CUREs for Introductory Biology: start small and think big!

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- Erika Vail- Laboratory Specialist WSU

Outline of Presentation – Workshop

- Inspiration
  - Beach Mice
  - (Bugs and Snakes)
  - Ducks and Worms
- Innovation
  - Birds and Frogs

What is the problem we are trying to solve?

- Introduction to Animal Biology
  - Traditional – March through the phyla
    - Memorization
    - Disconnected units
    - Inconsistencies with labs

Think about a course you teach can the historical legacy – is there something that is taught that way just because it has “always been taught that way?”

Inspiration

- Replace with critical thinking, scientific reasoning and connections among levels of biological understanding
  - Molecular, Cellular and Genetics to Evolution and Ecology
  - Integrate lecture (more based on chemistry of life and the “small” scales of biology) with organismal biology
  - Replace one – week labs with multi-week thematic units

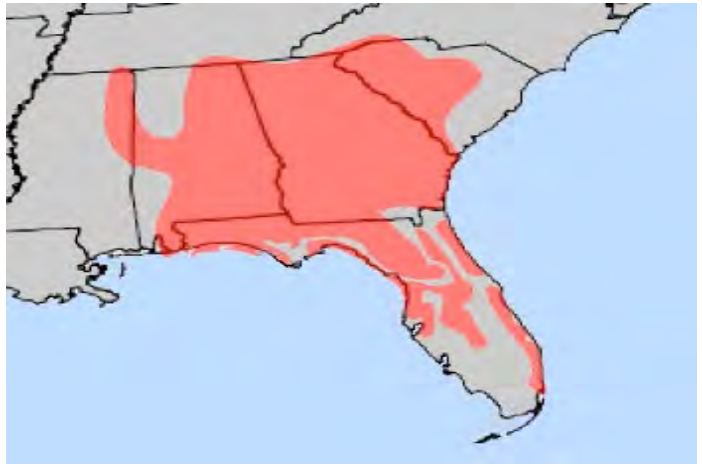
The Case of Fur Color Evolution in Beach Mice

slide version 2.0

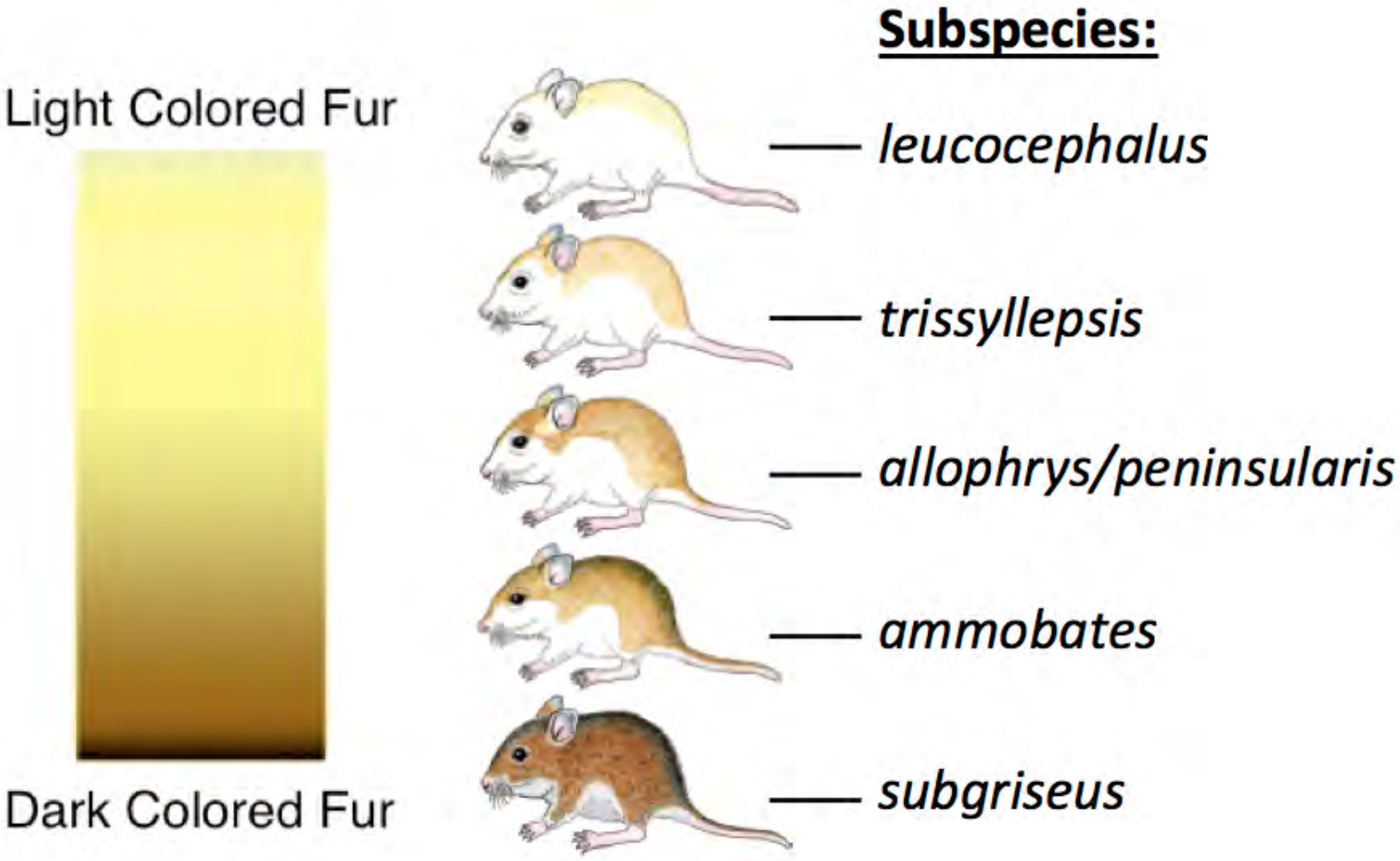
www.evo-ed.com

Fact Sheet:
Peromyscus polionotus

- **Common names:** Beach Mouse or Old Field Mouse.
- **Location:** Southeastern U.S.A.
- **Habitat:** Sand burrows in dunes or old fields.
- **Home-range:** ~1000 m^2
- **Breeding:** Monogamous pair-bonding. Litters of 2-8 pups, every 30 days.
- **Lifespan:** 9-12 months.



Fur Color:


Subspecies:
Light Colored Fur
leucocephalus
trissyllepsis
allophrys/peninsularis
ammobates
subgriseus
Dark Colored Fur

How are populations of these sub species distributed within the range of the Beach Mouse?

Question:

Assuming that ancestral populations of beach mouse had dark brown fur, what could have happened to explain the occurrence of light-colored coastal sub-species?

The Ecology of Fur Color in Beach Mice

Implementation – Week 1

- Students readily grasp the idea of camouflage and predation

- Practice Using the Scientific Method
  - Make hypotheses and predictions
  - Test in the laboratory or online
    - Easily adapted with COVID-19
  - Read peer-reviewed scientific literature

Is there a good gate-way study system you can use to introduce the process? What can students with a limited background relate to easily?

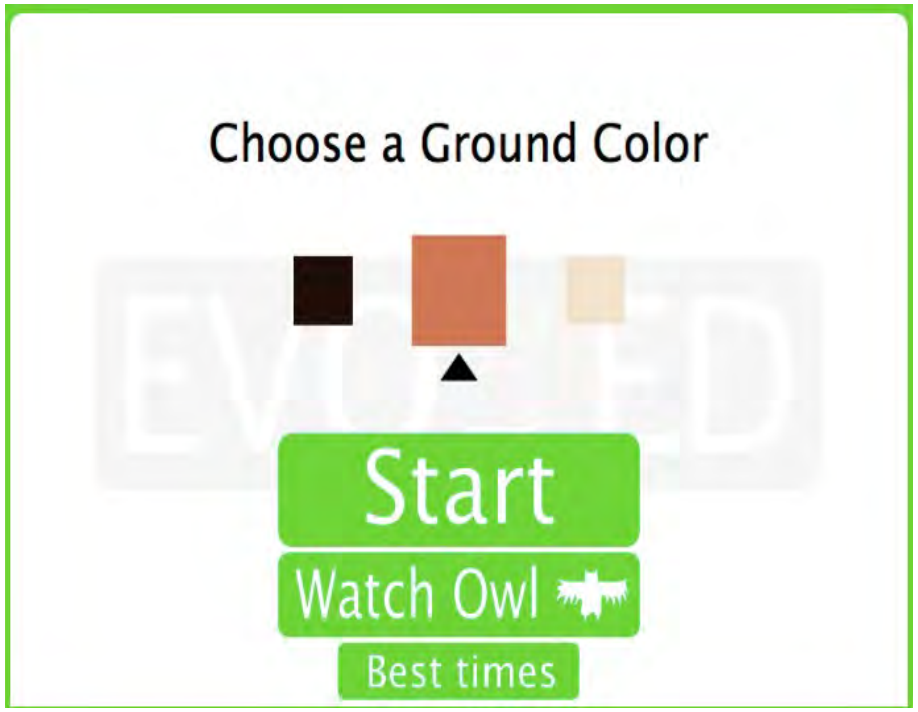
Predator-Prey Experiment

(Online Simulator)

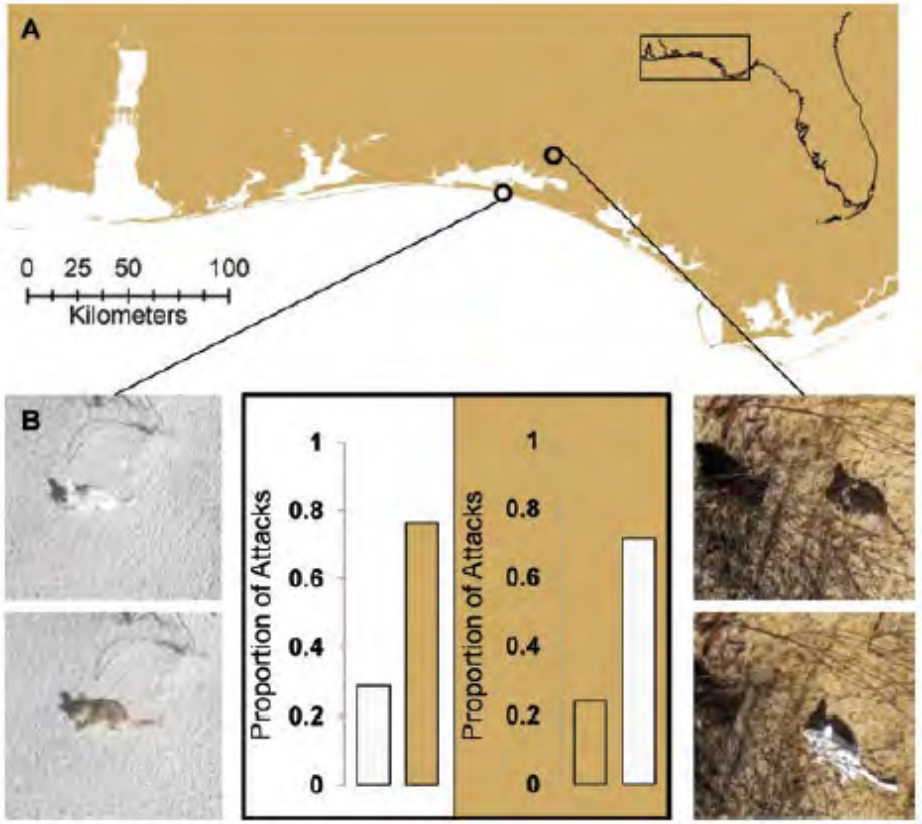
- You can replicate the predator-prey experiments yourself.

Visit: http://www.evo-ed.com/Pages/Mice/OwlandMice/OwlandMice.html

- Watch an owl catch mice on different soils – or play the role of the predator yourself and test your hunting skills.



