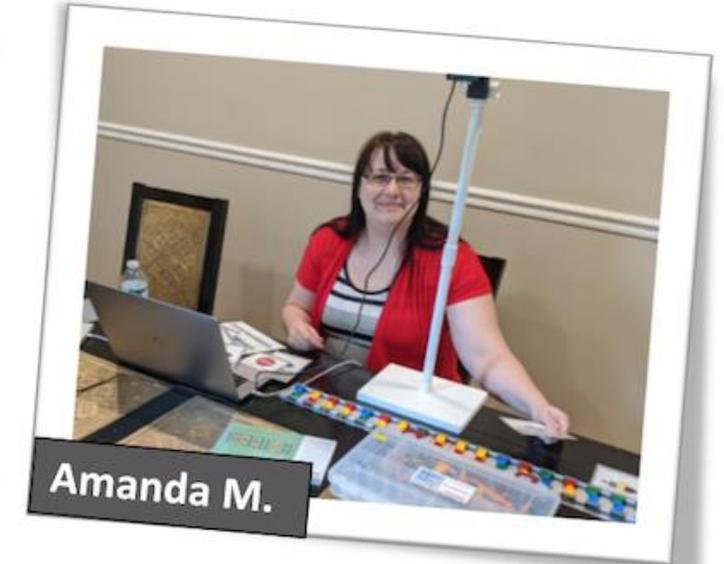


MIT DNA & Protein Models Adapt to Covid Times: Teaching Hands-on Biology via Online Instruction

PEPH Webinar September 29, 2020



Kathleen M. Vandiver, Ph.D., M.A.Ed.

Director, Community Engagement Core,
MIT Center for Environmental Health Sciences & MIT Superfund Research Program;
MIT Edgerton Center K-12 Curriculum Advisor

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MIT Edgerton Center Instructor and Graphic Designer

MIT project funded in part by Grant # P42-ES027707 and Grant # P30-ES002109

Prior Work: Benefits of Teaching with MIT Tactile

Models: Models provide students with opportunity for “learn-by-doing” (Experimental Learning)

1) MIT Edgerton Center Protein Set



Build flexible protein chains.
Use individual amino acids.

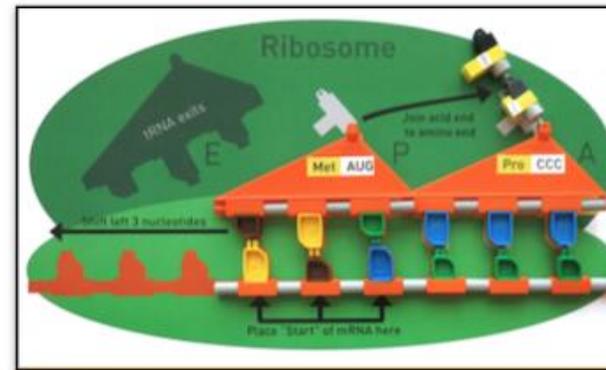
2) MIT Edgerton Center DNA/RNA Set



Build antiparallel DNA strands
Twist to form a double helix.

We teach proteins first—before Central Dogma.
Less confusion teaching this way! Sequencing matters 😊

3) MIT Edgerton Center tRNA Set



Translate mRNA from DNA's
sequence to create a pore.



Fold proteins into helices &
construct a channel protein.

Prior Work: Existing Teacher Resources for the MIT Models

1) Molecular Kits

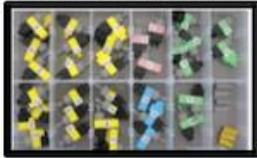
2) Student Booklets

3) Training Videos

4) PPTs for Class

5) YouTube "How to"

MIT Protein Kit

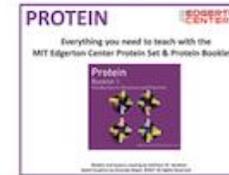


Basic & Advanced Booklets

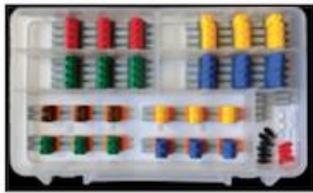


Protein Teacher Training Video

15



MIT DNA/RNA Kit

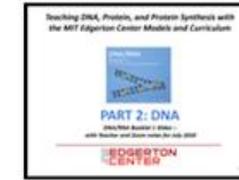


Basic & Advanced Booklets



DNA/RNA Teacher Training Video

14



MIT tRNA Kit

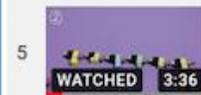
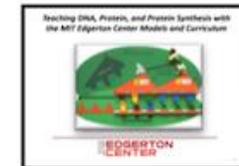


tRNA Basic Booklet



tRNA Teacher Training Video

13



Coming soon- new DNA Booklets

- "Genes & Health"
- "DNA Biotechnology"

Currently Adapting: Hands-on Kit Packages for Partners

Student Packages: DNA/RNA & Protein Kits, Booklets, Materials, & External Camera with Stand

A required TECH-CHECK event was scheduled one week before the first day. Highly recommended idea!



Each DNA & Protein Set can be configured into 14 student packages for loan. We are creating “Online Teacher Set” for purchase.



The students' packages have 5 student guide booklets: Basic & Advanced lessons for the DNA/RNA and Protein models. Appropriate for Biology + AP Biology.



Here are the assembly instructions for an external camera & stand. Two camera heights are possible. Built from PVC pipe: strong, simple and flexible!

Currently Adapting: Lesson Delivery from a Distance

Three 'Covid Times' Collaborations (see credits page for more info)

Lesson Details

1)



Program: LEAH Knox Scholars Program

Partner: Human Resources in Action Inc (HRIA, Inc.)

