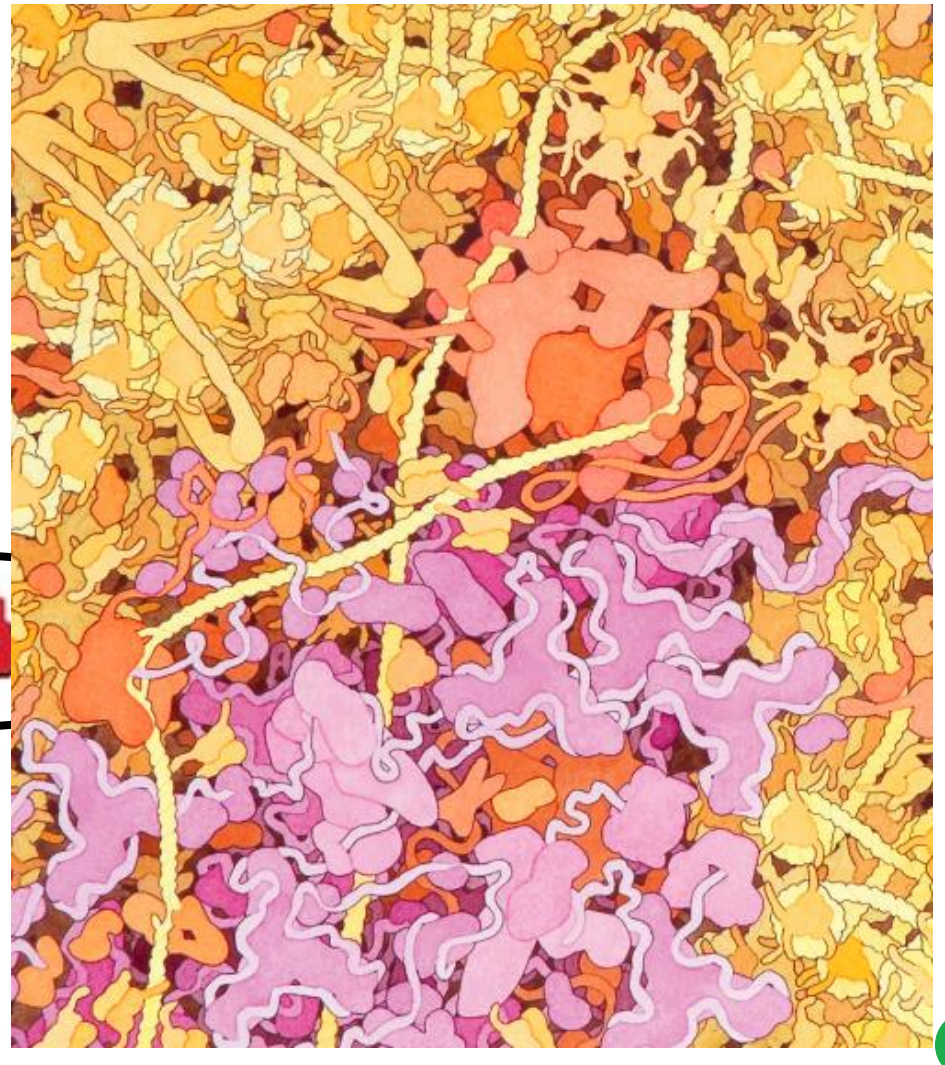




Acknowledgement: Illustration by David S. Goodsell. doi: 10.2210/rcsb_pdb/goodsell-gallery-006

Messenger RNA—It's not limp spaghetti.