Predation Study – Clay Mice



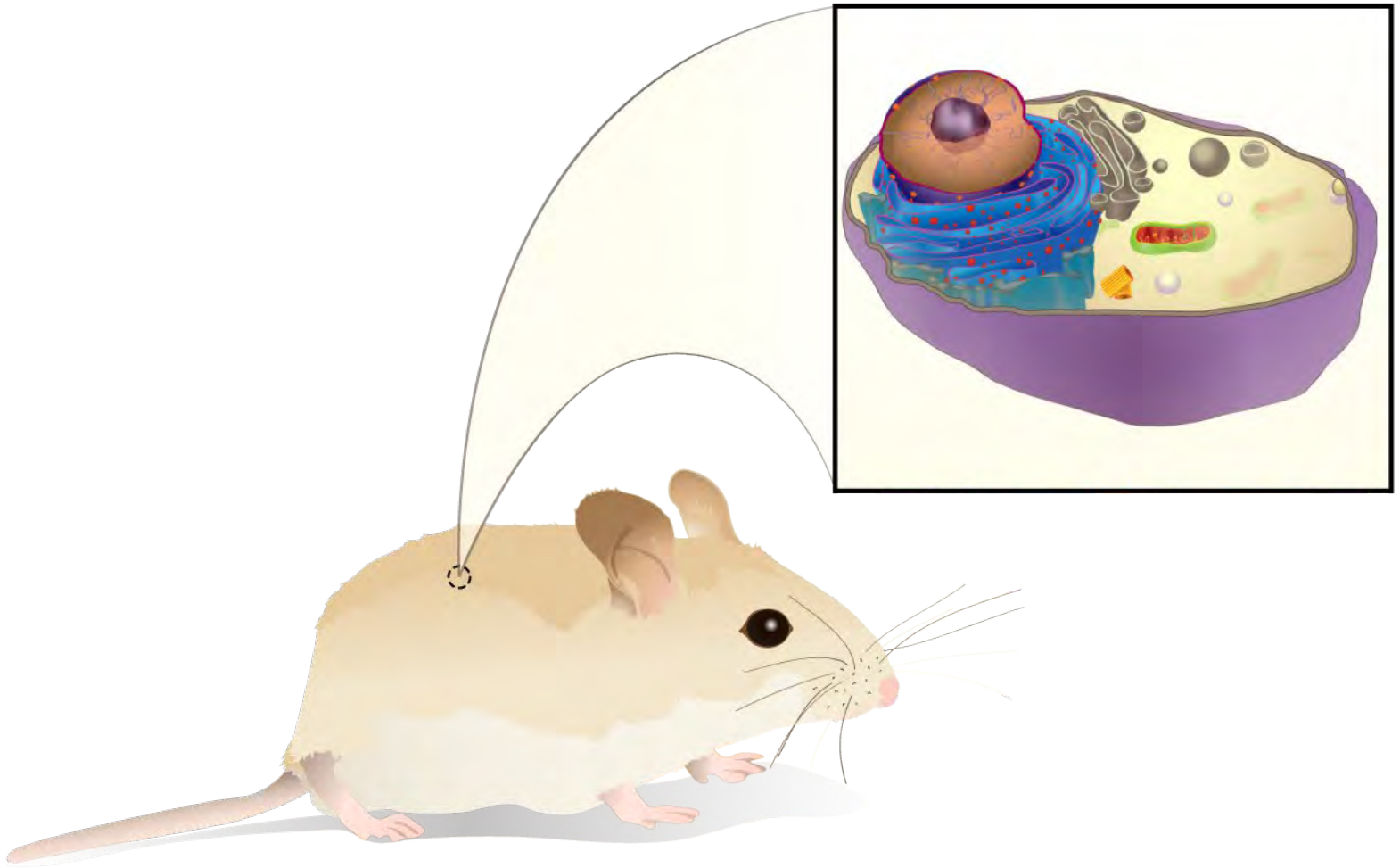
(A) Two locations with different color soil where predation on clay mice was tested. **(B)** Most attacks in light soil environments were on dark mice; most attacks in dark soil environments were on light mice.

Implementation – Week 2

- Build on Week 1
- Integrate with Lecture
  - Chemistry of Life, Molecular and Cell Bio
    - Macromolecules
    - Parts of a Cell
    - Cell Communication
  - Microscope lab
    - Parts of a cell
    - Hair color
    - Scientific Paper Discussion

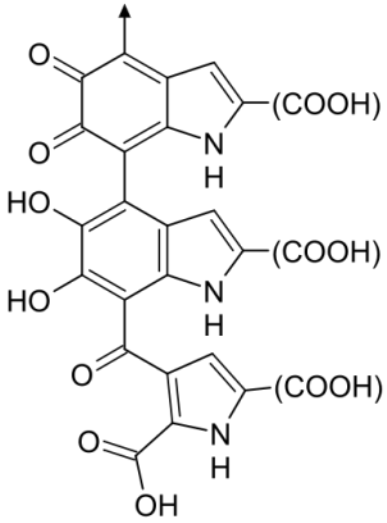
How can you reimagine an existing lab to reinforce or fit together with the theme of a unit? How can you make different techniques relate to the topic and reinforce one another?

The Cell Biology of Fur Color in Beach Mice



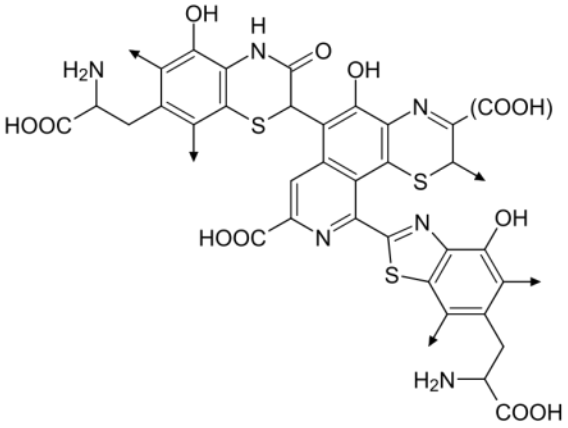
Hair Color

- Two pigments.
  - Eumelanin
  - Pheomelanin



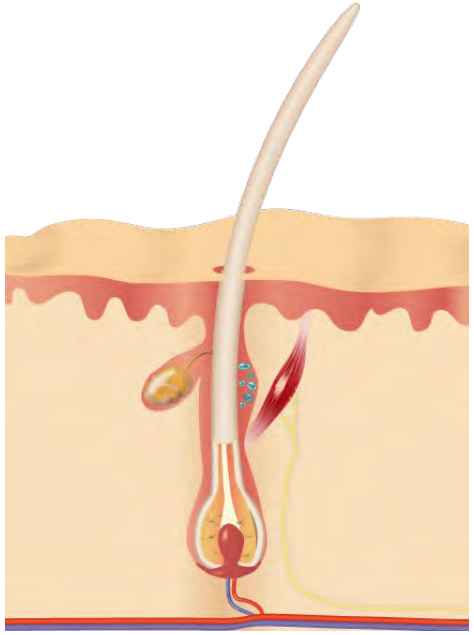
Eumelanin

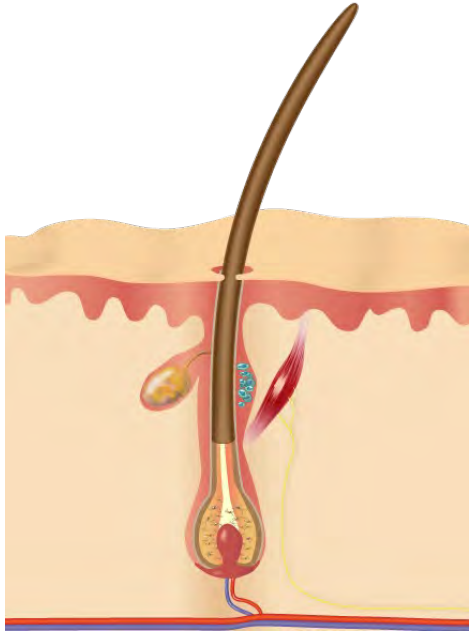
Image: Roland Mattern



Pheomelanin

Image: Roland Mattern

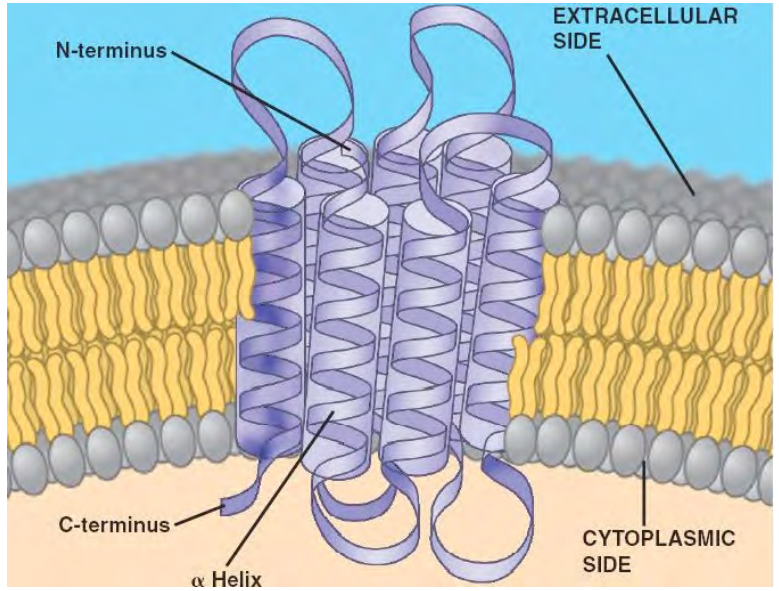




When is eumelanin produced?

- A transmembrane protein, the melanocortin-1-receptor (MC1R) is stimulated by a hormone called the alpha-melanocyte stimulating hormone (α-msh).

- When the MC1R protein is stimulated by α-msh, lots of eumelanin is produced.



A transmembrane protein: Image 7.8 from Biology 8th Ed. (Campbell and Reece)

How is eumelanin produced?

- When the MC1R protein is stimulated, it facilitates cAMP production (not pictured).

- cAMP is a molecule commonly used in the positive regulation of gene expression. Lots of cAMP within a melanocyte cell will facilitate the expression of at least four genes: ***c(tyr), Tyrp1, Tyrp2, p***

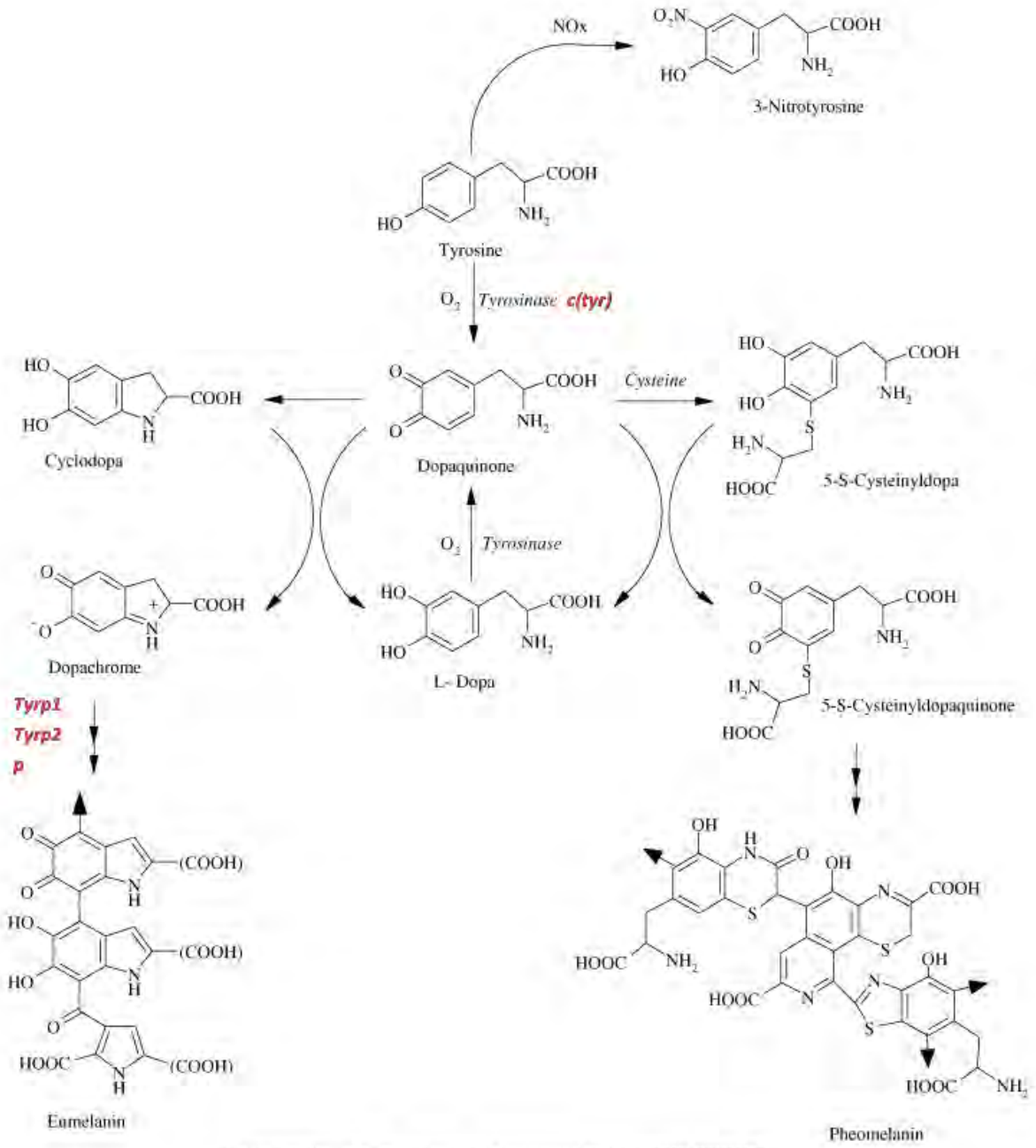


Image adapted from: http://www.sciencedirect.com/science/article/pii/S0021967307010199