Dates: June 6-10, 2020 for training MIT Teaching Assistants

Dates: July 9-12, 2020 for Molecular Modeling w. 24 students

Audiences: MIT grad school TAs and HS students

Description: A two-year internship program for rising high school juniors & seniors from backgrounds underrepresented in STEM fields (communities of color & low-income backgrounds) in the Greater Boston area providing a foundation for their future as leaders in the biomedical research field.

Instructors: Vandiver & Mayer taught 4 new MIT graduate Teaching Assistants (TAs) on zoom. With 6 instructors total, we each led 4 HS students in our breakout rooms. Nice!



Topics: Biotech laboratory protocols visualized w. DNA models: Restriction enzymes, Gel electrophoresis, PCR + Central Dogma

2)



Program: Environmental Health Sciences CEHS Teacher Summer Institute

Partner: Prof. Robin Fuchs-Young, Texas A & M University, Medical School

Dates: July 22, 2020 Daylong Workshop for 8 teacher participants

Audiences: High school science and health teachers

Description: ~7 hour teacher professional development (PD) workshops for science and health teachers on EHS topics. Workshop hours give PDE credits in Texas.

Instructors: Vandiver & Mayer lead a daylong EHS workshop

Topics: Teaching Bio Teachers for in-class & online teaching:

- Protein Video topics—watch & discuss together
- DNA/RNA Video topics-- Self-directed viewing time
- We did live demos with models for DNA repair, etc. Excellent discussions!

3)



Program: Signature Experience for Public Health Undergraduate Program

Partner: Dr. Christa Wright, School of Public Health, Georgia State Univ.

Dates: August 25 & 27, 2020 for first session; ongoing MIT mentorship with Dr. Mayer into fall term 2020 for new lesson for HS students.

Audiences: Public Health Majors in College, HS teacher and HS students.

Description: GSU Capstone project gives public health majors the opportunity to integrate and apply public health knowledge through experiential activities.

Instructors: Vandiver & Mayer taught 4 GSU undergrads; North Atlanta Public Schools' Biology Teacher, Dr. Patke; & Dr. Wright how to teach with models. Undergrads will be teaching next.

Topics: GSU is Developing a EHS Lesson on CYP proteins & pesticides with the models!



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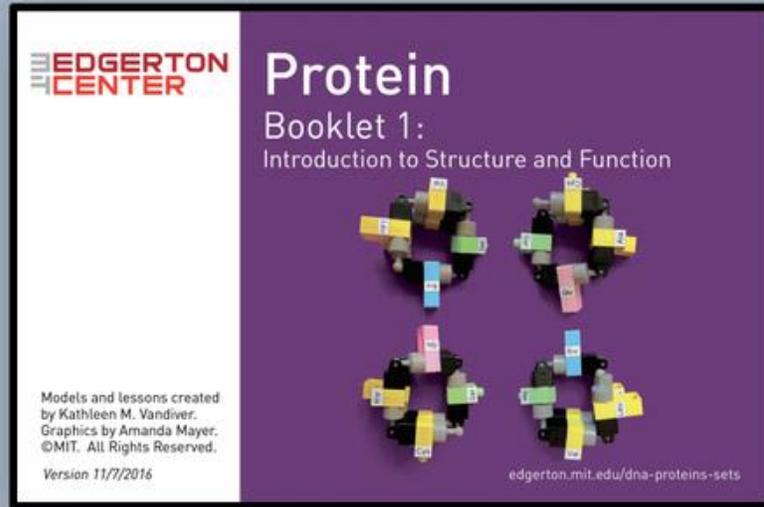
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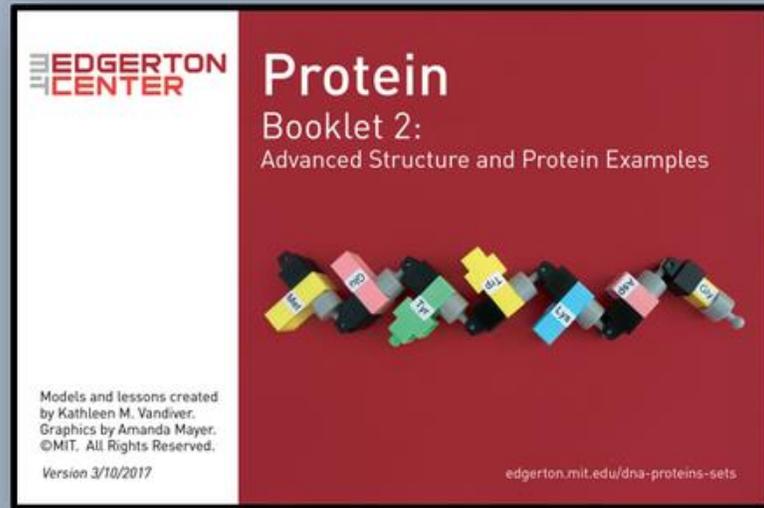




FOR STUDENTS:

Booklet 1
Basic Instructional
Booklet: 32 pages

Amino Acid Info



Booklet 2
Advanced Instructional
Booklet: 48 pages

Using Your Booklet and Kit

BOOKLET INSTRUCTIONS:

Q: = Helpful Questions (answers on Page 30)

Bold type = required actions

Underlined = new vocabulary

1. Open the kit. Check the number and location of all amino acids using the inside label shown on the right.

2. Check the small pieces in the bottom right section:

- 4 gray cylinders (phosphates)
- 3 yellow tubes (disulfide bonds)

Hydrophobic 			Hydrophilic   		
4 Met 	3 Cys 	1 Ala  1 Phe  1 Trp 	2 Asp  1 Glu 	4 Ser 	1 Thr  1 Tyr 
5 Pro 	3 Val 	2 Gly  1 Ile  1 Leu 	1 Arg  1 His  1 Lys 	1 Asn  1 Gln 	4 Phosphates  3 Disulfide bonds 



PART I: BUILDING PROTEINS

Introducing the Amino Acids

Proteins are the molecules that do most of the work inside the cell. Amino acids are the building blocks of proteins. An amino acid is a small molecule with different groups of atoms. Let's look at the structure of an amino acid.