mRNA—Is this unstructured?

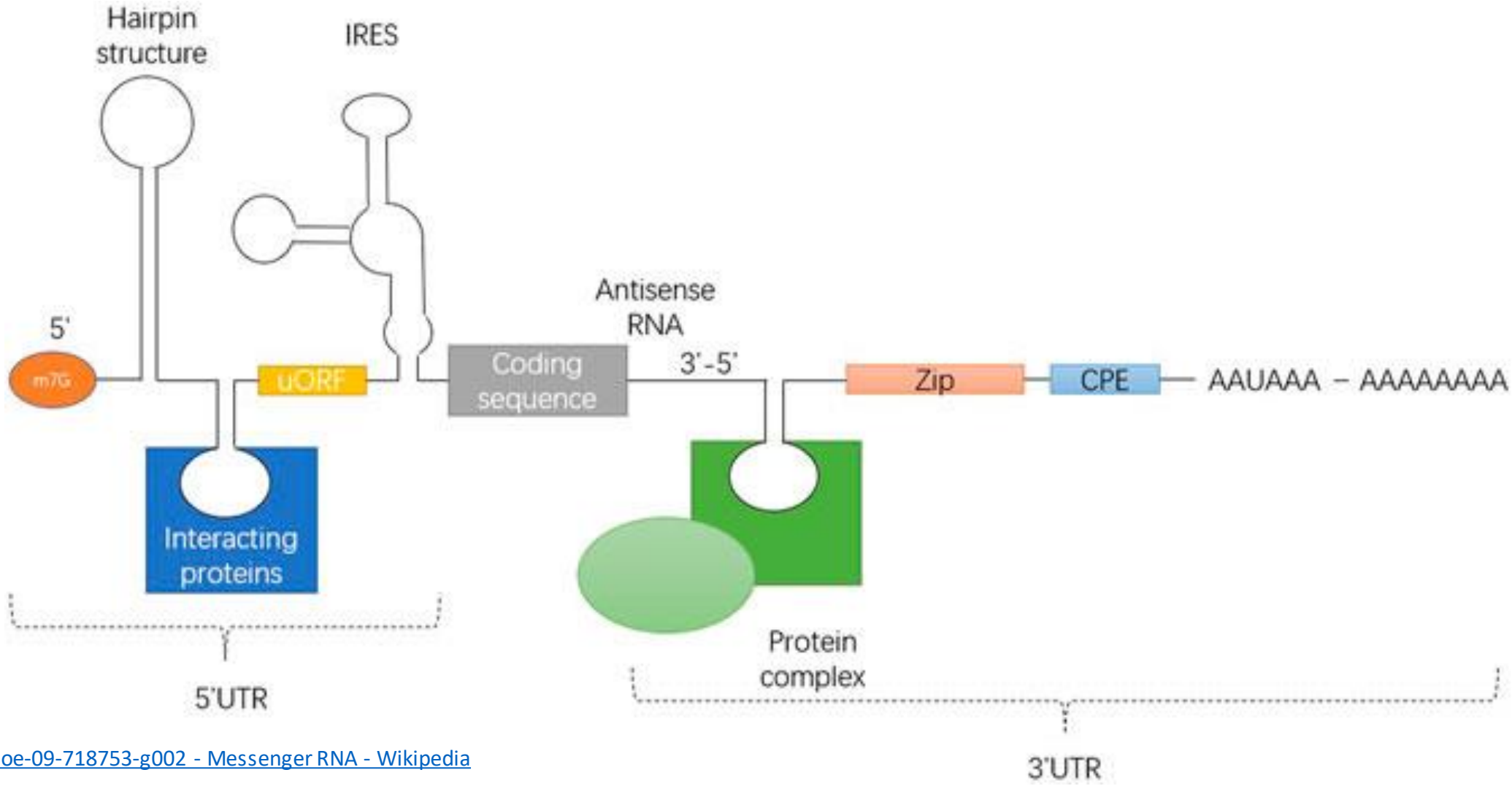
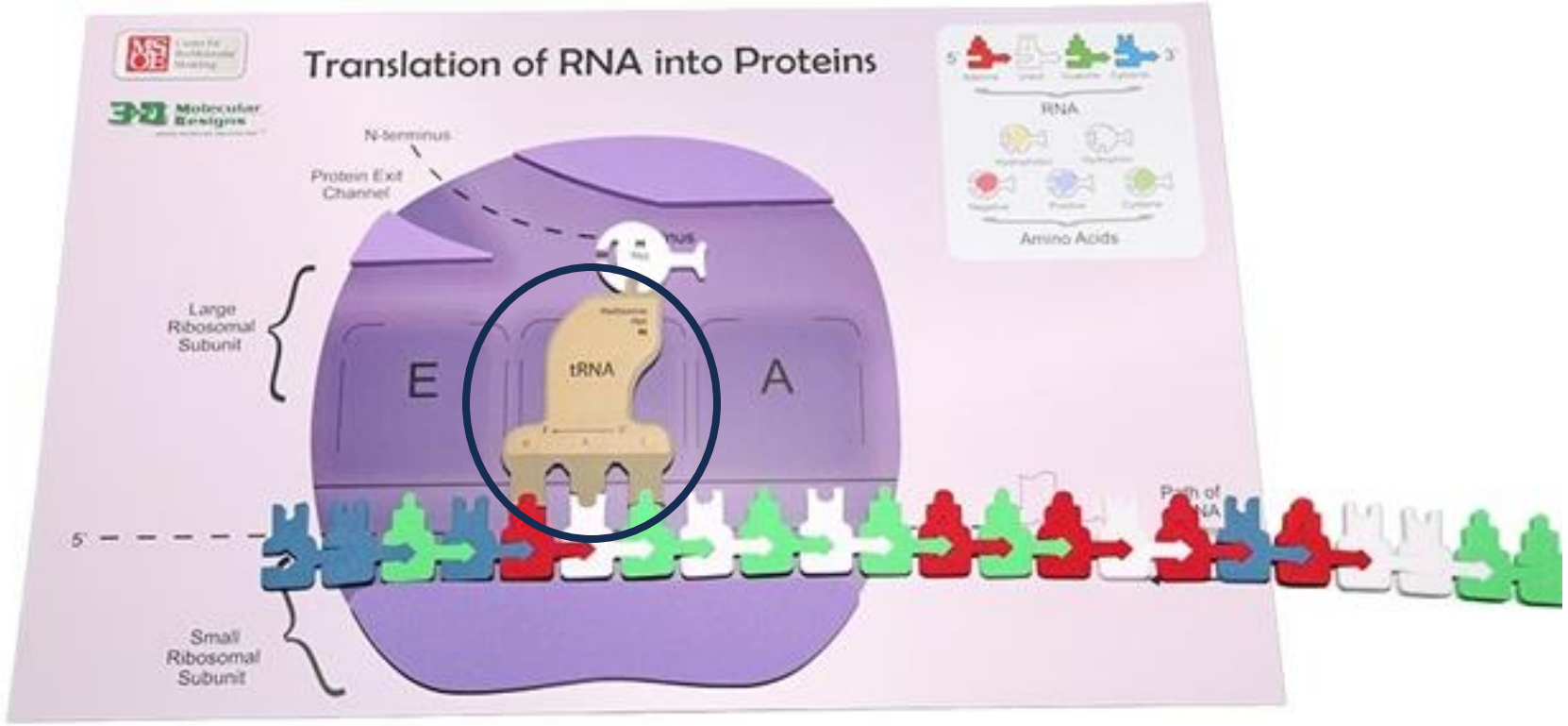
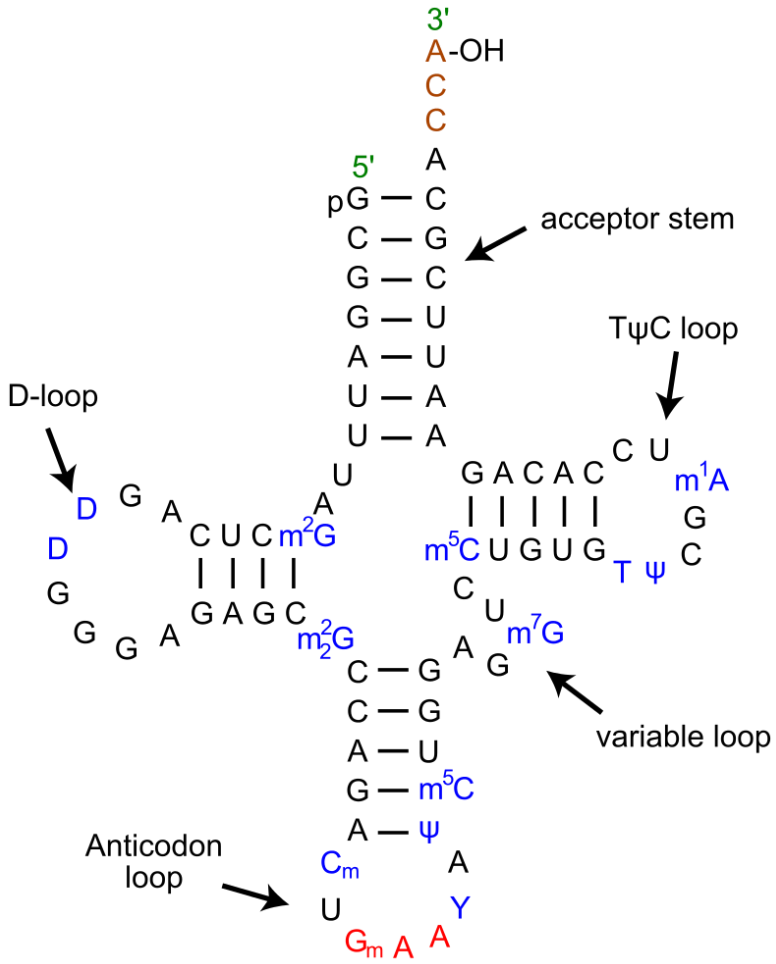