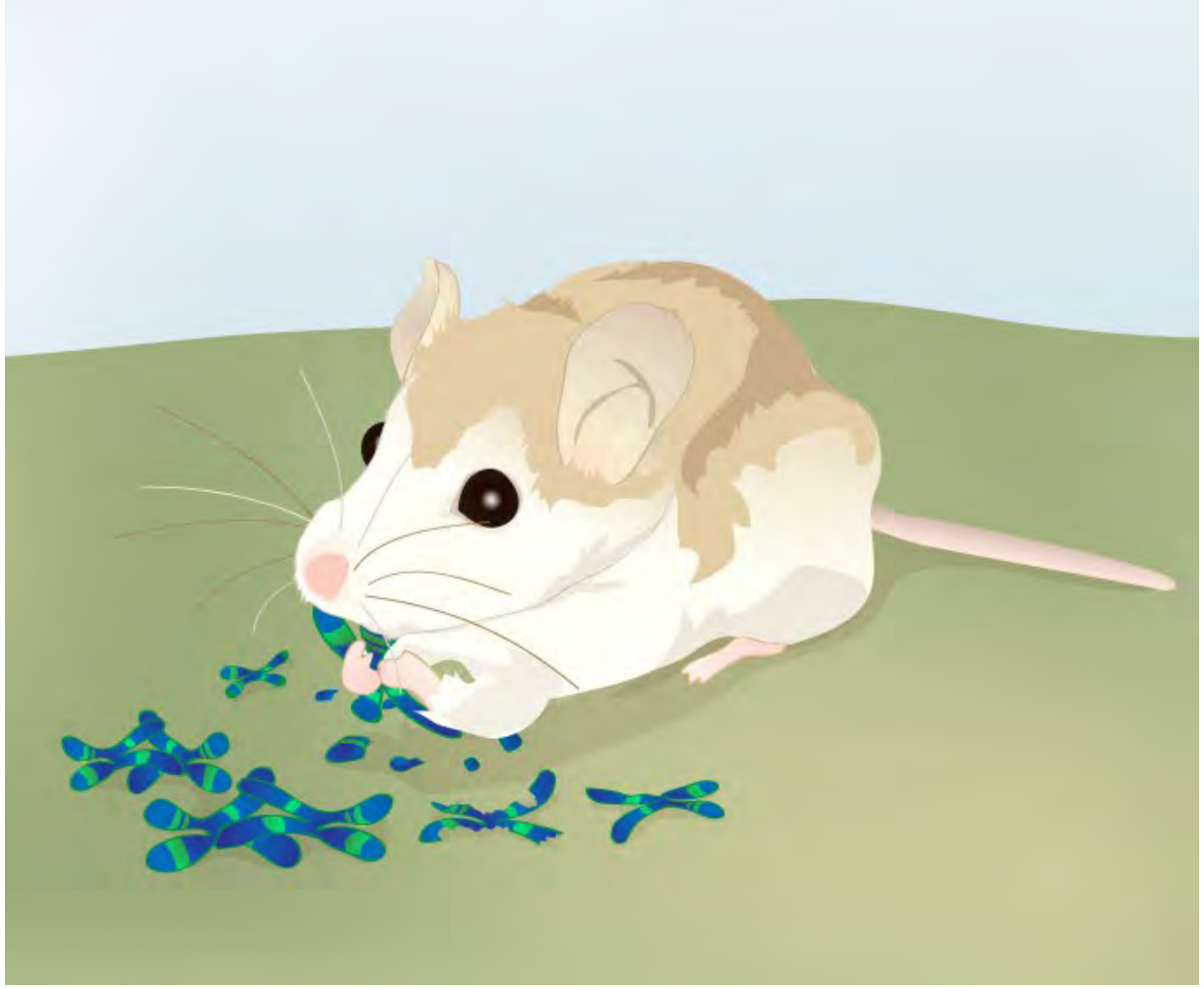
Implementation – Week 3

- Central Dogma and Gene Expression

- Move beyond recognition and memorization to understanding and connecting
  - Computer Simulations of DNA Replication, Transcription and Translation
  - Reading Scientific paper
    - Build on the previous paper!

How can you use technology to address learning outcomes? How can you build in new procedures that prepare students for skills they need in the future?

The Genetics of Fur Color in Beach Mice



Substitution Mutation

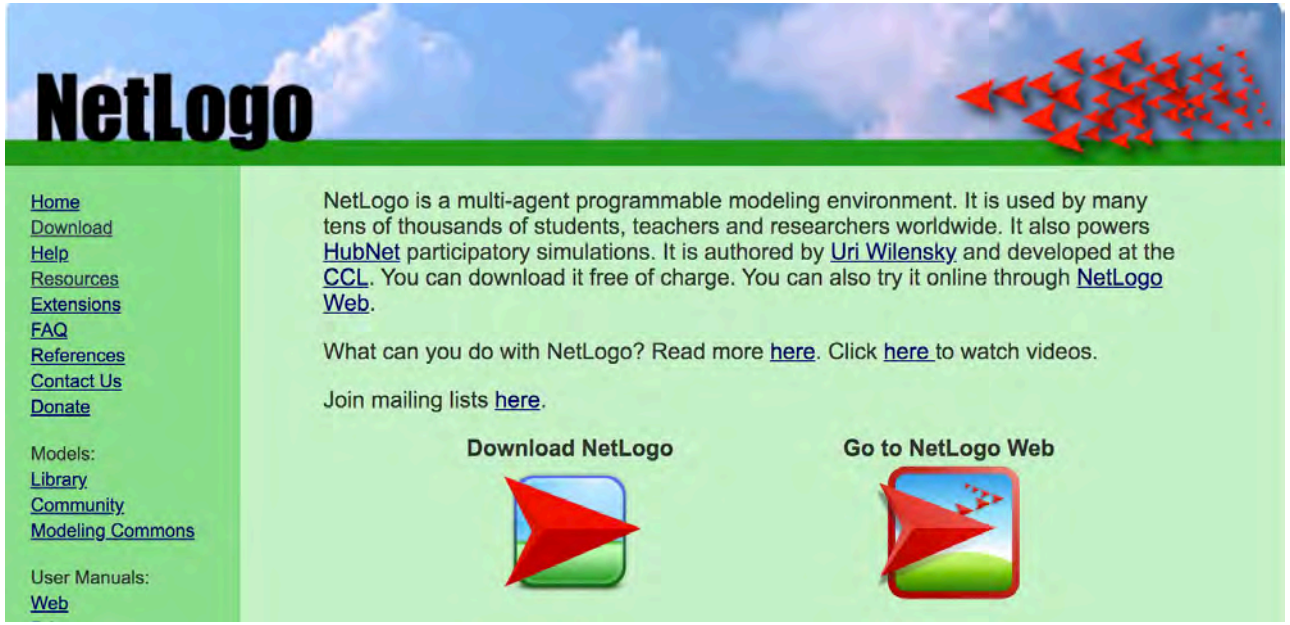
- A single nucleotide substitution mutation in the mc1r gene causes a change in amino acid #67 in the MC1R protein chain.
- When amino acid #67 is cysteine, the MC1R protein is unable to effectively bind the α-MSH. This changes the pigment pathway and eumelanin is not produced.

```
Amino Acids ...IleThrLysAsnArgAsnLeuHisSer...
Nucleotides ...ATCACCAAAAACCGCAACCTGCACTCG...

Amino Acids ...IleThrLysAsnCysAsnLeuHisSer...
Nucleotides ...ATCACCAAAAACTGCAACCTGCACTCG...
```

Computer Simulation

http://www.netlogoweb.org/launch#http://www.netlogoweb.org/assets/modelslib/Curricular%20Models/BEAGLE%20Evolution/DNA%20Protein%20Synthesis.nlogo



Research – Level Software

Agent Based Model – Incorporates “Random Chance” every simulation is different

Real – Life Example!

A Single Amino Acid Mutation Contributes to Adaptive Beach Mouse Color Pattern

Hopi E. Hoekstra,[1*] Rachel J. Hirschmann,[1] Richard A. Bundey,[2]
Paul A. Insel,[2] Janet P. Crossland[3]

Natural populations of beach mice exhibit a characteristic color pattern, relative to their mainland conspecifics, driven by natural selection for crypsis. We identified a derived, charge-changing amino acid mutation in the melanocortin-1 receptor (*Mc1r*) in beach mice, which decreases receptor function. In genetic crosses, allelic variation at *Mc1r* explains 9.8% to 36.4% of the variation in seven pigmentation traits determining color pattern. The derived *Mc1r* allele is present in Florida's Gulf Coast beach mice but not in Atlantic coast mice with similar light coloration, suggesting that different molecular mechanisms are responsible for convergent phenotypic evolution. Here, we link a single mutation in the coding region of a pigmentation gene to adaptive quantitative variation in the wild.

The identification of the specific molecular changes underlying adaptive variation in quantitative traits in wild populations is of prime interest (*1*, *2*). Pigmentation phenotypes are particularly amenable to genetic dissection because of their high heritability and our knowledge of the underlying developmental pathway (*3*). In a series of classic natural history studies (*4*, *5*), Sumner documented pigment variation in *Peromyscus polionotus*, including eight extremely light-colored "beach mouse" subspecies, which inhabit the primary dunes and barrier islands of Florida's Gulf and Atlantic coasts (*6*). This light color pattern is driven by selection for camouflage (*7*, *8*) as major predators of *P. polionotus* include visual hunters (*9*). Because the barrier islands on the Gulf Coast are <6000 years old (*10*), this adaptive color variation may have evolved rapidly.

We examined the contribution of the melanocortin-1 receptor gene (*Mc1r*) to this adaptive color patterning. MC1R, a G protein–coupled receptor, plays a key role in melanogenesis by switching between the production of dark eumelanin and light pheomelanin (*11*). Mutations in *Mc1r* have been statistically associated with Mendelian color polymorphisms in several mammalian species (e.g., *12*–*14*) and in natural variants of avian plumage (*15*, *16*).

[1]Division of Biological Sciences and [2]Department of Pharmacology, University of California, San Diego, La Jolla, CA 92093, USA. [3]*Peromyscus* Genetic Stock Center, Department of Biological Sciences, University of South Carolina, Columbia, SC 29208, USA.

*To whom correspondence should be addressed. E-mail: hoekstra@ucsd.edu

Implementation Week 4

- Genetics, Population Genetics, and Evolution
- Traditional Genetics Problems – Punnett Squares
- Natural Selection
  - Computer Simulation
  - Return to the Scientific Method – design experiment, collect and analyze data, interpret results
    - Assessments – Figures, Results and Discussion Sections modeled after scientific papers

How can you incorporate assessments that represent outcomes consistent with professional practice?

Mechanism: Alleles of mc1r Gene

- The mc1r gene has two alleles:

Allele ***R***

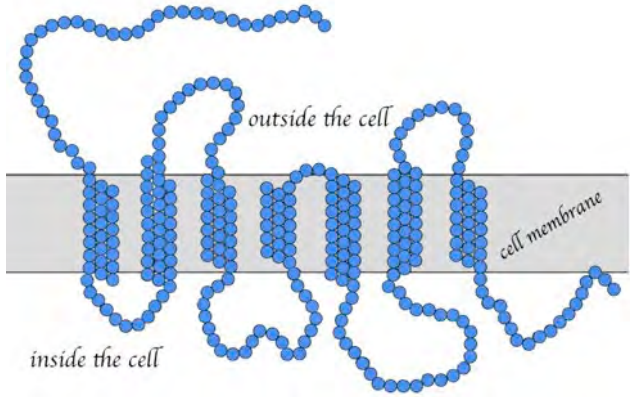
[Arginine at pos #67]

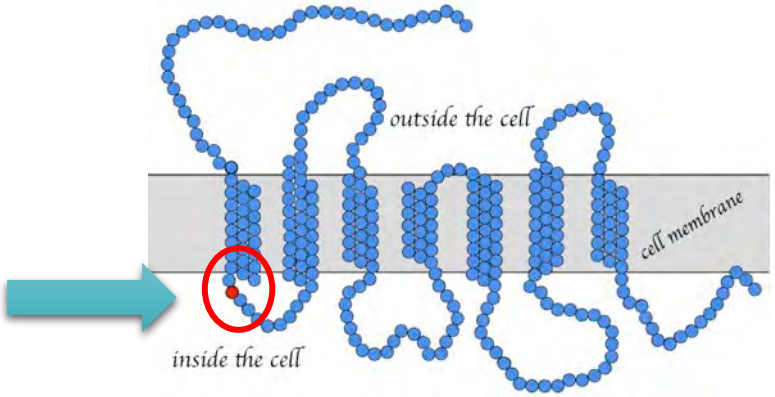
Codes for a functional MC1R protein.