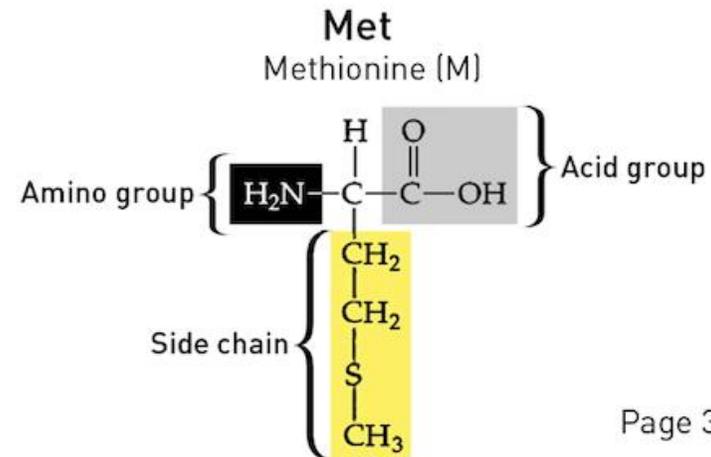
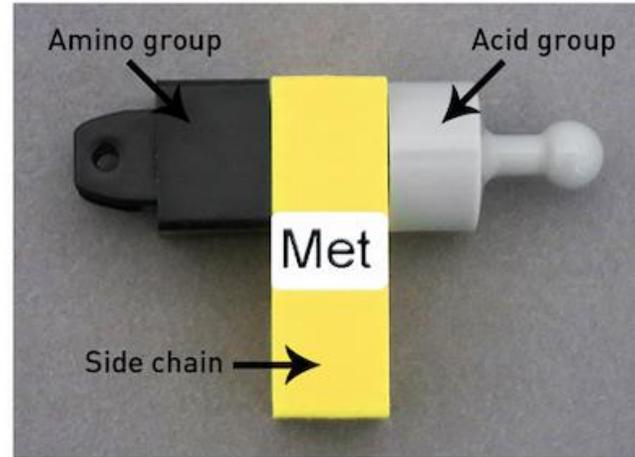
1. Look at the chemical diagram below the photo. The diagram shows the atoms in a methionine.

Q: Name the different kinds of atoms you see in the diagram.

2. Find a methionine, or Met, in your kit. Hold it in your hand. Use the photo to identify the 3 parts of every amino acid:

- amino group (black block)
- acid group (gray cylinder with knob)
- side chain (colorful shape with abbreviation)

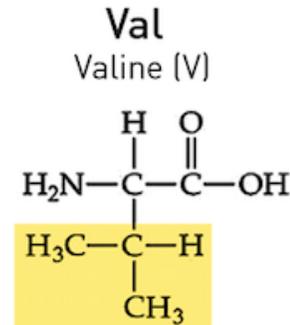
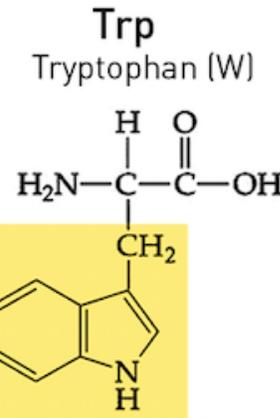
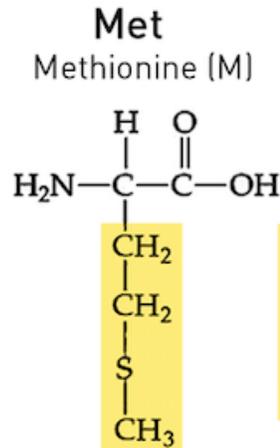
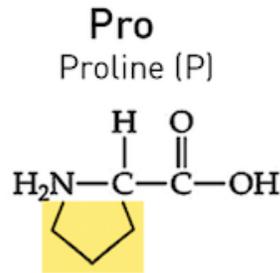
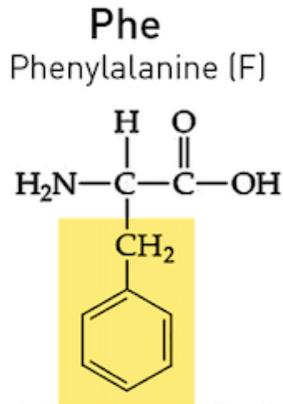
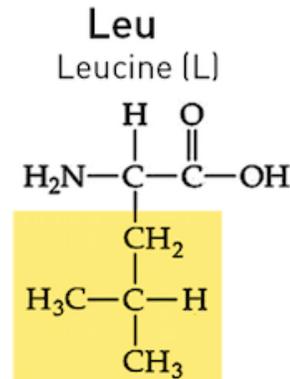
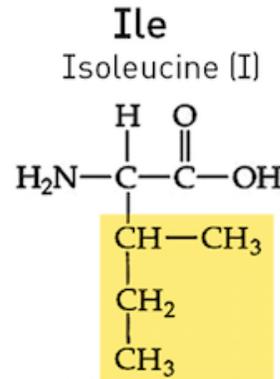
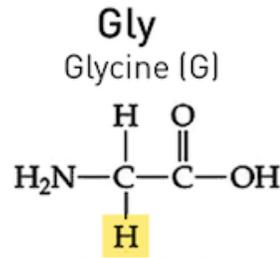
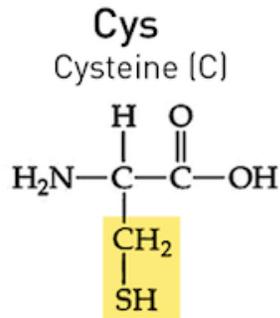
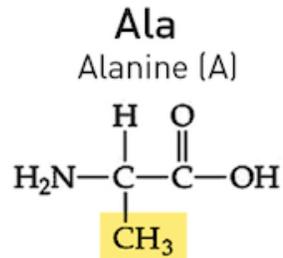
All amino acids have the same amino part and acid part. The side chains of amino acids are what make them different. Let's look at all the different side chains.