Image credit: Fbioe-09-718753-g002 - Messenger RNA - Wikipedia

Transfer RNA



Comparing tRNA models



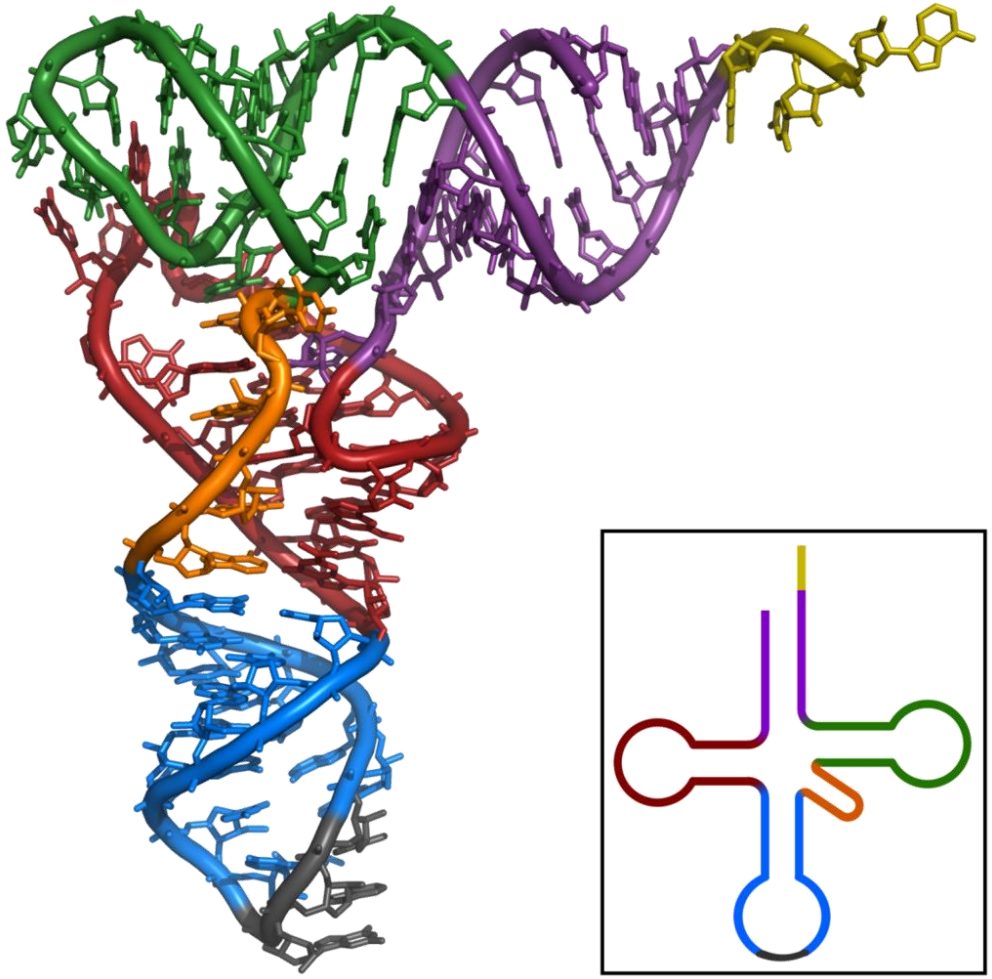


Image credit: TRNA-Phe yeast 1ehz - Transfer RNA - Wikipedia

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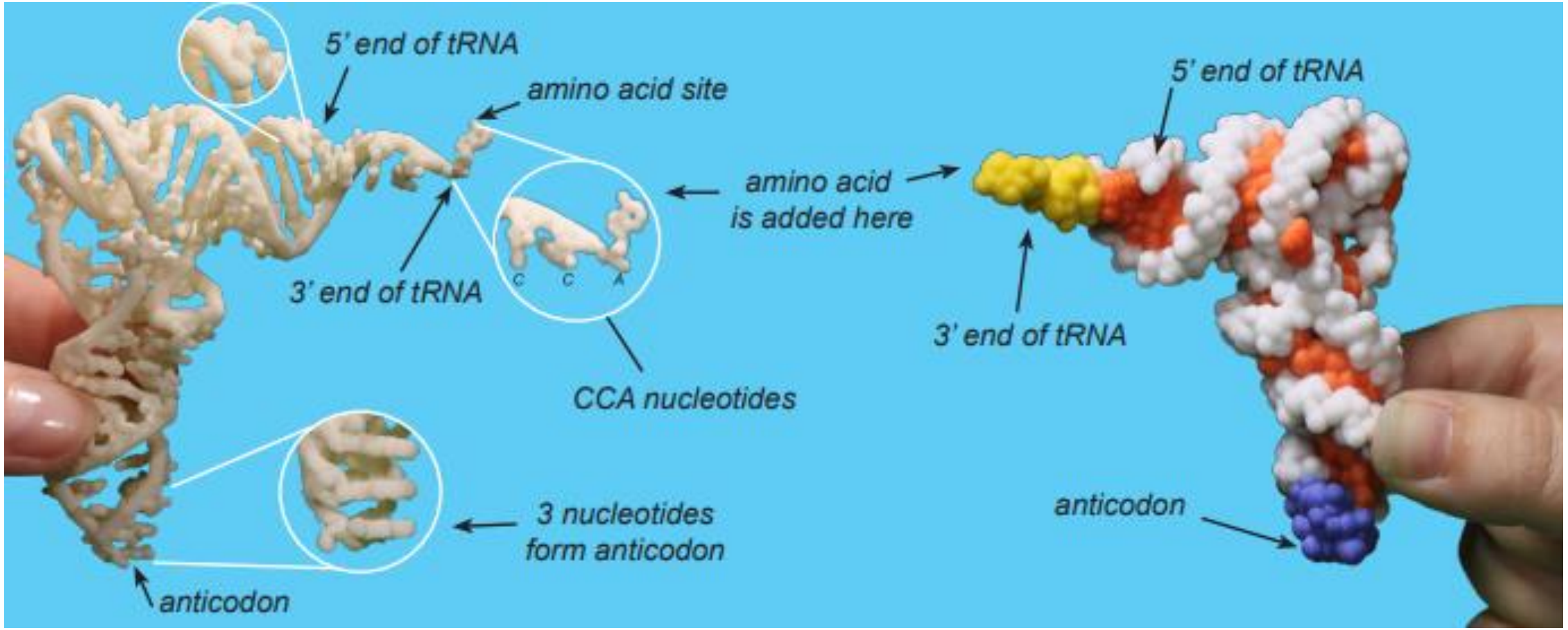
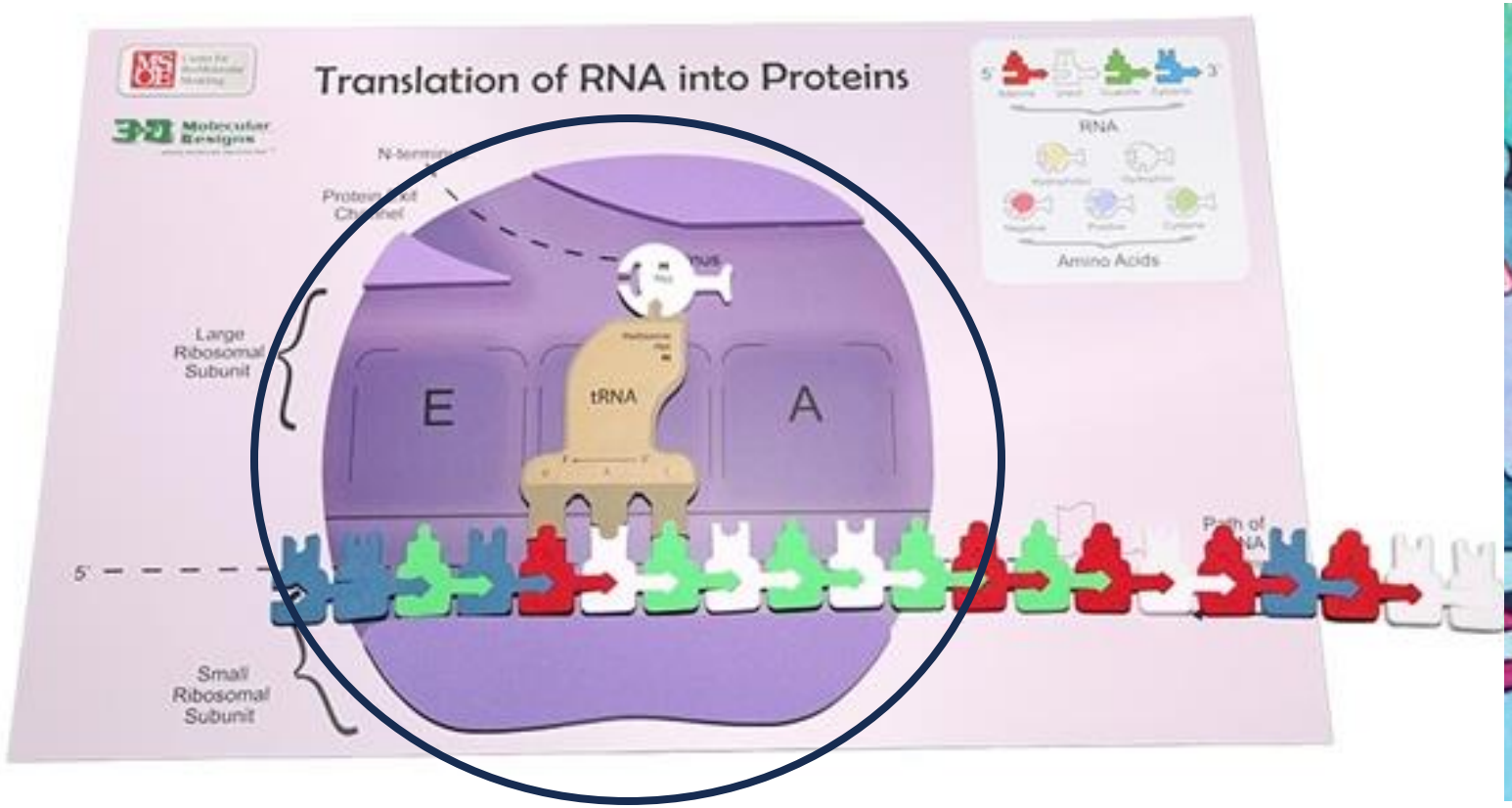
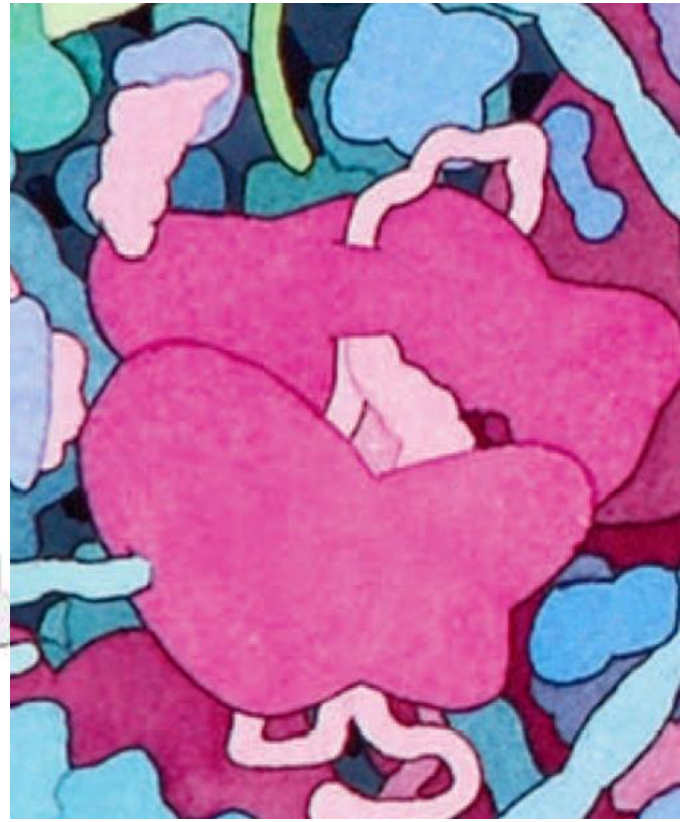
Comparing tRNA models