Allele ***C***

[Cysteine at pos #67]

Codes for a non-functional MC1R protein.



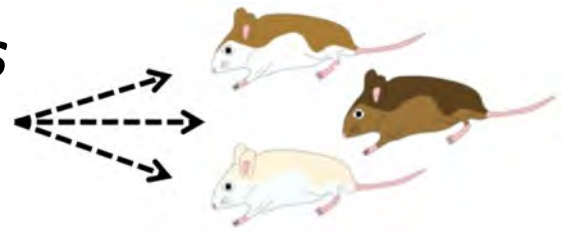


These genetic code for these two alleles differs by a single nucleotide substitution.

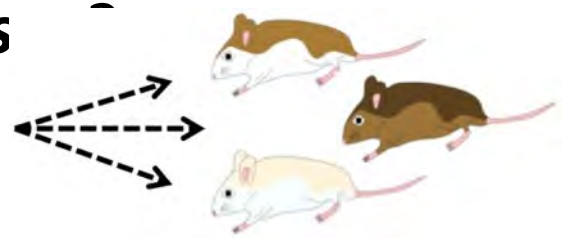
Observable Relationship: Genes vs. Fur Color

- Is there a relationship between the fur color of beach mouse individuals and the allele combinations (genotypes) they possess?

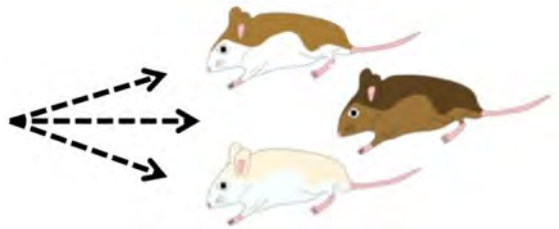
CC homozygous



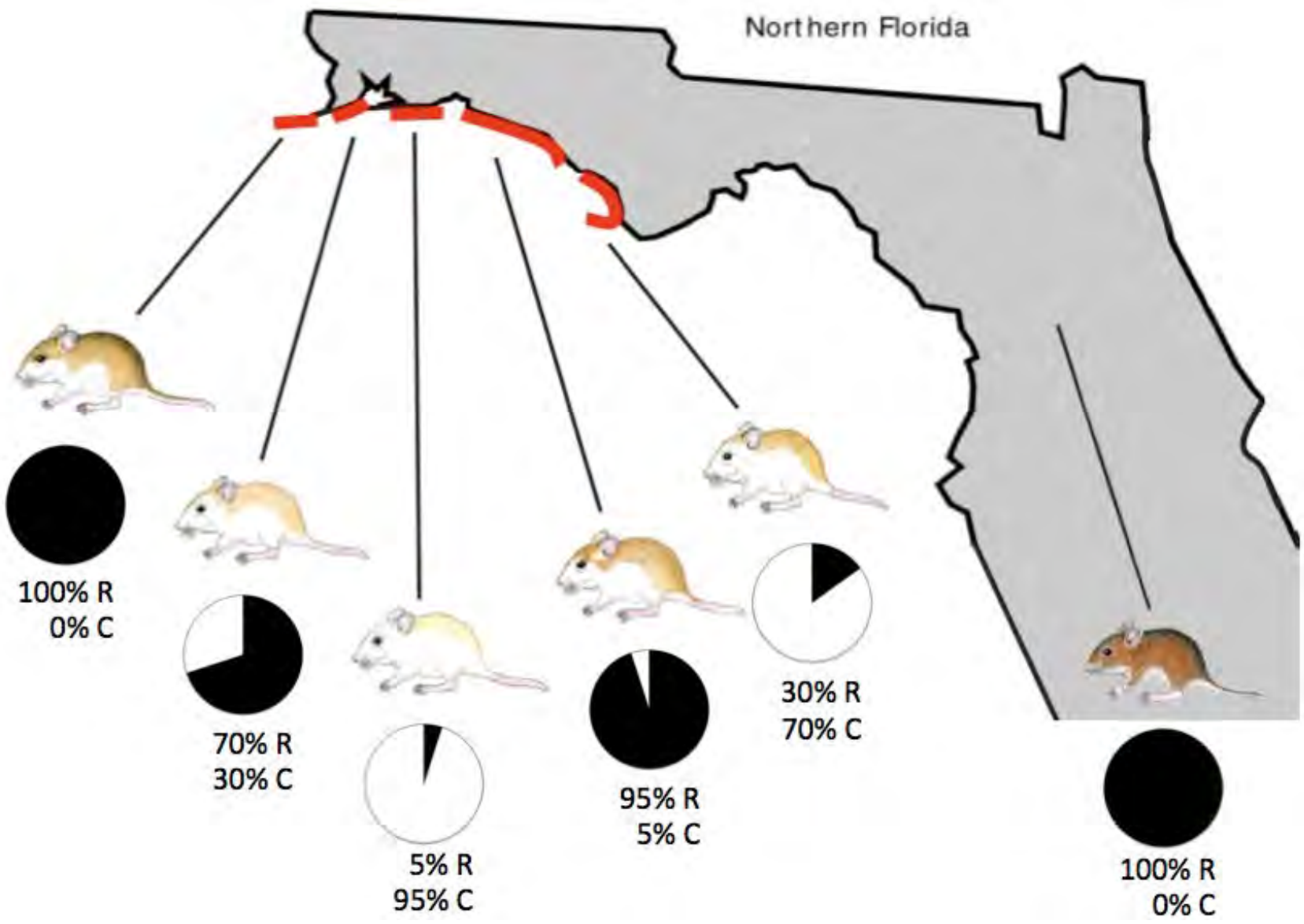
RR homozygous



RC heterozygous = ?



Actual Allele Frequencies



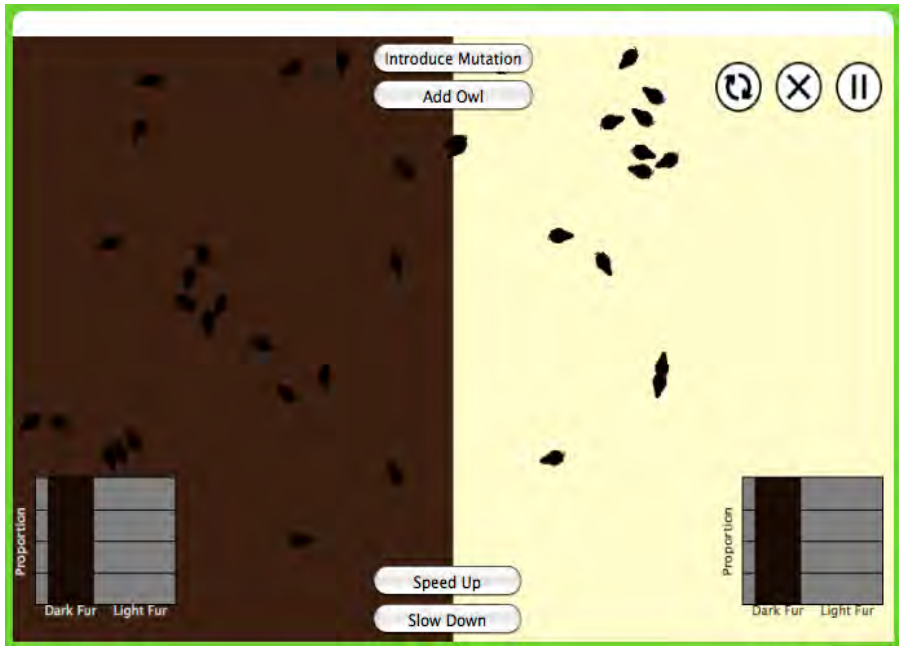
Colonize the Beach!

(Online Simulator)

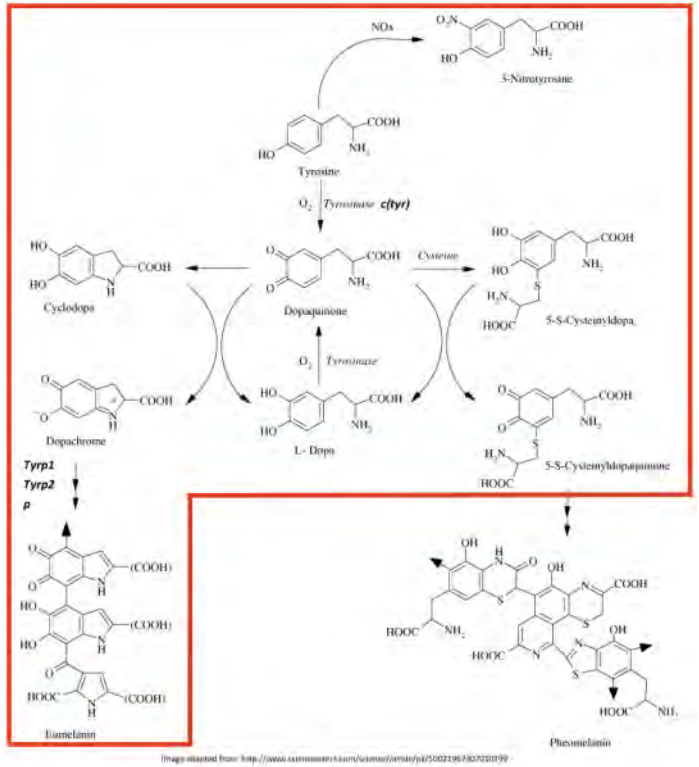
- You can experiment with population phenotype patterns with and without predation pressure.

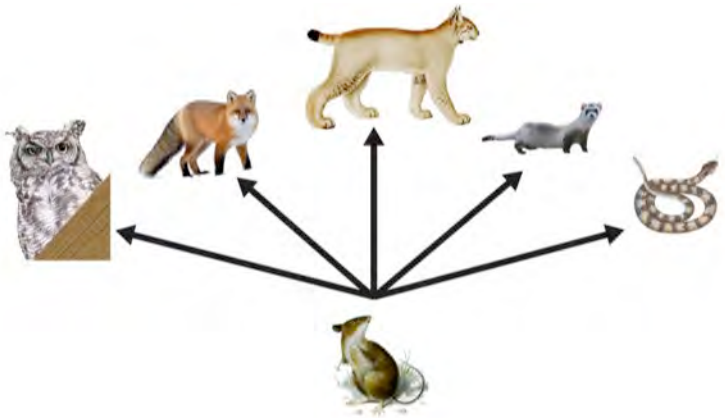
Visit: http://www.evo-ed.com/Pages/Mice/Beach/Beach.html

- Introduce a mutation to the population – then introduce a predator!
- What will happen if you found a new population…..



Summary and Application - Fur Color in Beach Mice





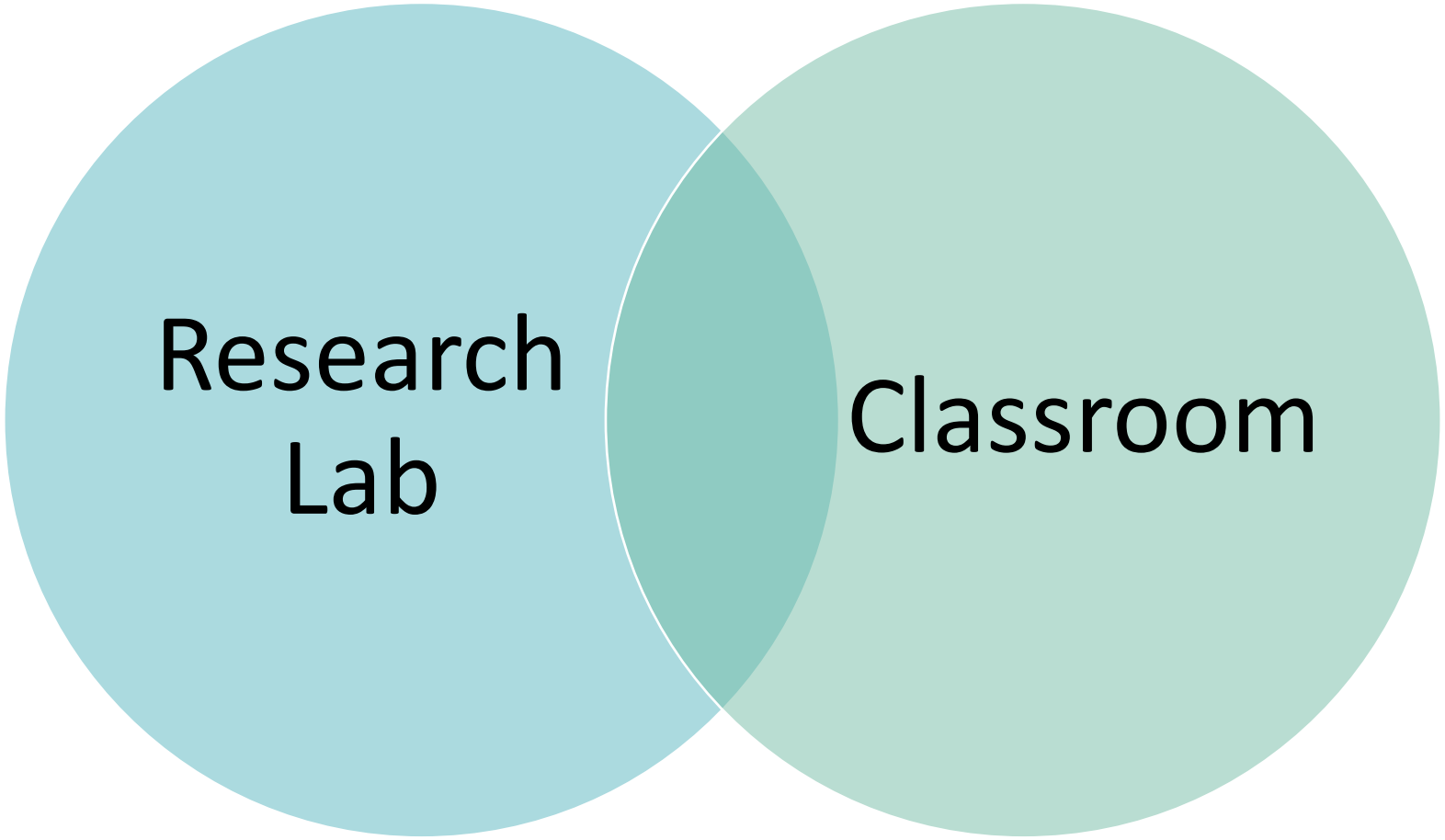
Amino Acids → ValSerLeuValGluAsnValLeuValValIleAlaIleThrLysAsnArgAsnLeuHisSerProMetTyrSerPheIleCysCysLeuAlaLeuSerAspLeuMetValSerIleSerLeuValLeuGluThrAlaIleIleLeuLeu