Amino Acid Info

Hydrophobic Amino Acids (water-fearing)

HYDROPHOBIC
(not charged)



Hydrophobic Amino Acids (**water-fearing**)

Folding Proteins in Water

Proteins must always fold into the same shape to do their job correctly. One of the rules for folding proteins is based on how the amino acids will behave in water. Hydrophobic amino acids will avoid water molecules. Hydrophilic amino acids will be attracted to water molecules. Let's practice folding a protein with this rule!

1. Build the protein chain below with the 12 amino acids shown. Keep the amino end (black) to the left as you build.

1	2	3	4	5	6	7	8	9	10	11	12
Asn	Val	Met	Ile	His	Ser	Thr	Glu	Val	Trp	Met	Val

**Fold this protein as if it were in water ?
Students can show what they know!**

One possible answer is shown:

- **Yellow hydrophobic** amino acids have side chains placed away from water.
- **All hydrophilic** amino acids have side chains facing towards water.

Amino Acid Info



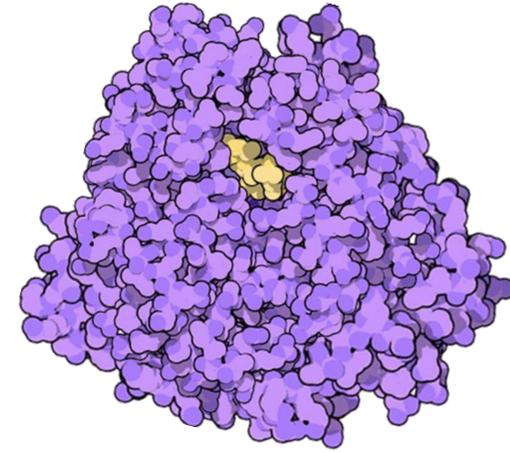
Using these MIT Edgerton Center protein models here is...

A Short Lesson on the Effects of Genetic Susceptibility On Environmental Health

**Three Factors That Influence
the Severity of a Person's
Environmental Health Problem**



Special thanks & credit goes to my colleague, Amanda Gruhl Mayer, PhD for the CYP variants literature research. Dr. Mayer was a major contributor to design of this lesson in our "Genes and Health" Booklet



CYP Proteins and Health:

1. What are Cytochrome-P450 (CYP) proteins?

CYP proteins are enzymes that metabolize molecules like drugs, hormones, and toxic compounds:

Drugs

- pain killers
- antibiotics
- antidepressants

Hormones

- testosterone
- estrogen

Toxic Compounds

- pesticides
- cigarette smoke
- diesel exhaust

2. How do CYP proteins work?

CYP proteins in the liver add an oxygen atom to drugs, hormones, and toxic compounds to help eliminate them from the body.

3. How do CYP proteins affect health?

Differences in the amino acid sequence of CYP proteins can have significant health effects.

Let's model a CYP protein in three different people:

C: Carey is taking two different drugs that interact with each other

Y: Yeshana is trying to stop smoking and has a high risk of lung cancer

P: Paxton quit smoking last year and has a low risk of lung cancer

C

Carey



Carey is taking two different drugs that interact with each other.

Y

Yeshna



Yeshna is trying to stop smoking and has a high risk of lung cancer.

P

Paxton



Paxton was exposed to a toxin and has a high risk of liver cancer.

Molecules must be bound in the CYP protein active site before metabolism.
Build the CYP protein active site for Carey.

Carey



1	2	3	4	5	6	7	8	9	10
Ala	Ser	Thr	Gly	Gln	Arg	Cys	Trp	Phe	Leu

Find the CYP Protein Active Site Mat for Carey (purple).

Place the built protein chain on the mat.

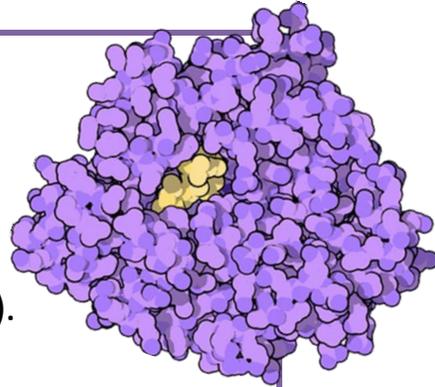
Different people can have different amino acids, or variants, in their CYP active sites.

Carey has Phe and Arg as variants.

Where is the active site?

The substrate (yellow) is inside the

active site in this CYP protein (purple).



Let's look at how CYP metabolizes toxic compounds.

Cigarette smoke is an environmental poison that contains many toxic compounds, including nicotine and benzo[a]pyrene.

- **Nicotine** increases the level of dopamine in the brain, increasing feelings of pleasure and well-being. When nicotine leaves the body, a person will crave more.
- **Benzo[a]pyrene** can be metabolized differently by CYP proteins. When the CYP protein adds an oxygen atom to benzo[a]pyrene it can turn into a carcinogen! This sometimes happens with toxic compounds.