Ribosome-Ribosomal RNA and protein biological machine





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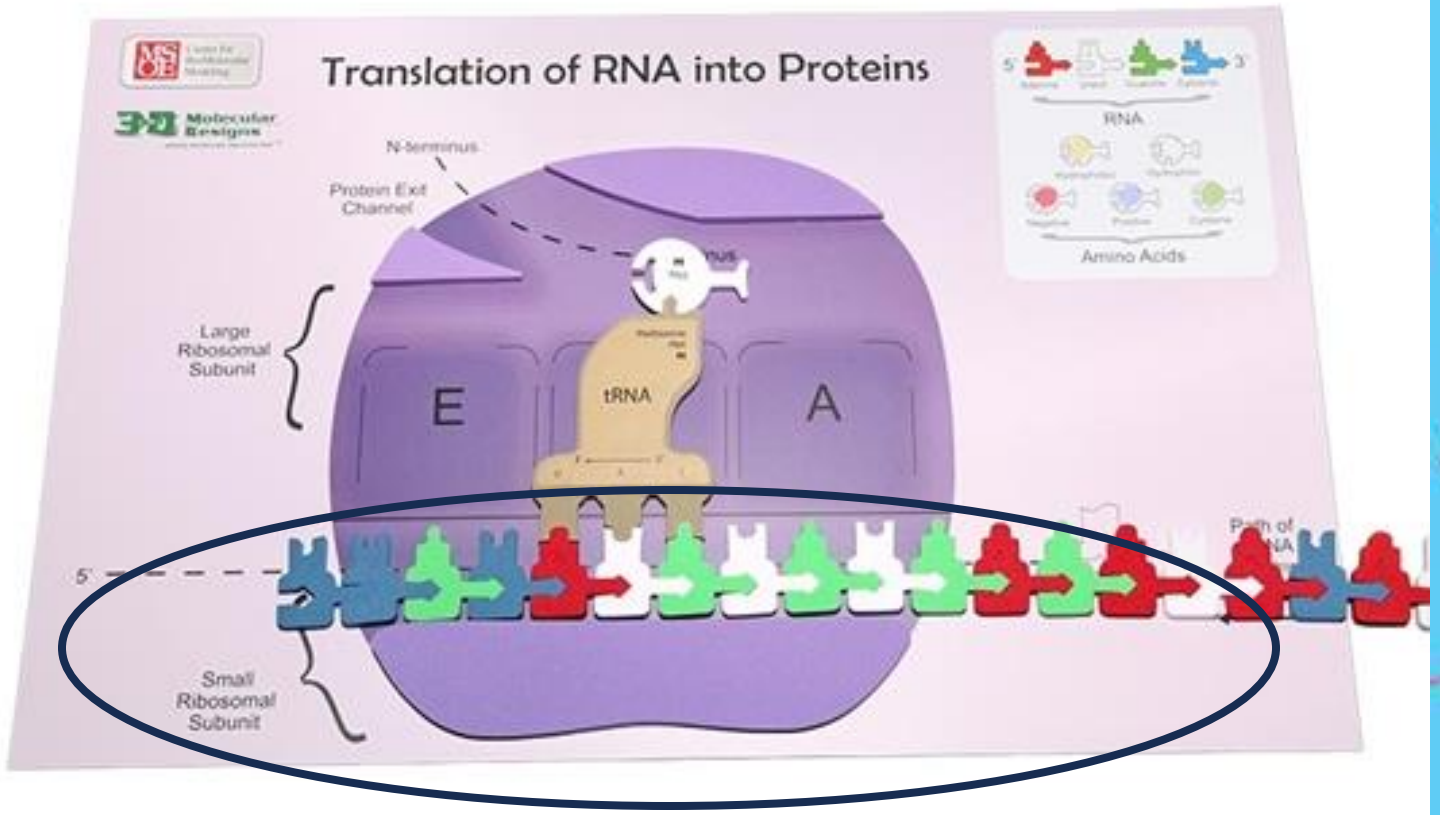
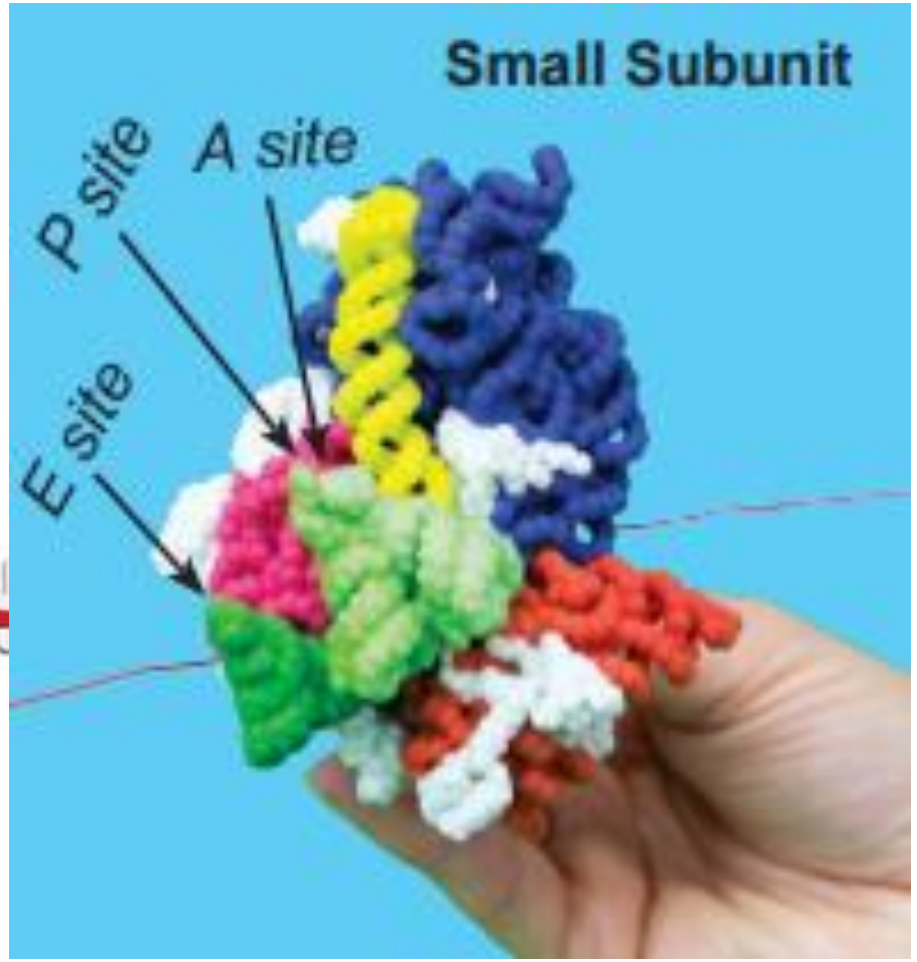
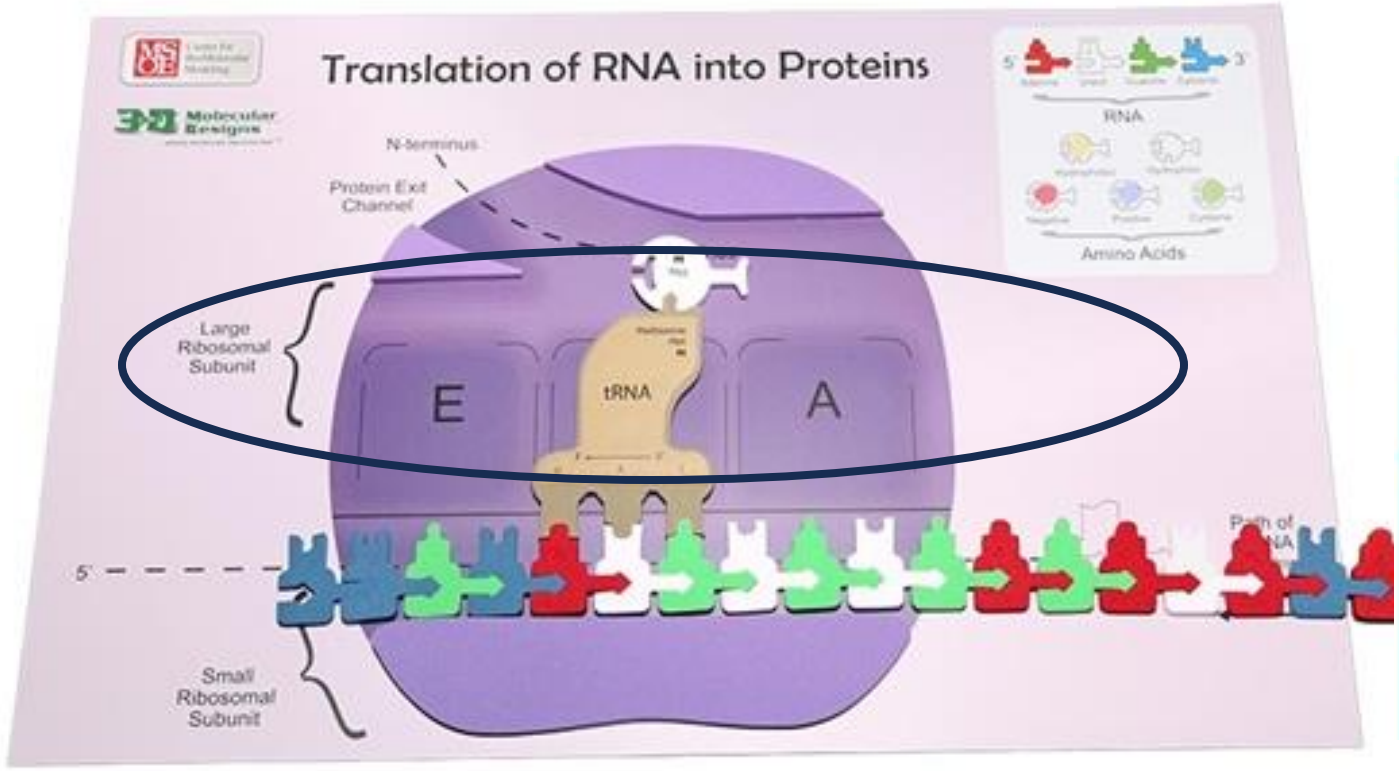
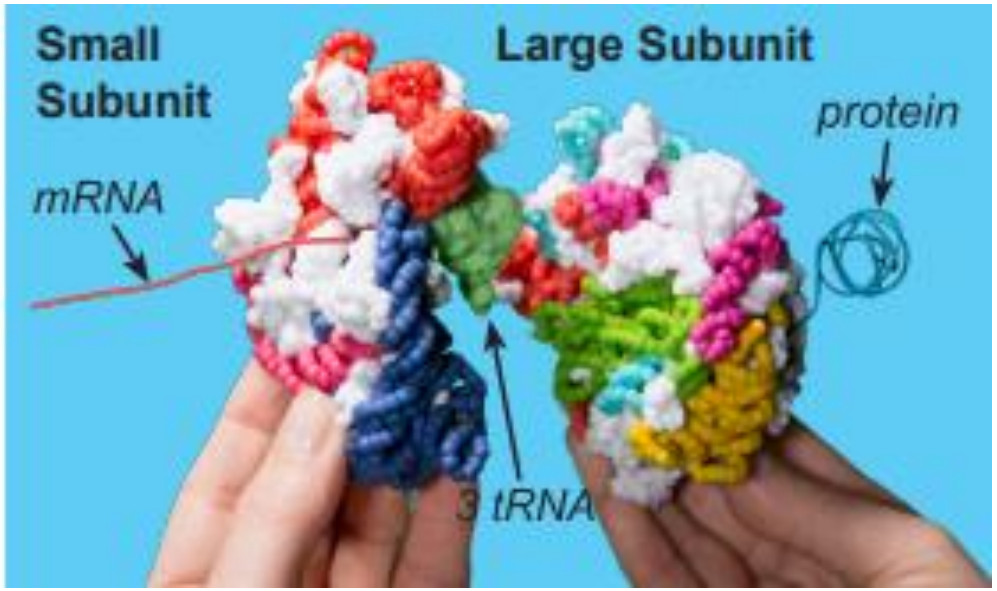