Nucleotides → GTGAGTCTGGTGGAGAATGTGCTGGTCGTGATAGCCATCACCAAAAACCGCAACCTGCACTCGCCCATGTATTCCTTCATCTGCTGTCTGGCCCTGTCTGACCTGATGGTGAGTATAAGCTTGGTGCTGGAGACGGCTATCATCCTGCTG

Amino Acids → ValSerLeuValGluAsnValLeuValValIleAlaIleThrLysAsnCysAsnLeuHisSerProMetTyrSerPheIleCysCysLeuAlaLeuSerAspLeuMetValSerIleSerLeuValLeuGluThrAlaIleIleLeuLeu

Nucleotides → GTGAGTCTGGTGGAGAATGTGCTGGTCGTGATAGCCATCACCAAAAACTGCAACCTGCACTCGCCCATGTATTCCTTCATCTGCTGTCTGGCCCTGTCTGACCTGATGGTGAGTATAAGCTTGGTGCTGGAGACGGCTATCATCCTGCTG

Course-Based Undergraduate Research Experiences (CUREs)



Course-Based Undergraduate Research Experiences (CUREs)

- Active learning that offers a scalable way for all students to obtain research experience early in college
- Levels the playing field and closes the gap for students from historically excluded communities
- Improve retention in STEM majors
  - “Unlike any other teaching method—just one well-run CURE taken early in college increases student persistence”.
- Offers all students an opportunity to be scientists, enable students to take intellectual ownership of their projects, and helps them identify as a scientist.

Handelsman et al. 2022 *Science* 376, 6597, 1057-1059

What to do with the rest of the semester?

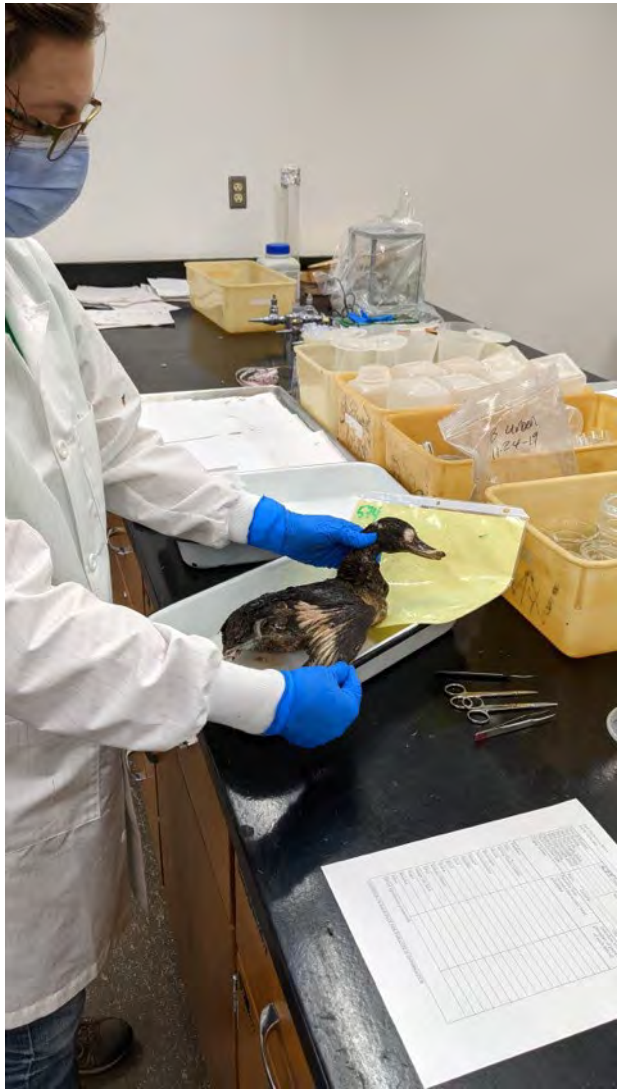
- Experiment with new units
  - Diversity of Life, Anatomy and Physiology
  - Dissection Skills
  - Ecology

  - Scientific Communication
    - Finding and reading scientific papers
    - Scientific Writing
    - Oral Presentations
    - Group Projects

Safety Considerations

- Biosafety Approval
  - Types of specimens and handling
  - Space considerations
  - Handling of waste
- Training
  - Video introduction & protocols in advance
    - Biosafety quiz prior to coming to lab
  - Review safety info in class
  - Proper PPE

In the classroom/research lab – Logistics



Vertebrate diversity & anatomy topics

Data collection and record keeping

- Host ID, measurements, locations

Invertebrate Diversity

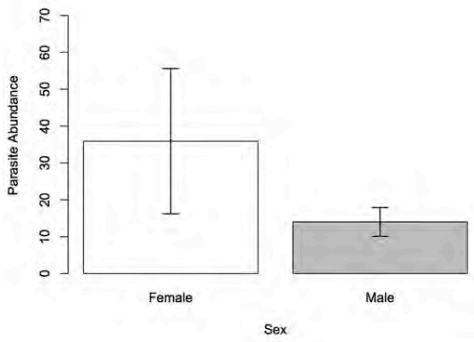
Parasite photographing & preservation
Parasite identification: Morphology

Instructors and Peer-Mentors

- Undergraduate Research Students
  - TA role – demonstrate techniques
  - Answer student questions
  - Identify safety concerns
  - Quality control data recording and parasite ID’s
  - Assist with parasite preservation
  - CLEAN UP!!!

Types of Assessments

- Oral presentations
  - Original research questions/hypotheses
  - Data analysis, stats, figures
  - Incorporation of peer-reviewed scientific literature
- “Practical Exams”
  - Biosafety, tools and techniques, animal diversity, anatomy – structure and function
  - Parasite ID – basic levels



Student Impact and Feedback

- Peer-mentors
  - Enjoyed the experience and thought it was extremely valuable
- Introduction to Animal Biology
  - Over 200 students in 9 sections across fall and spring semesters
  - Recruitment of future research students
  - Limited data to compare – but lower DFW rate than previous semesters
- Animal Parasitology (UWSP & WSU)
  - Students loved the experience and connection to existing research projects
  - Community created among the class and small groups
- All classes
  - Students can get overwhelmed at first but as courses progress see the purpose
  - Gave them insight into what research is really like

Student Impacts and Outcomes

Future Plans

- BIOL 160 Introduction to Animal Bio – course will no longer be taught at UWSP main campus
- What to do with all this?
- New course proposal
  - Department Approval – last week!
  - Critical thinking course – “BIOL 107: CUREs in Biodiversity Science and Biological Collections”
    - Critical Thinking General Education Course
    - “Applied Scientific Literacy”

Questions?

Do you have suggestions or comments?

Do you want to try this in your classroom?

Do you have a current research project you think might be “CURE-ABLE?”

Contact me! sorlofsk@uwsp.edu

What to do with the rest of the semester?

- Experiment with new units:
  - Phylogeny and Diversity of Life
    - Molecular Phylogenetics
      - DNA Extractions
      - PCR
      - Gel Electrophoresis

    - Combined with Beach Mouse Simulation Labs
      - Groups worked in molecular lab while others worked on computer simulations
      - Returned sequence data in time to implement in these labs
      - Molecular methods connected Beach Mice to other units of the course

What to do with the rest of the semester?

- Experiment with new units:
  - Ecology and Conservation Biology
    - Invertebrate Diversity and identification
    - Properties of Water and Water Chemistry
    - Field techniques
    - Statistical Analysis
  - Outdoor field trip labs
  - Combine data across sections and semesters

Improvements and Future Plans

Animal Parasitology - UWSP

- More dissections to increase dataset
- Student presentations as final assessment
- Longer lab sections - increase emphasis on preservation and data recording
- Slide making – start early!

Parasitology - WSU

- Group students more equally
- More dissections
- PCR earlier
- More in-class time for poster preparation

Winona State University
Biology
@biologyWSU · College & university

- Erika Vail- Laboratory Specialist WSU
- Research Mentors (Bates Lab)
  Carson Lovedale
  Hwmkong Lee (Brandon)
  Ayomide Oloyede (Tobi)

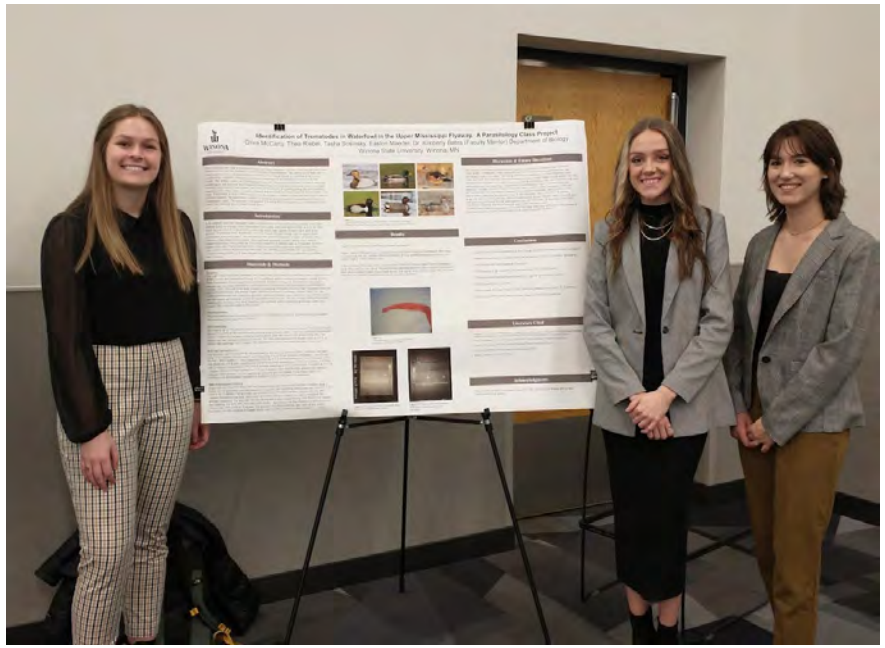
University of Wisconsin
Stevens Point

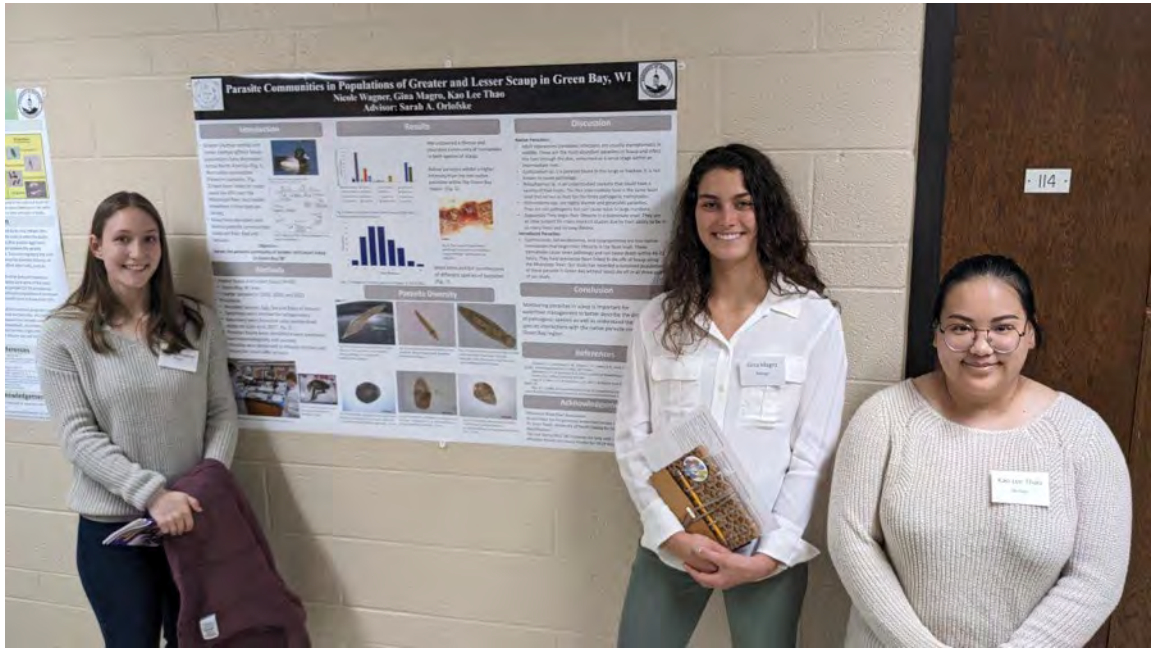
Challenges CUREs can solve

Research” intensive labs and capstones often don’t expect students to ask their own questions