Substrate



Substrate Chemical Group

Amino Acid Side Chain

Pink - (negative)	is most attracted to	Blue +
Blue + (positive)	is most attracted to	Pink -
Green +/- (partially charged)	is most attracted to	Green +/- Pink - Blue +
Yellow (not charged)	is most attracted to	Yellow

Rotate the nicotine card in Yeshna's CYP active site to maximize the attractions between chemical groups and amino acid side chains.
Where will nicotine bind in the active site?

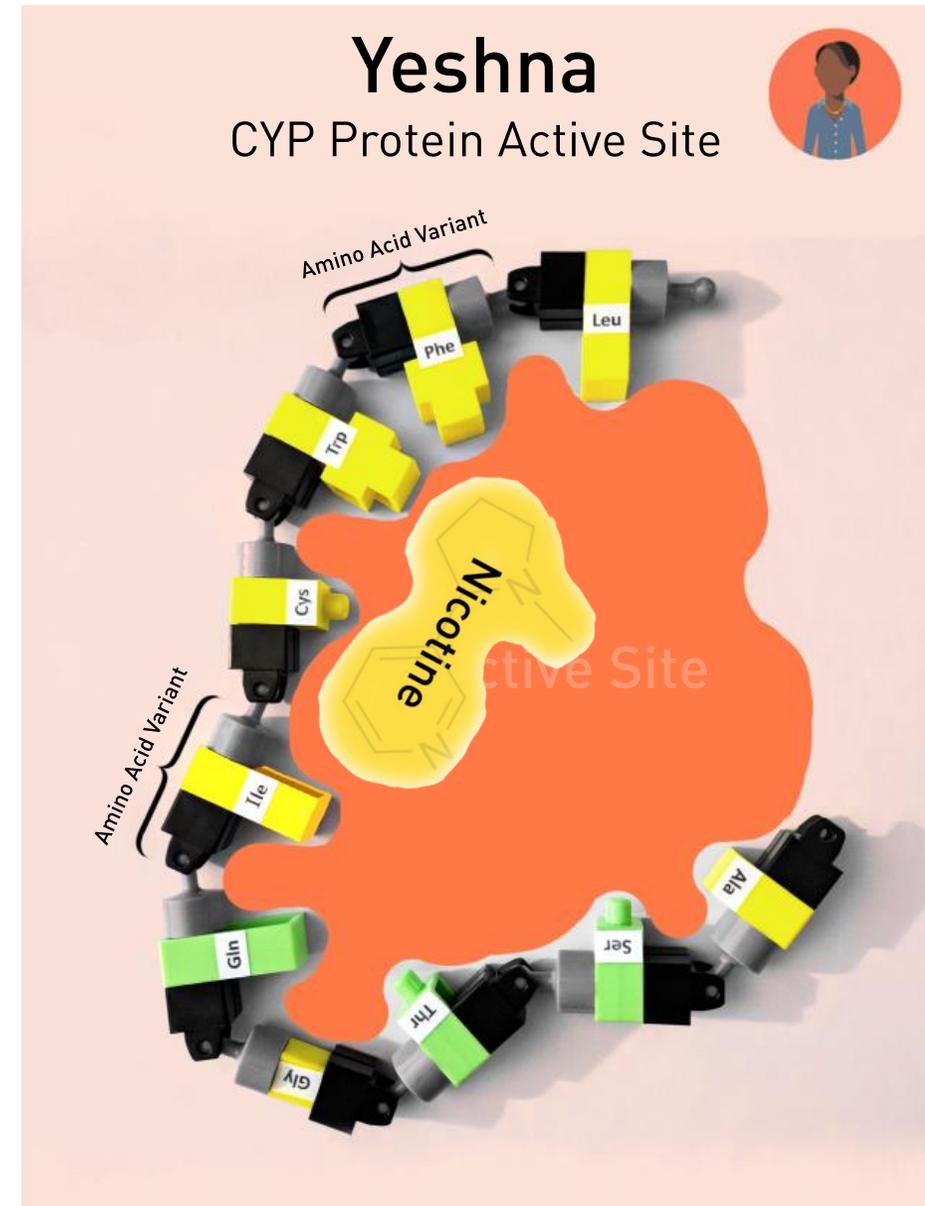
Amino Acid Side Chain



- Yellow hydrophobic nicotine is attracted to the large hydrophobic section of amino acids at the top and side.
- Nicotine can bind in multiple locations in the active site – it is metabolized very quickly.

CYP protein adds an oxygen atom to nicotine so it can be easily flushed out of the body in the urine.

If nicotine is metabolized quickly, will cigarette cravings increase or decrease?



Answer on next slide

**If nicotine is metabolized quickly, will cigarette
cravings increase or decrease?**

INCREASE

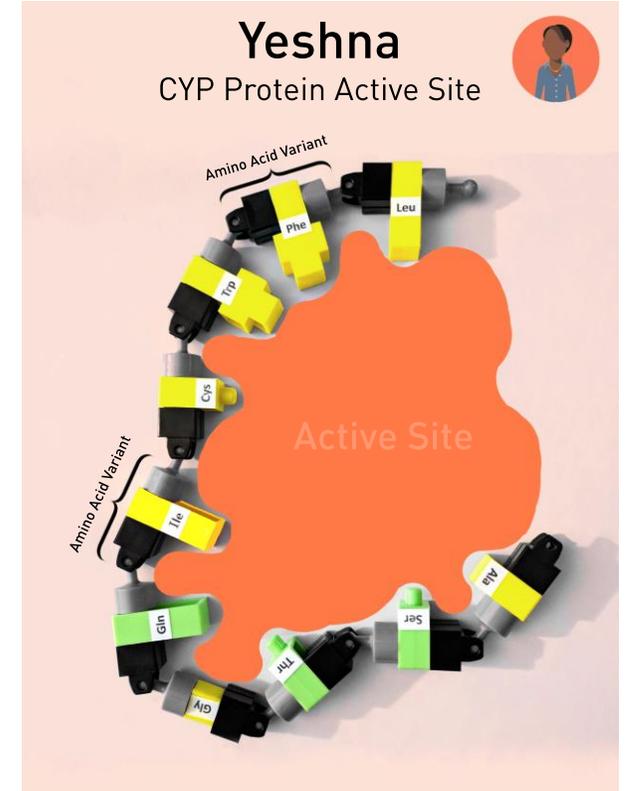
The nicotine is being metabolized more
quickly and leaving the body sooner.