Ribosome-Ribosomal RNA and protein biological machine





The Genetic Codon Chart®

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

Amino Acid Properties

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

3-D Molecular Designs
...where molecules become real™
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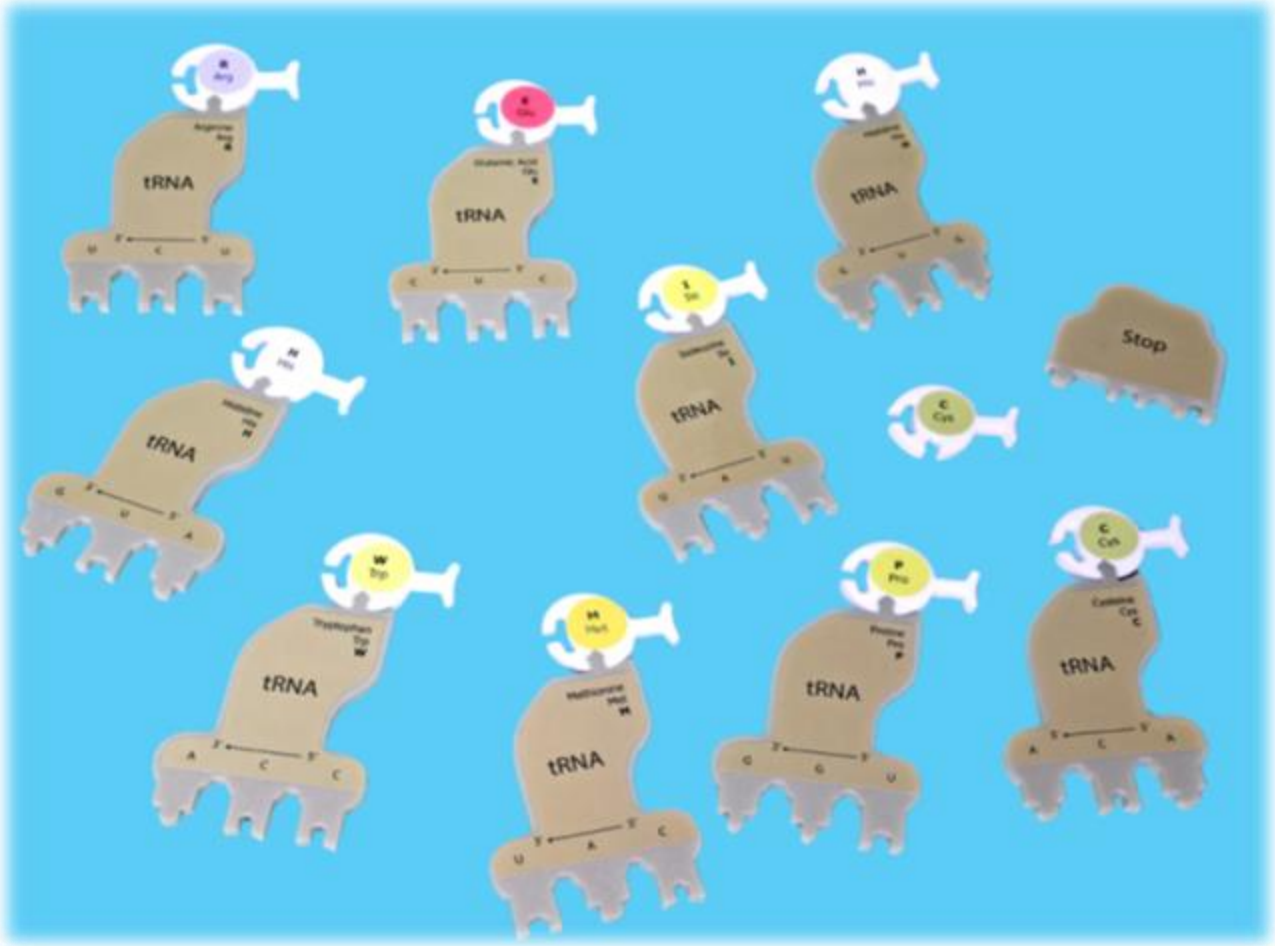
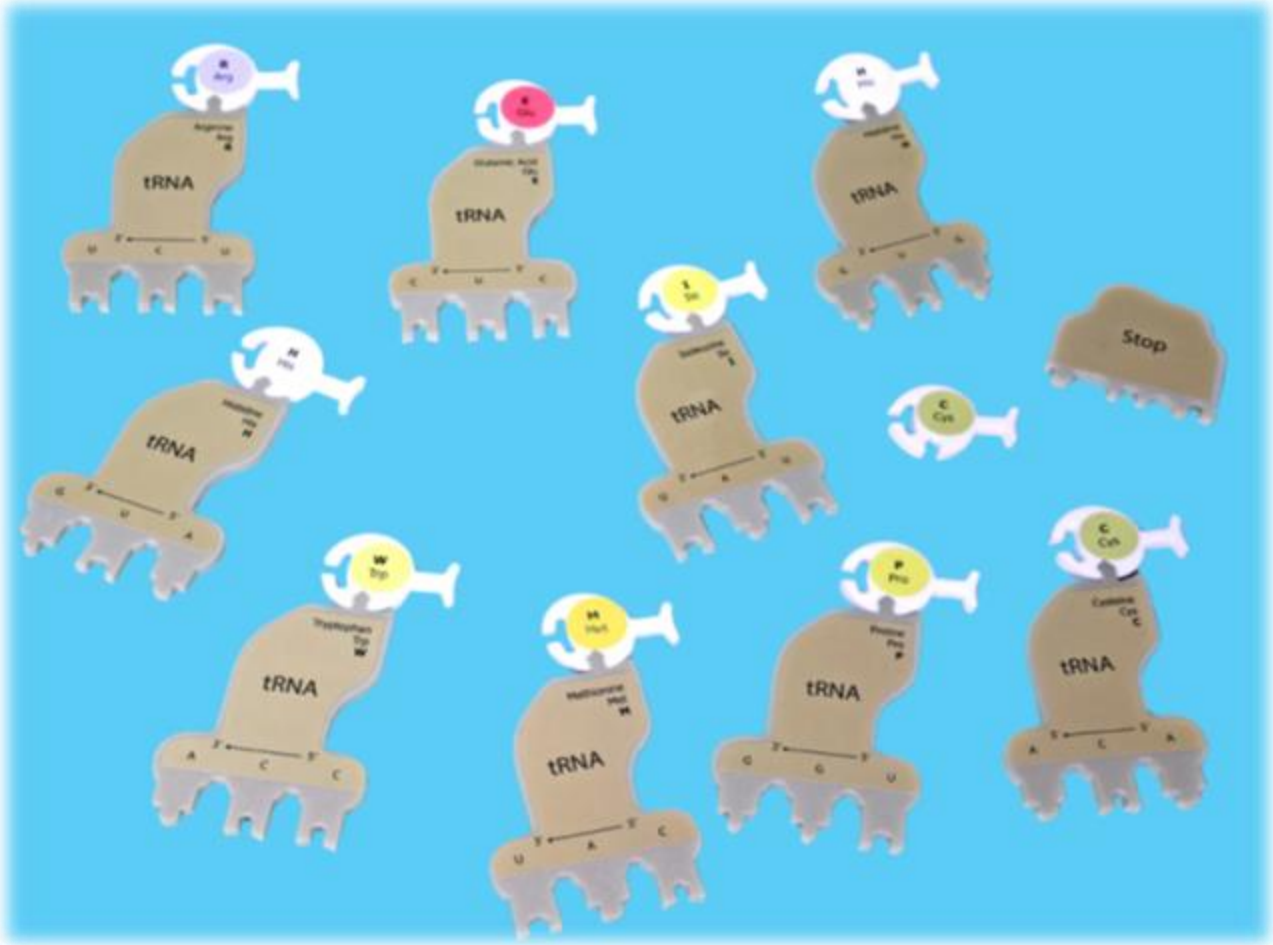
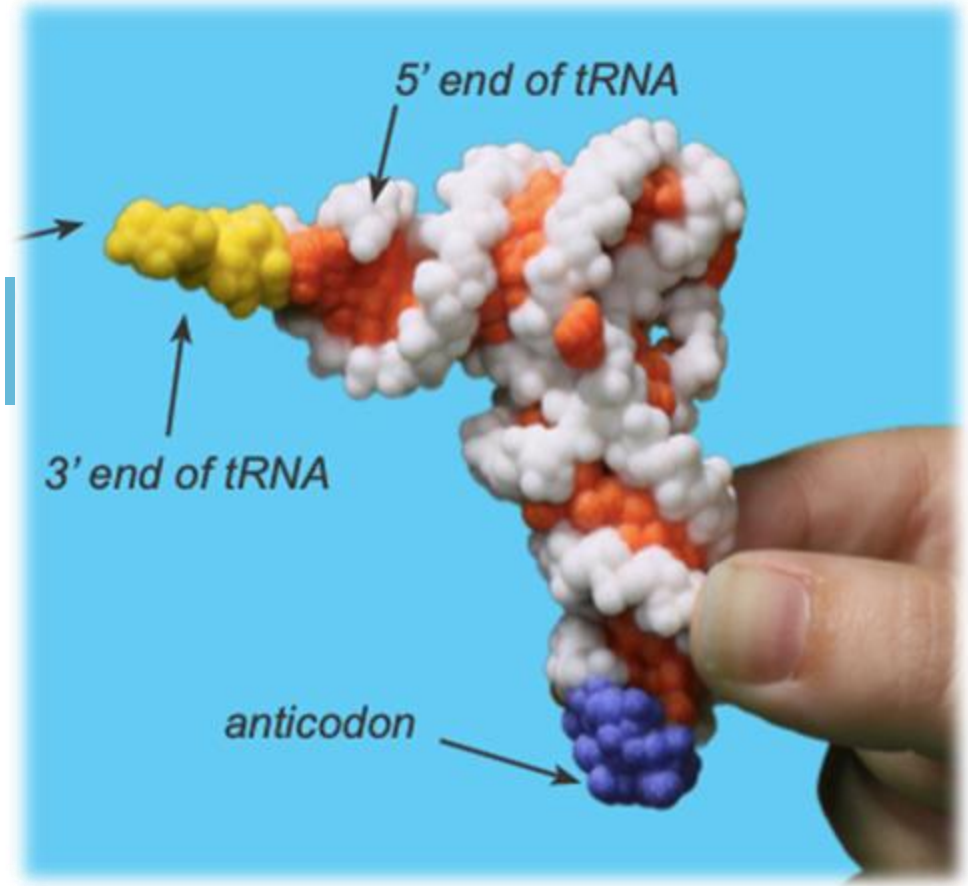
Pair the tRNA with the amino acids