- Lack meaningful group work
- Don’t result in important research outcomes

- Provides opportunities for students to present research to peers and public





Challenges with CUREs

- Current designs are limited (particularly in Parasitology)
- Challenges with research persist in classroom
  - Lack taxonomic training
  - Time consuming and tedious work

- Balance between lecture and lab – what essential content needs to be covered, why and how?

- Extra effort required for an in-class presentation vs. a symposium presentation

Curriculum Connections – UWSP

- Introduction to Animal Biology (5 credit, 3 hours lecture, 1 3hr lab/week)
  - 100 level, majors biology (Biology and Natural Resources Majors)
  - Invertebrate diversity, anatomy and physiology, ecology
  - 6 sections of 24 person labs with 2 different instructors
- Create a 5 week “Unit” on Parasitology of Waterfowl*
  - 2 weeks of dissection labs in the research lab
    - 12 students (other ½ of class participated in an online scientific literature assignment)
  - 1 week data analysis
  - 1 week presentation creation
  - 1 week group presentations

* This was their final CUREs project of the course. All labs were grouped into 4 CUREs projects

- Animal Parasitology (2 hours lecture 2-75 minute labs/week)
  - Upper-level elective
  - 24 students total and 1 instructor
  - Biology, Wildlife and Captive Wildlife majors/minors
  - Dissection Techniques, Specimen Collection and Parasite Diversity

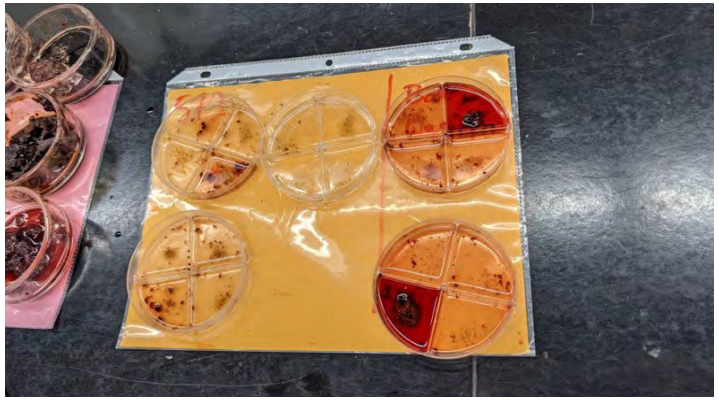
- Create Dissections and Slide Collection
  - 2 weeks of dissection labs in the research lab
    - ~9 students per 75-minute lab (Reduced lab size due to COVID
  - Specimen Collection – permanent slides turned in at the end of the semester

Parasitology- (4 credits, 3 Hours Lecture/week, 1- 3 Hour Lab/Week)

- 400 level, majors biology elective, high enrollment of Medical Lab Science Majors
- Mostly Human Parasitology with some important animal parasites
- 1 Section up to 24 Students. Typically has between 18-24.

- Create a 10 week “Unit” on Parasitology of Waterfowl*
  - 4 weeks of dissection labs in the research lab
    - 6 students per duck, each led by a trained student mentor (Capstone Research Student)
    - By Week 2- students were dissecting themselves with guidance from the mentors
  - 1 week staining and mounting
  - 4 weeks PCR/gel electrophoresis – sent good results to be sequenced
  - 1 week Poster Preparation

Dissection Techniques

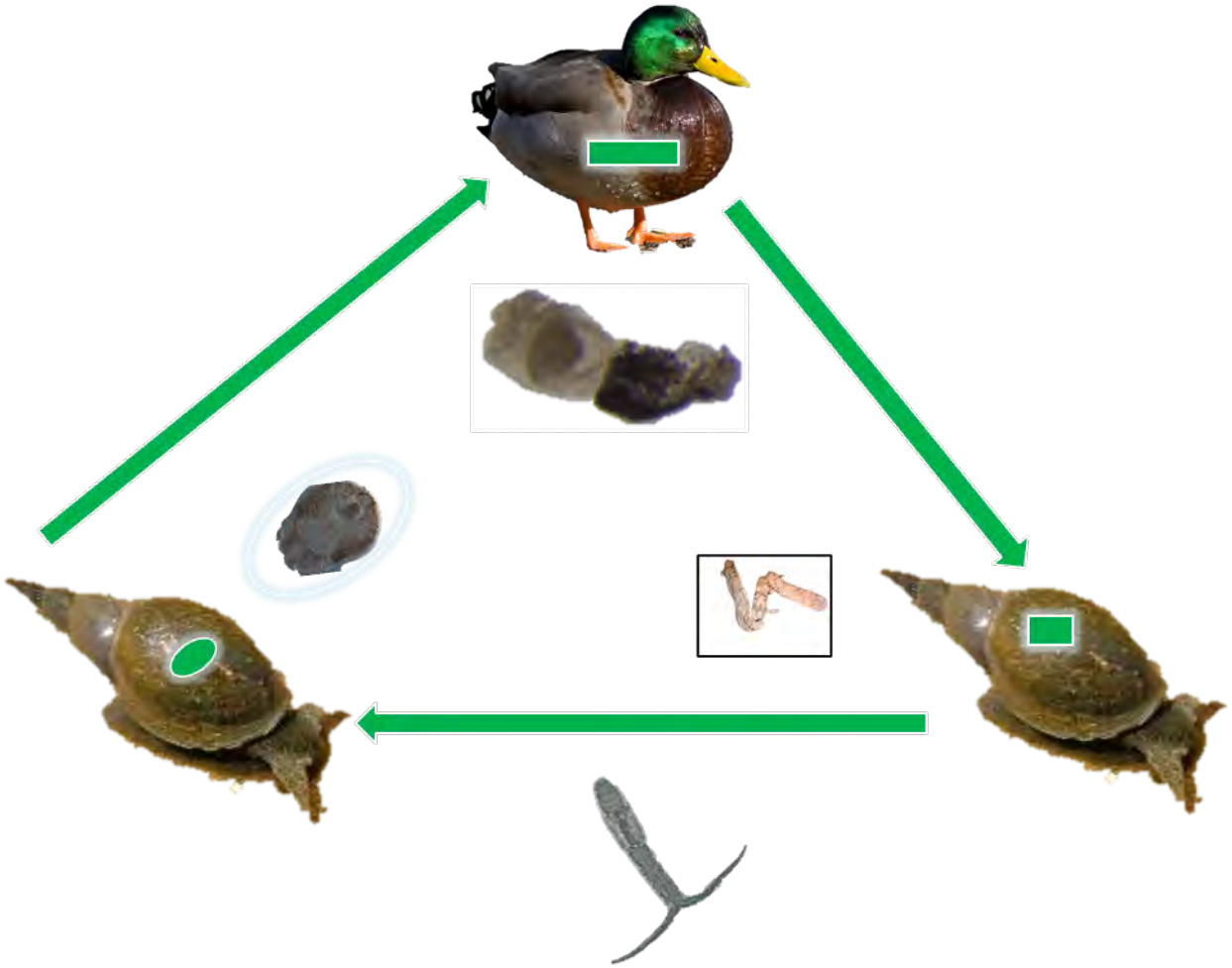


Introductions and Identity

Research Interests: Parasite and disease ecology and evolution

Teaching Roles: Majors and Non-majors Intro Bio, Parasitology, Senior Seminar, Ecology