Substrate



Substrate Chemical Group		Amino Acid Side Chain
Pink - (negative)	is most attracted to	Blue +
Blue + (positive)	is most attracted to	Pink -
Green +/- (partially charged)	is most attracted to	Green +/- Pink - Blue +
Yellow (not charged)	is most attracted to	Yellow

Amino Acid Side Chain



Benzo[a]pyrene is another toxic compound found in cigarette smoke. Let's see how CYP metabolizes benzo[a]pyrene differently.

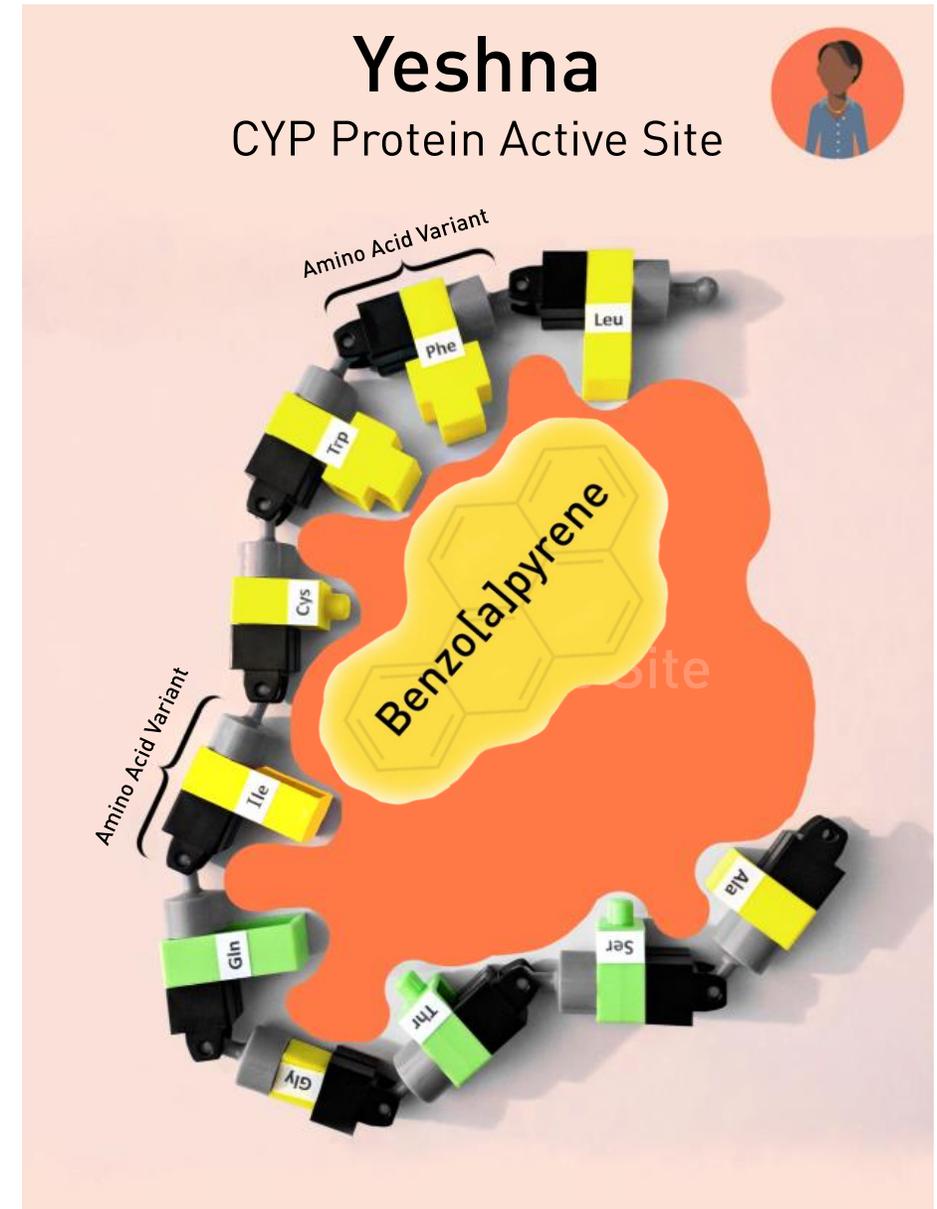
Rotate the benzo[a]pyrene card in Yeshna's CYP active site to maximize the attractions between chemical groups and amino acid side chains.

Where will benzo[a]pyrene bind in the active site?

Yellow hydrophobic benzo[a]pyrene is attracted to large hydrophobic section of amino acids at the top and side.

When the CYP protein adds an oxygen atom to benzo[a]pyrene it turns into a carcinogen!

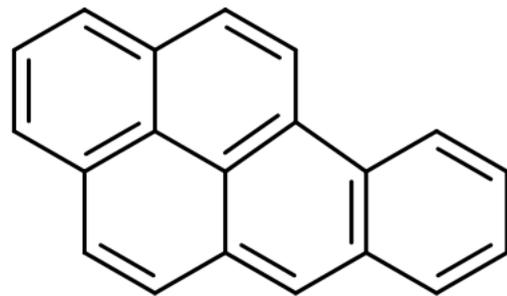
If benzo[a]pyrene is metabolized quickly, will cancer risk increase or decrease?