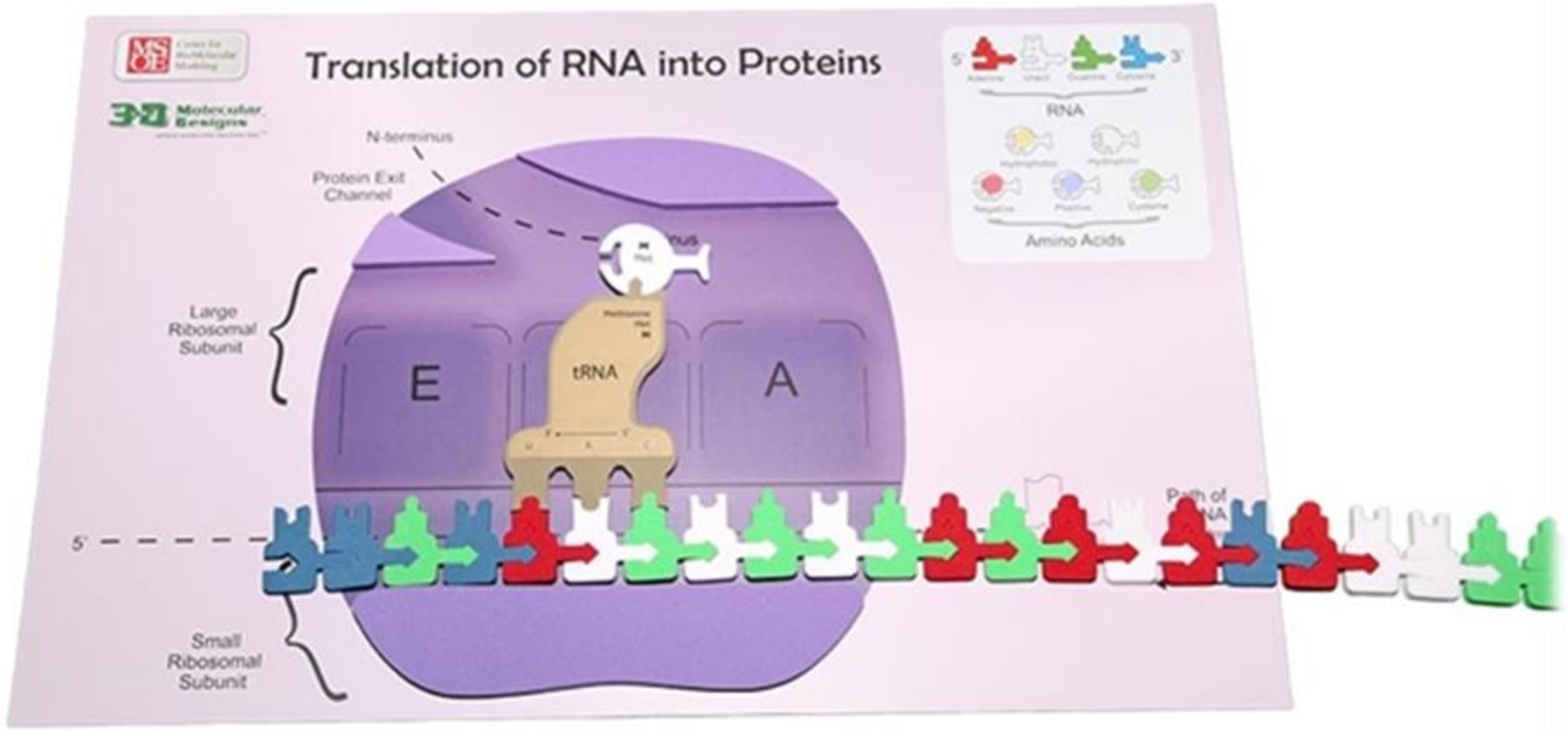


A closer look at tRNAs

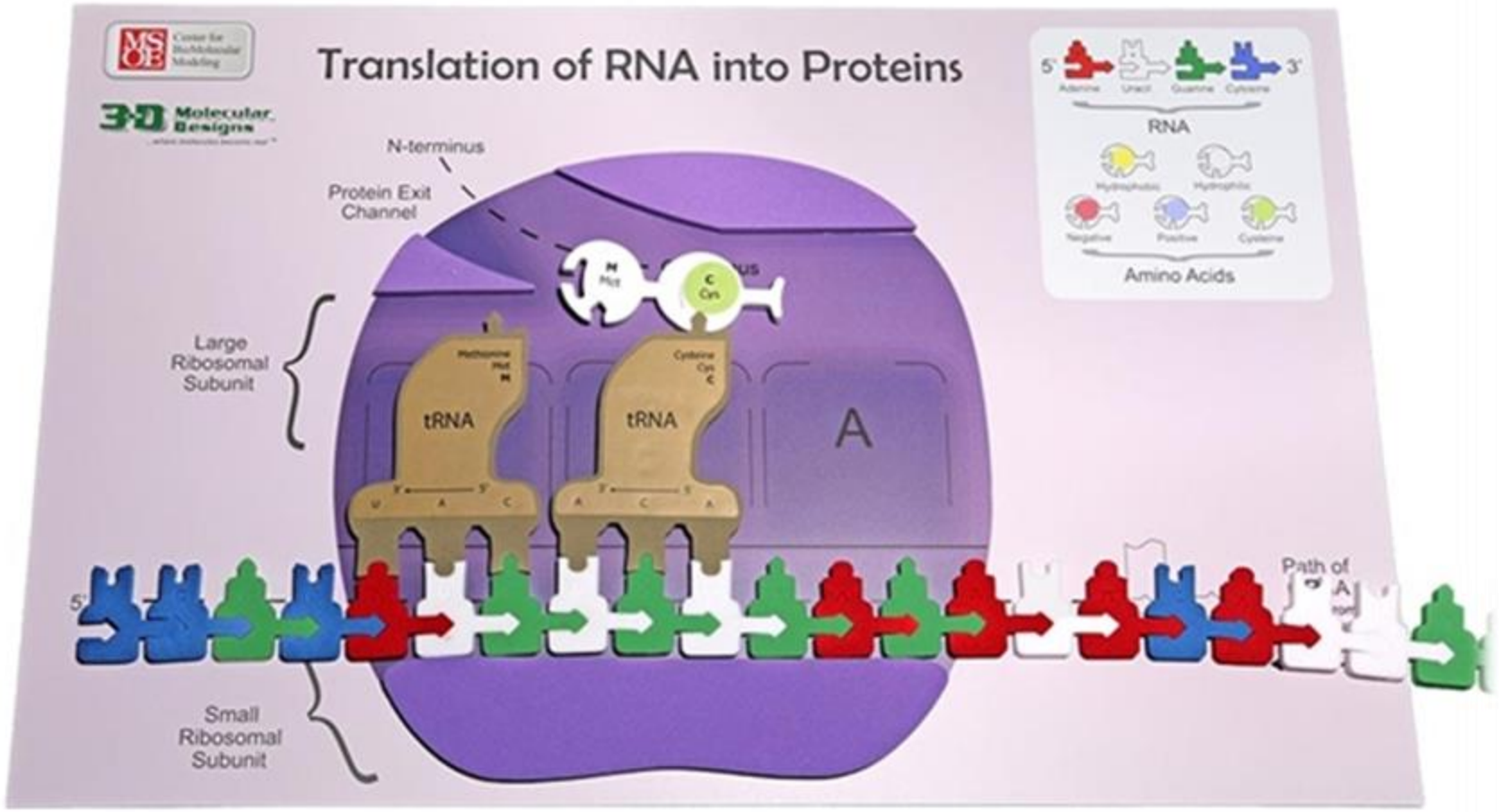




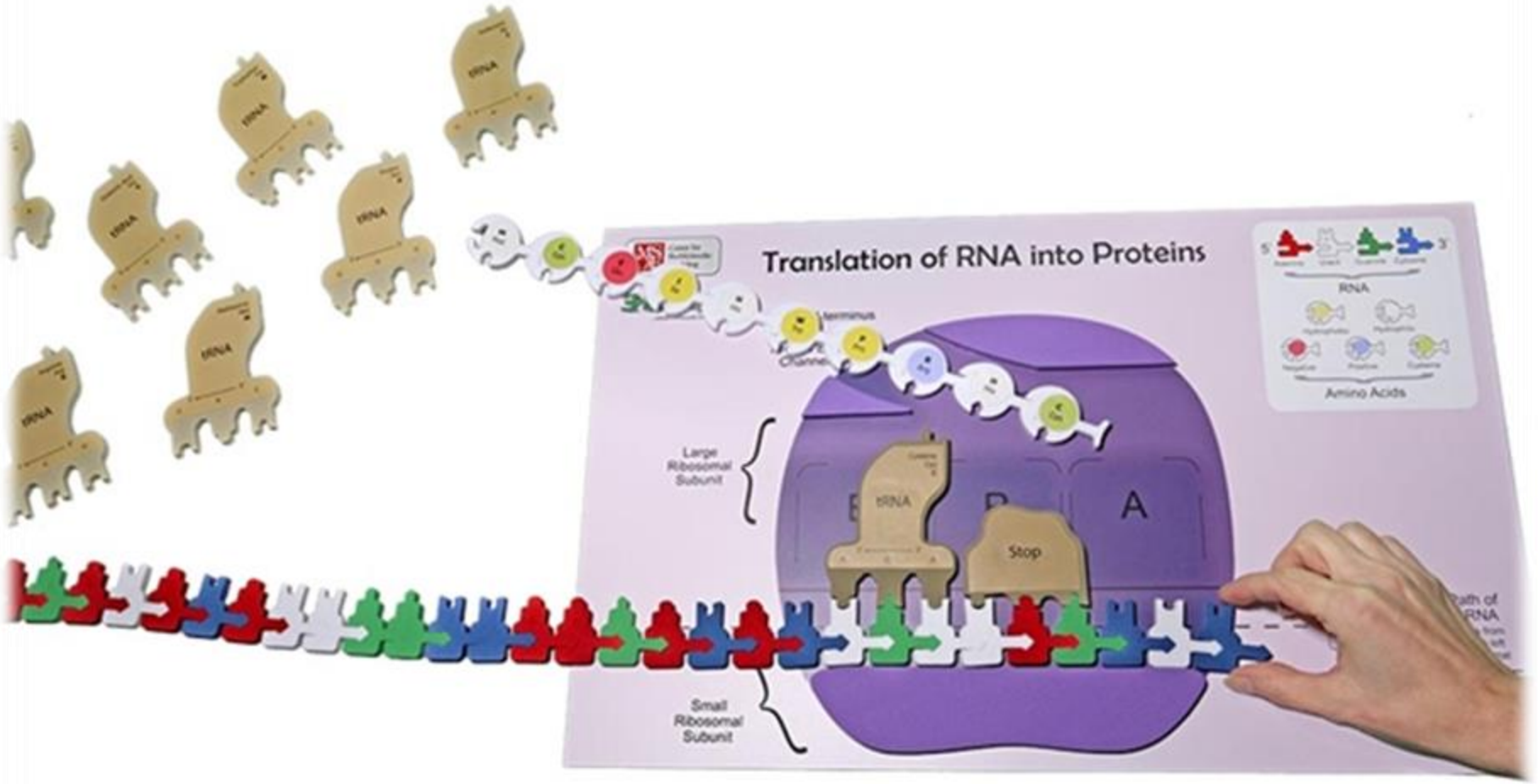
Translation: Initiation



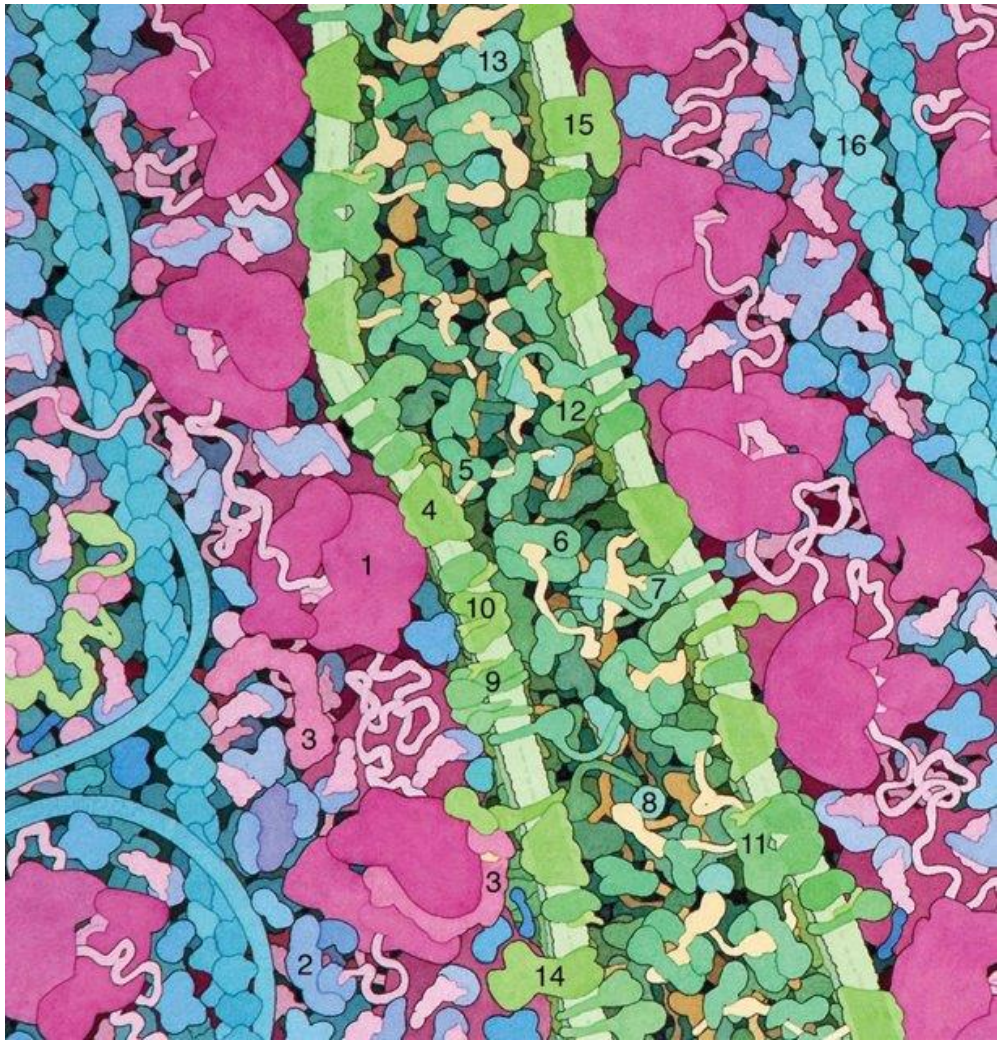
Translation: Elongation



Translation: Termination