General Parasite Life Cycle



Teaching – Research Life cycle

Implementation Activity

- What is one aspect of your background/experience/identity that informs and enriches your teaching?
- How does your teaching influence that part of your identity?
- How can you combine the two in a meaningful way?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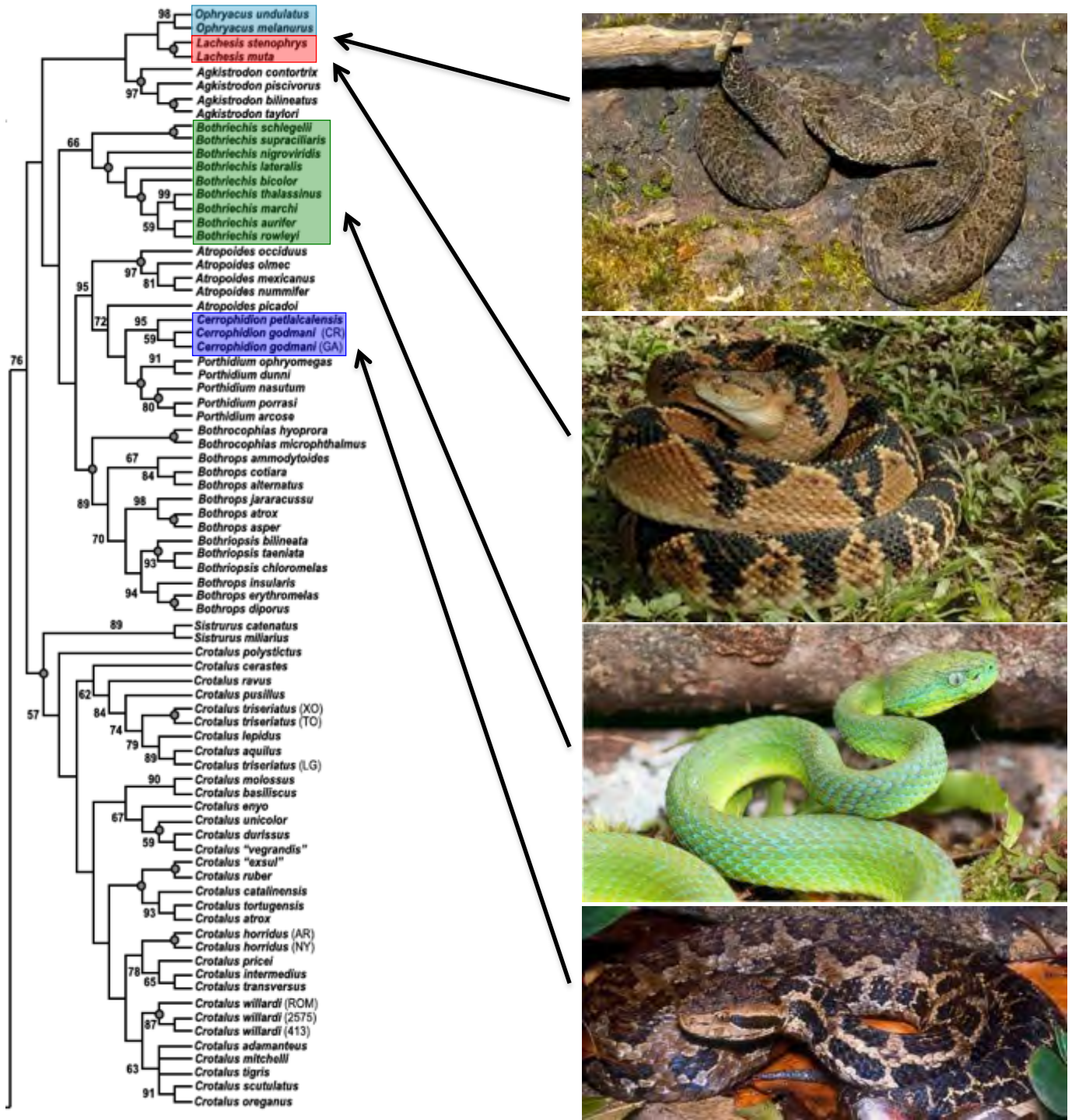
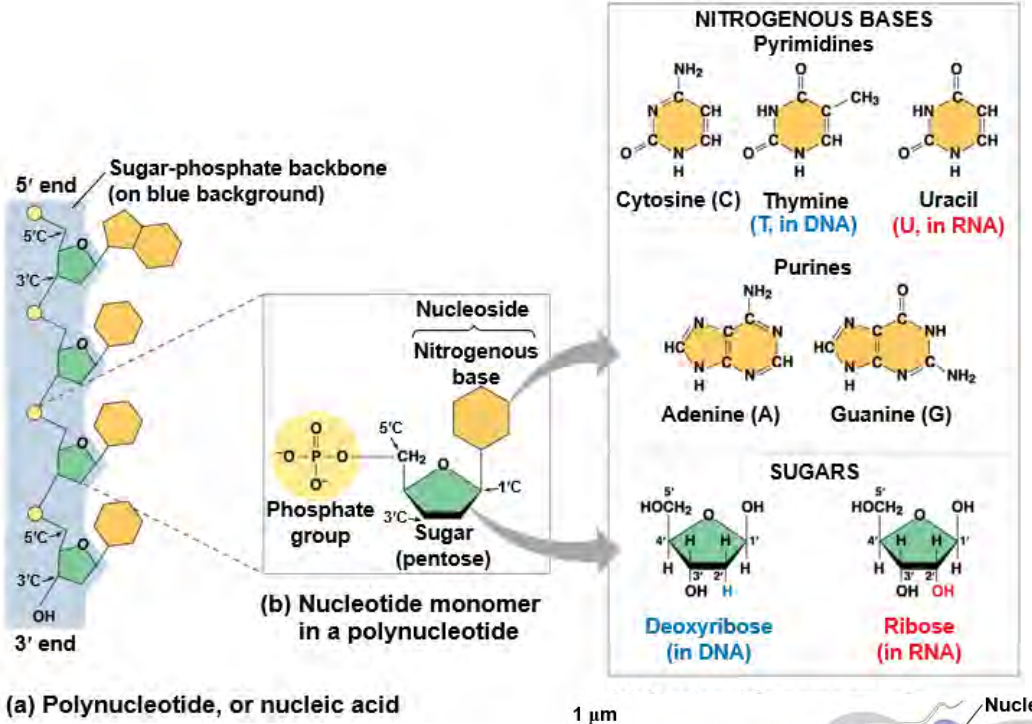
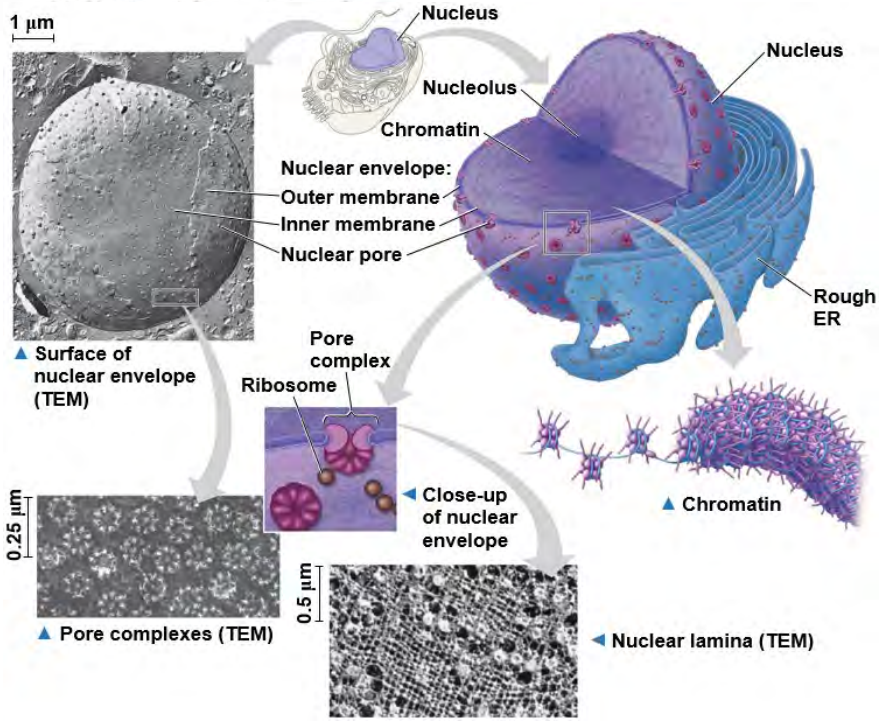

Ophryacus undulatus
Ophryacus melanurus
Lachesis stenophrys
Lachesis muta
Agkistrodon contortrix
Agkistrodon piscivorus
Agkistrodon bilineatus
Agkistrodon taylori
Bothriechis schlegelii
Bothriechis supraciliaris
Bothriechis nigroviridis
Bothriechis lateralis
Bothriechis bicolor
Bothriechis thalassinus
Bothriechis marchi
Bothriechis aurifer
Bothriechis rowleyi
Atropoides occiduus
Atropoides olmec
Atropoides mexicanus
Atropoides nummifer
Atropoides picadoi
Cerrophidion petlalcalensis
Cerrophidion godmani (CR)
Cerrophidion godmani (GA)
Porthidium ophryomegas
Porthidium dunni
Porthidium nasutum
Porthidium porrasi
Porthidium arcose
Bothrocophias hyoprora
Bothrocophias microphthalmus
Bothrops ammodytoides
Bothrops cotiara
Bothrops alternatus
Bothrops jararacussu
Bothrops atrox
Bothrops asper
Bothriopsis bilineata
Bothriopsis taeniata
Bothriopsis chloromelas
Bothrops insularis
Bothrops erythromelas
Bothrops diporus
Sistrurus catenatus
Sistrurus miliarius
Crotalus polystictus
Crotalus cerastes
Crotalus ravus
Crotalus pusillus
Crotalus triseriatus (XO)
Crotalus triseriatus (TO)
Crotalus lepidus
Crotalus aquilus
Crotalus triseriatus (LG)
Crotalus molossus
Crotalus basiliscus
Crotalus enyo
Crotalus unicolor
Crotalus durissus
Crotalus "vegrandis"
Crotalus "exsul"
Crotalus ruber
Crotalus catalinensis
Crotalus tortugensis
Crotalus atrox
Crotalus horridus (AR)
Crotalus horridus (NY)
Crotalus pricei
Crotalus intermedius
Crotalus transversus
Crotalus willardi (ROM)
Crotalus willardi (2575)
Crotalus willardi (413)
Crotalus adamanteus
Crotalus mitchelli
Crotalus tigris
Crotalus scutulatus
Crotalus oreganus

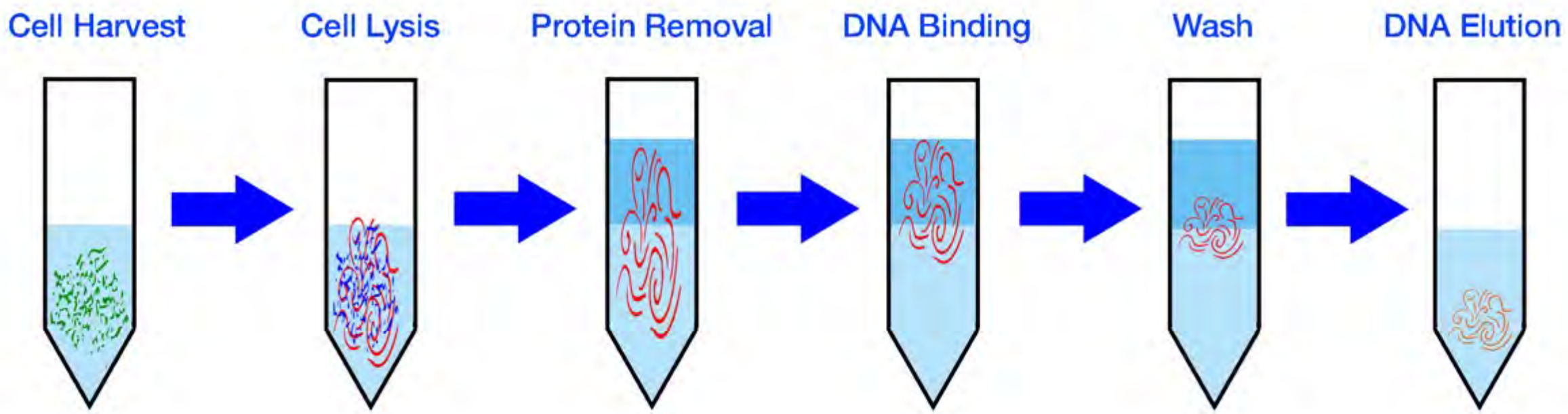
Connect with Lecture

- Chemistry of Life!
  - Polar vs. Non-polar
  - Solvents and Solutions
- Biological Molecules
  - Structure and Function of DNA
  - Structure and Function of Proteins = Enzymes!
- Tour of the Cell – Where is the DNA?