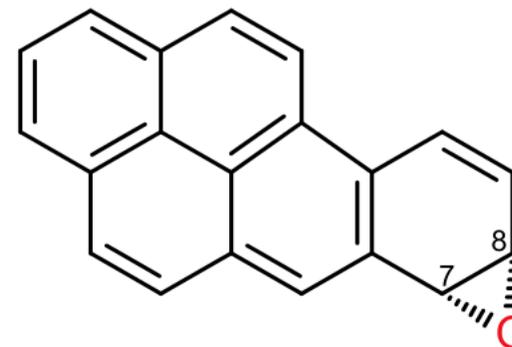
If benzo[a]pyrene is metabolized quickly, will cancer risk increase or decrease?

INCREASE

More benzo[a]pyrene is being made into a carcinogen,
so the cancer risk increases.



benzo[a]pyrene

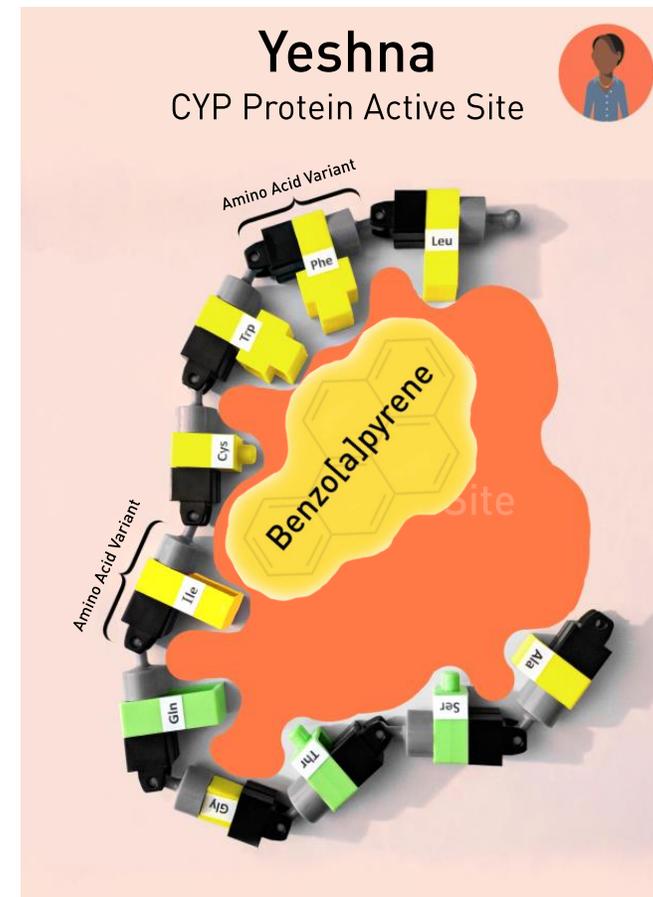


(+)benzo[a]pyrene-7,8-epoxide

Yeshna

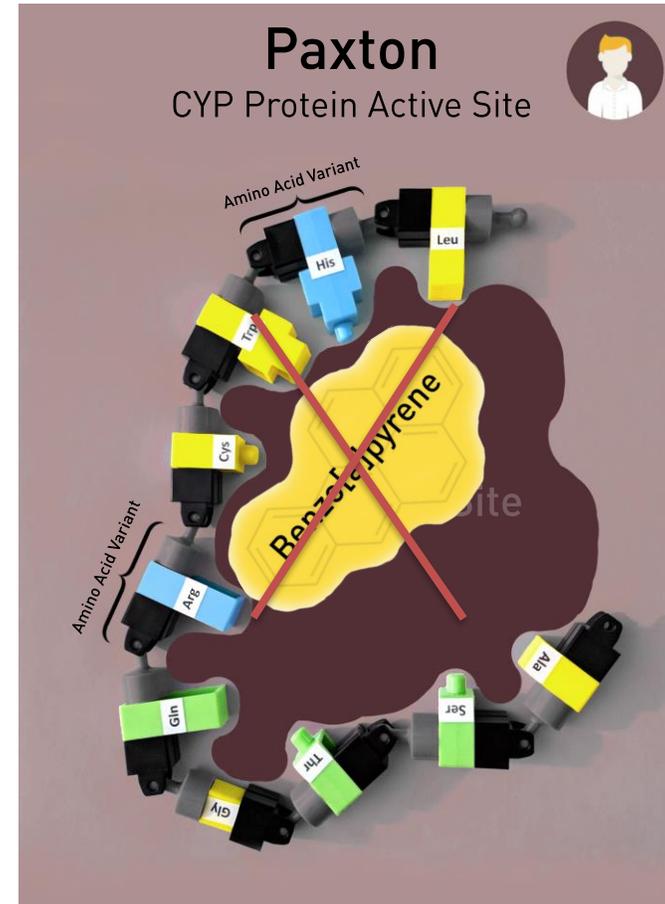
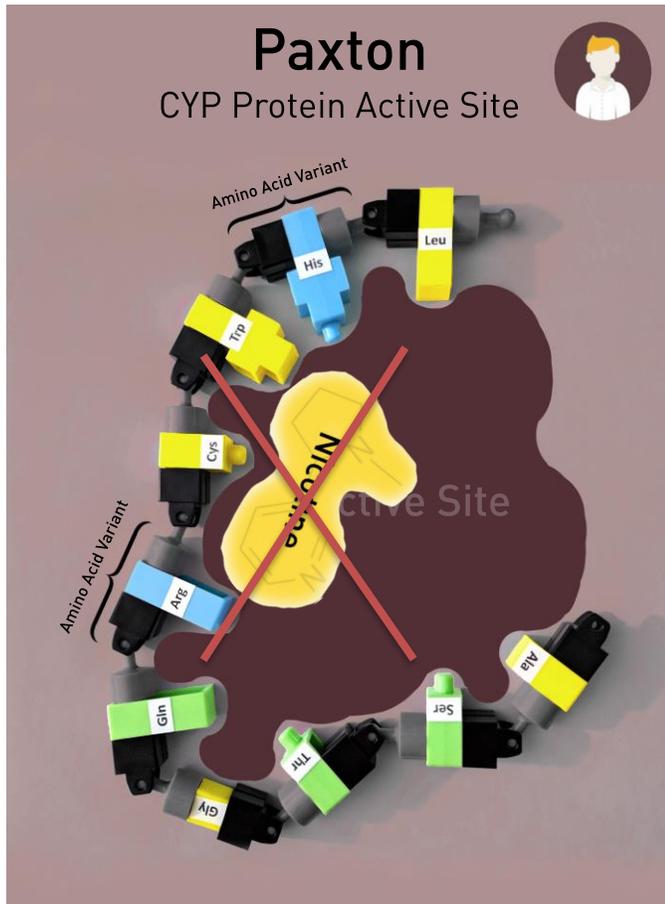
Metabolizes nicotine very well. The nicotine will leave her body quickly and increase cigarette cravings.