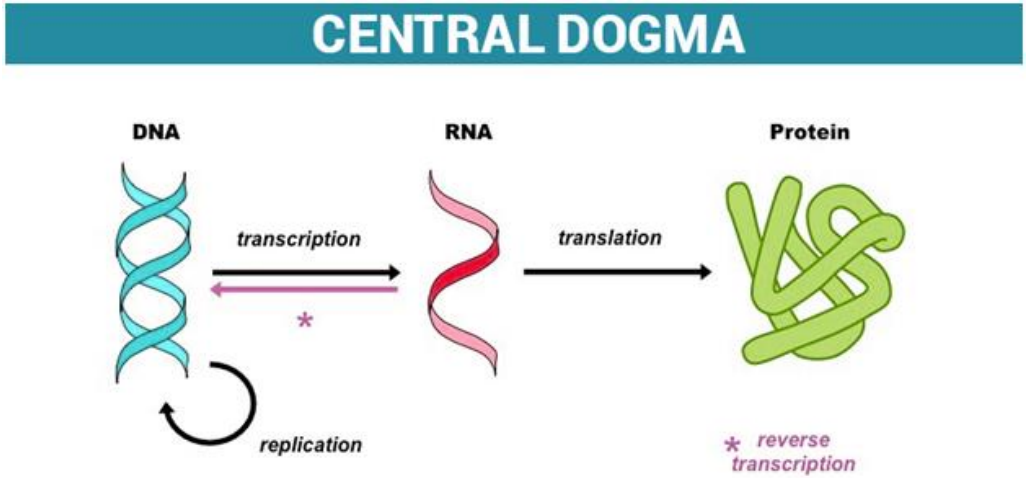


Revisit the panorama

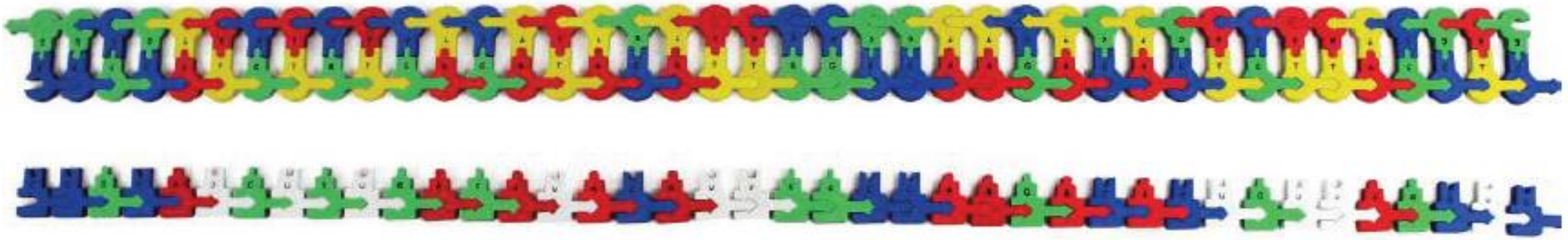


Let's review

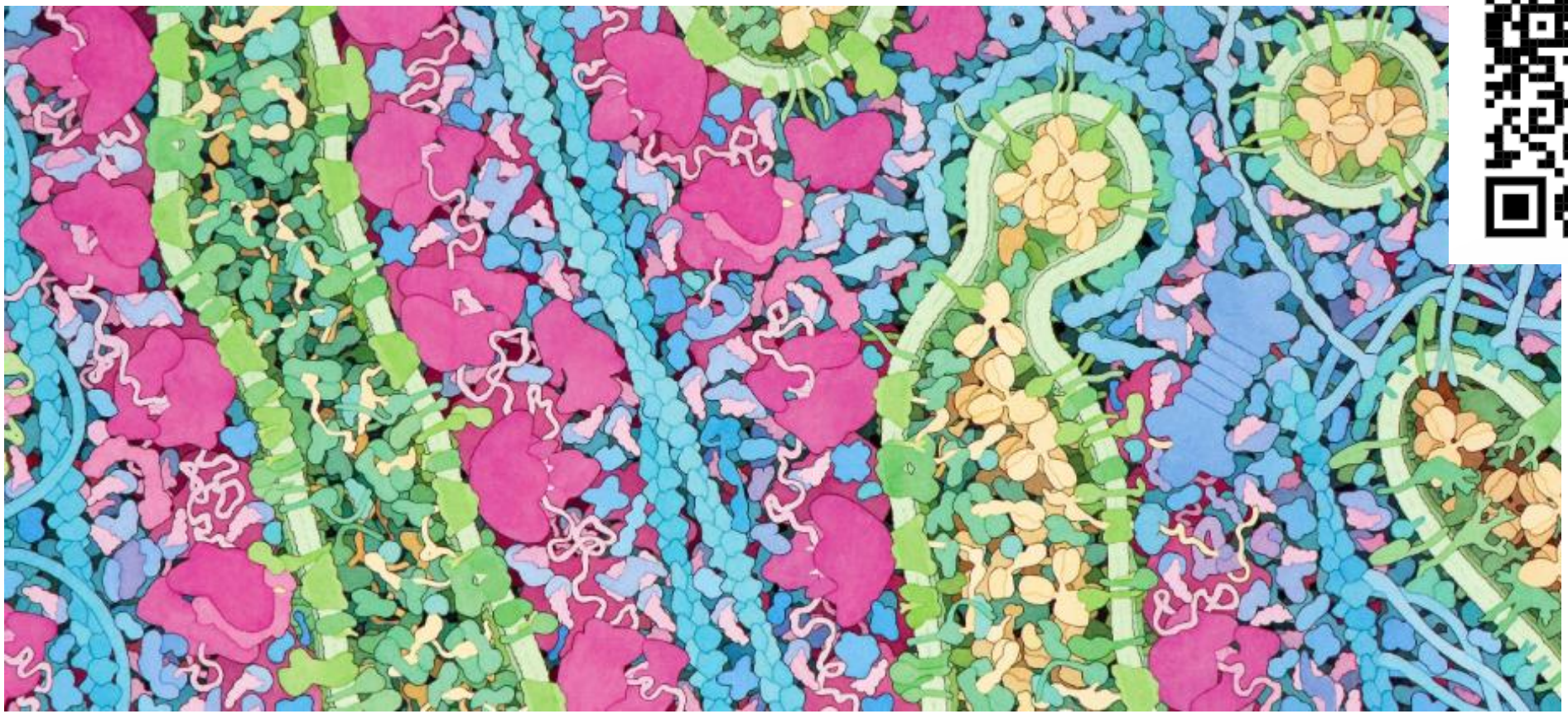
DNA Base	RNA Base
T	*A*
G	*C*
C	*G*
A	*U*
C	*G*
A	*U*



DNA and RNA