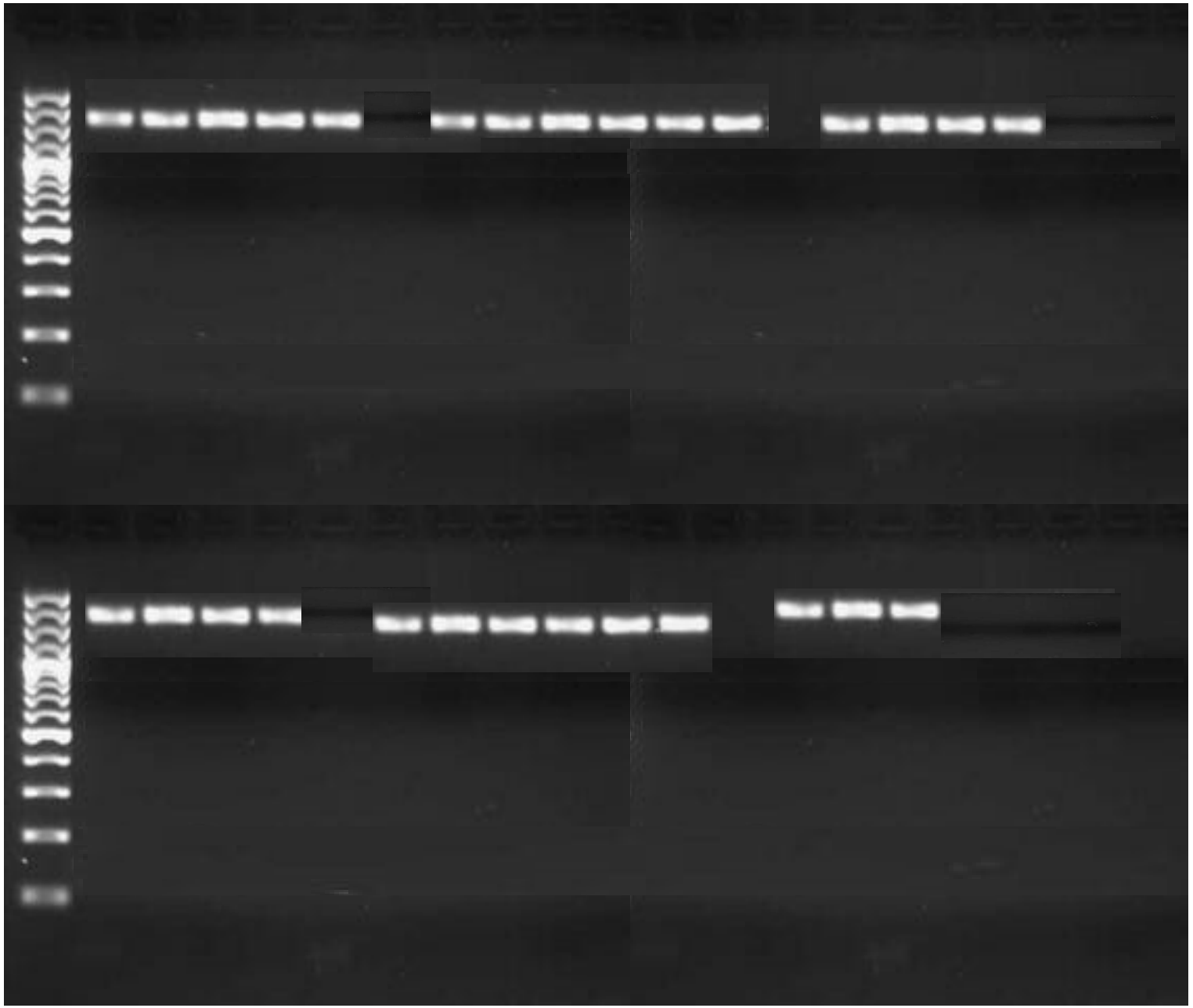


Develop Techniques



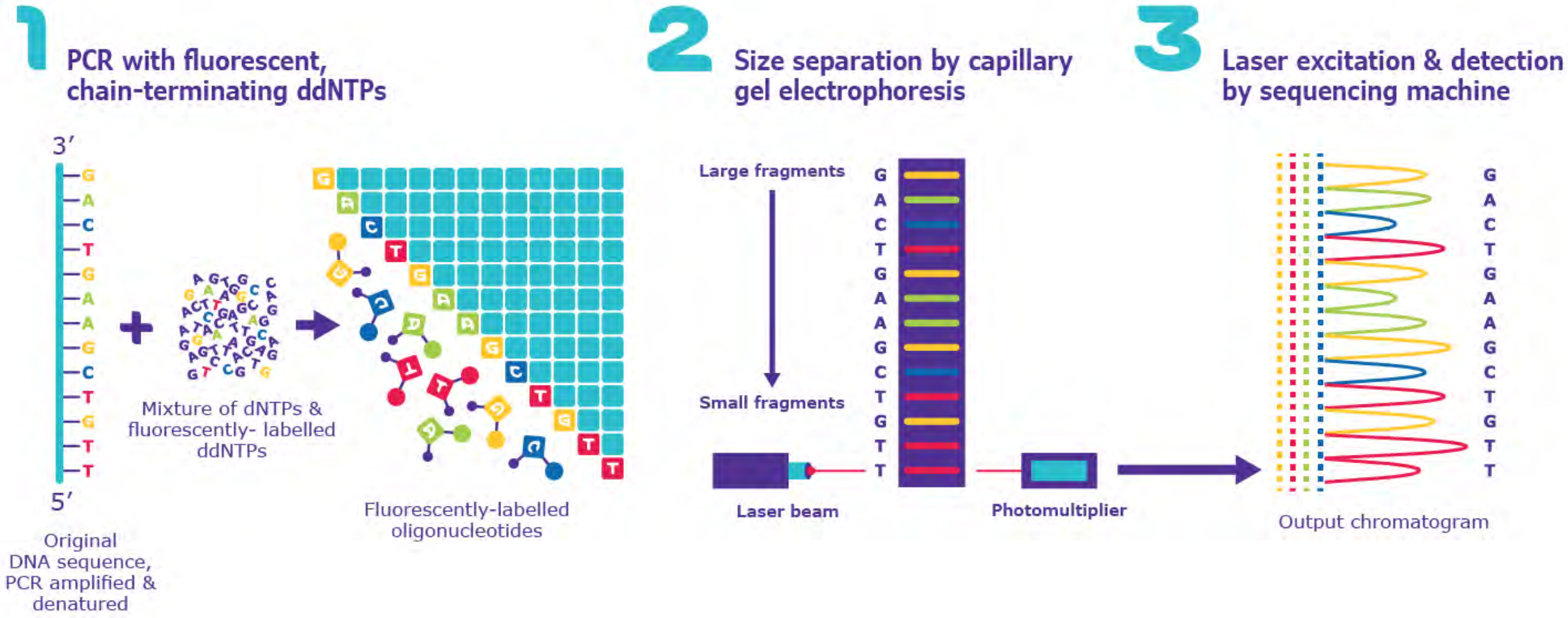
As an environmental consultant, you are going to use this snake's genetic material to determine if this is a new record for the state

Specimen #3 – New distribution record?

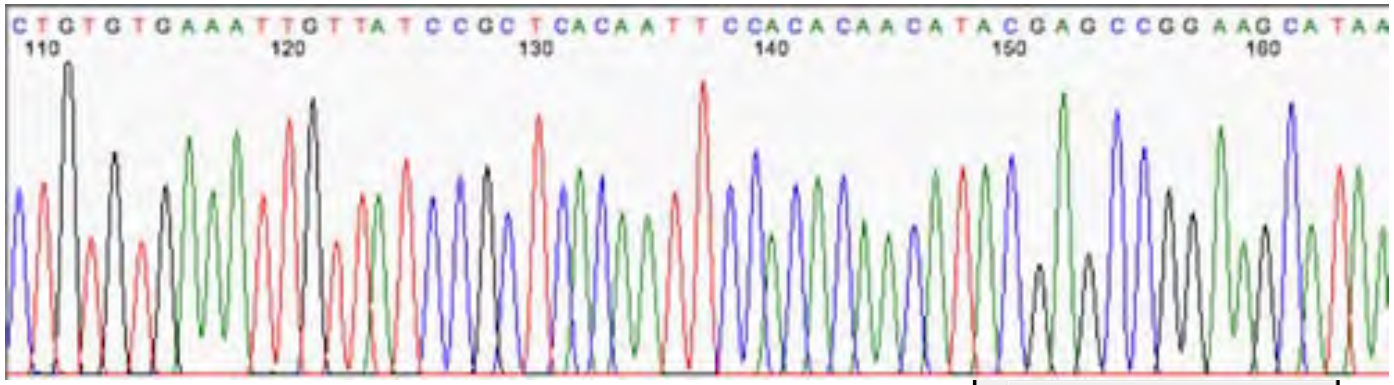


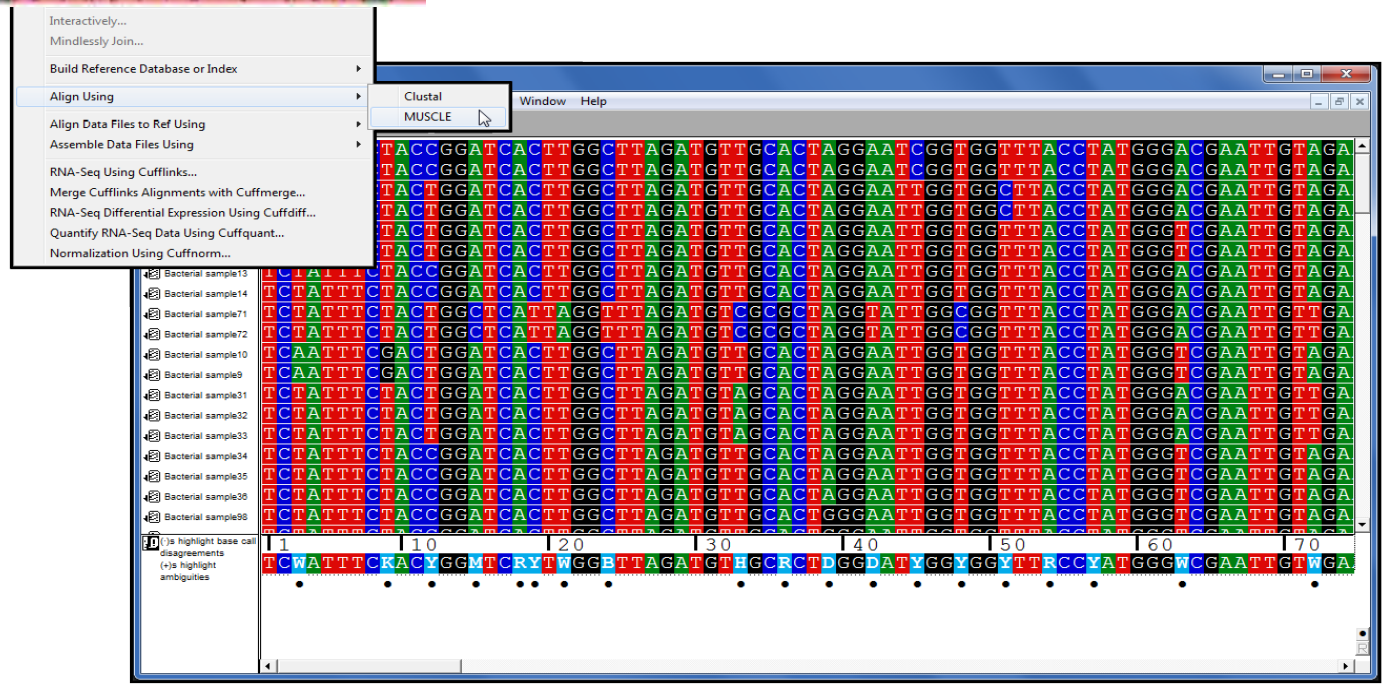
~700 bp for Cytb
Gene Fragment

Sanger Sequencing



Sanger Sequencing – Results

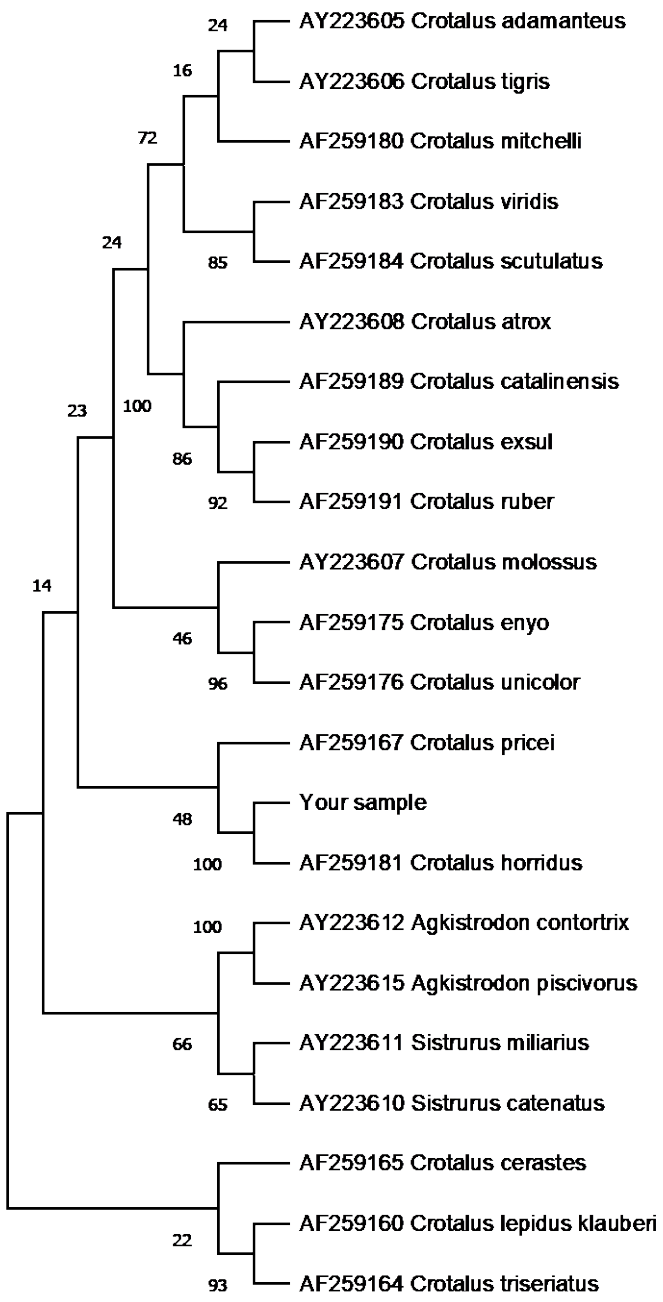




Instructions for Mega – Creating your Phylogeny

- Follow along with handout and example!

- Understand how trees are constructed and how to interpret the results
  - Understanding relationships and common ancestry
  - Relate this to the scenario



- Students loved the project - wondered why they hadn’t done real research projects in other labs.
- Students loved the community the project created - most commented that they met people in the class they probably would never have met or talked to otherwise.
- Students said they felt overwhelmed at times but as things progressed, they were able to make the connections as to why we were doing what we were doing.
- Students commented that they really had no idea what went into a research project, and this gave them that insight.

- Use of PCR/sequencing to identify parasites
- Tapeworms are often difficult to amplify using PCR, students learned this first-hand.
- Discussion of primers used and why
- Taught students to read articles critically to determine what the expected results should look like
- PCR trouble-shooting
- Helped students determine which samples should be sequenced
- Unfortunately, sequencing data came back AFTER the poster presentations - Next Year!

- Parasitology has 3 hours lecture/3 hours lab Scheduled per week.
  - Use 10/15 of the 3 Hour Lab sections to do CURE
  - During the 3 Hours of Lecture, incorporate slide learning/identification of important parasites. (Lab during lecture)
  - This allows them to still learn to identify important medically important parasites while conducting a real parasitology research project
  - Parasitology is an Oral Intensive Class - Students present 2 parasites per semester and include a journal article to discuss. Gives them practice before they make their posters on finding and evaluating research articles.
  - Last Oral Intensive Project is to present their CURE findings to the University.

- Implement CURE activity into an Upper-Level Parasitology Class

  Reasoning:

  1. Students are already interested in the subject, but most are Human Health related majors and lack taxonomic training.
  2. Students lack the understanding of how specimen slides were created.
  3. While all WSU students do a capstone research project almost none of the students have to come up with their own question. This project forces them to ask questions.
  4. Meaningful group work with real outcomes.
  5. Students proudly display their work at a University sponsored Creative Research Day.