Metabolizes benzo[a]pyrene very well. She will have more carcinogens in her body.



Paxton

Metabolizes nicotine poorly. The nicotine will stay in his body longer and decrease cigarette cravings
Metabolizes benzo[a]pyrene poorly. He will have fewer carcinogens in his body.



**Compare Yeshna and Paxton.
How do their CYP variants affect their
health with regard to smoking?**

YESHNA

will have a harder time quitting smoking and has a higher risk of lung cancer.

PAXTON

will have an easier time quitting smoking and has a lower risk of lung cancer.

SUMMARY:

**Yeshna and Paxton have different responses to smoking
because of their protein variants.**

This CYP Proteins & Health Lesson has been included in the MIT Edgerton Center Booklet “GENES and HEALTH[©]” The MIT DNA and Protein Models
“Teach Abstract Concepts in Concrete Ways[©]”
Active and Exploratory in Nature
Providing for Memorable Learning Experiences



COLLABORATION CREDITS

...and thanks for this opportunity to learn together !

- 1) **LEAH Knox Scholars Program:** A two-year internship program for rising high school juniors and seniors from backgrounds underrepresented in STEM fields (communities of color and low-income backgrounds) in the Greater Boston area providing a foundation for their future as leaders in the biomedical research field.

Project Collaborators for the 2020 LEAH Knox Scholars Program Summer Biotechnology Lab for First Years:

- MIT Graduate Student Teaching Assistants: Ryan Elbashir; Gabriella S Lopez Perez; Bryanna Isela-Inez Canales; and Karla Alejandra Montejo
- MIT Biology Dept Instructors: Drs. Mandana Sassanfar and Vanessa Cheung
- Health Resources in Action, Inc. LEAH Program Director: Lisa Aslan. Principle Investigators: Laurie Jo Wallace, and Lisa Wolff, and with student coordination by Brandon Morgan

LEAH Knox Scholars Program is funded in part by the NIH Grant # R25OD023756-01

- 2) **Environmental Health Sciences Teacher Summer Institute:** A long-running teacher professional development program for middle and high school science teachers in the Texas. This week-long series of daily workshops provides teachers with hands-on training and EHS content knowledge. Texas Teachers earn PDE credits.

Project Collaborators: The whole k-12 Team put together a terrific offering of a four day virtual program in amazing time.

- Prof. Robin Fuchs-Young, PhD. Texas A & M University, Principle Investigator

EHS Teacher Summer Institute is funded in part by the NIH Grant #R25ODO20219-01A1

3) **EMPOWER: Engaging Multi-Discipline Professional Opportunities for Women in Environmental Health:**

The EMPOWER summer camp is a partnership with the School of Public Health and College of Education and Human Development, which aims to provide high school students and teachers with a 2 week virtual research experience.

- Asst. Prof. Christa Young Wright, PhD. , School of Public Health, Georgia State University, Principle Investigator
- GSU Undergraduates participating with MIT collaboration: Mariah Stallworth, Mckeda Knight, Franki Algarin, Tran Nyguyen
- EMPOWER Partner Teacher: Dr. Usha Patke, North Atlanta High School

EMPOWER Program is funded by NIH Grant # R25ES030240-01A1

RESOURCES

<https://edgerton.mit.edu/DNA-proteins-sets>

Videos for different purposes from the playlist:

YouTube Playlist for all MIT DNA and Protein Set Instructional Videos: (For both educators and students)

<https://www.youtube.com/playlist?list=PLMvYhn9sjfL7YXxpN-6ImvzZuWUS7Fdlk>

“Teacher to Teacher” Video: Connect the concepts of genes, proteins, and traits

<https://www.youtube.com/watch?v=U8eKuOhyzMg&list=PLMvYhn9sjfL7YXxpN-6ImvzZuWUS7Fdlk&index=17&t=0s>

“Summarizing the Content” Video: Introduction to Amino Acids:

<https://www.youtube.com/watch?v=tXLXDr8QhOI&list=PLMvYhn9sjfL7YXxpN-6ImvzZuWUS7Fdlk&index=2&t=0s>

“How To” Videos: Designed to help everyone learn how to build it right.

https://www.youtube.com/watch?v=cuZa_9X1myA&list=PLMvYhn9sjfL7YXxpN-6ImvzZuWUS7Fdlk&index=2