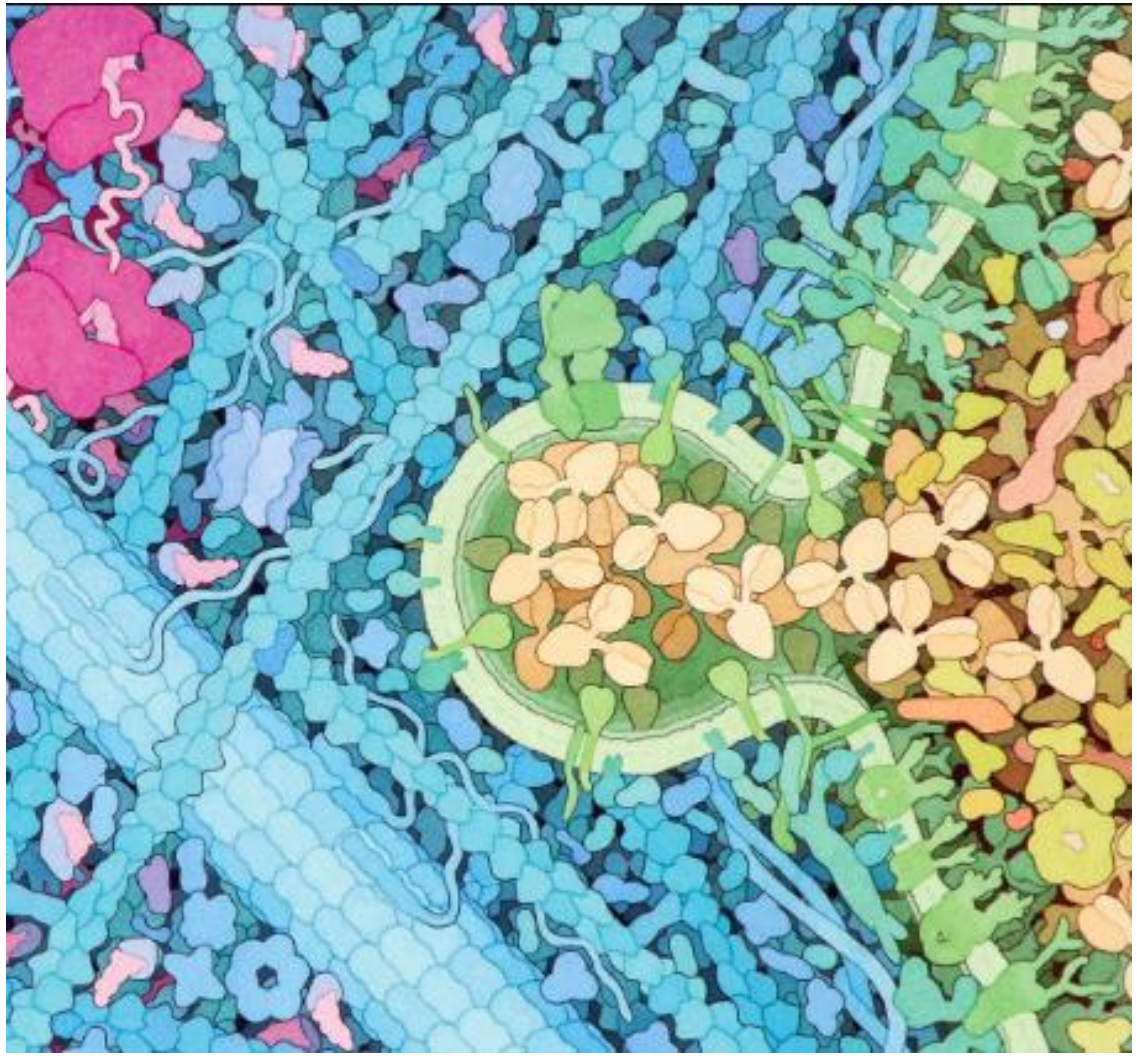


Revisit the panorama



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

We value your opinion! Let us know what you think.

Scan the QR Code and complete this short survey.

3d molecular designs

Trans*forming* Science Learning