

## SSE2013 PDUE/K12 Workshops Evo-ED Mouse Case Lesson Plan

### Base Materials

1. Evo-ED Mouse Case PowerPoint Slides ([www.evo-ed.com](http://www.evo-ed.com); edited for personal use)

### Handouts

1. Objectives and Study Questions
2. Exam Questions
3. Mouse Case Lesson Plan
  - 4a. In Class Exercise – Predicting Allele Frequencies
  - 4b. In Class Exercise – Evolution Scenario
  - 4c. In Class Exercise – Clicker Questions
  - 4d. In Class Exercise – Mouse Karyotype

### Outline of Instructional Activities

#### *Day One (Approx. 60 minutes out of an 80 minute class period.)*

1. Mini-lecture on hair follicles (Slides 1-7).
2. Mini-lecture on MC1R Cell Biology, showing alternate pathways to eumelanin and pheomelanin (Slides 8-13).

#### **Student Activity 1: Small Group Exercise**

On Tabletops, student teams draw the MC1R protein in a melanocyte membrane. In debrief, we go through the different possible pathway outcomes, emphasizing functional versus non-functional pathways, which are then related to protein structure.

3. Brief orientation to the *Peromyscus* system and its Natural History (Slides 14-18). Emphasize that different sub-species have different coat color phenotypes, and that these sub-species are not randomly distributed throughout the range of *Peromyscus polionotus*. Habitat appears to be involved.

#### **Student Activity 2: Minute Paper**

Part I (Slide 19) – Question: Assuming that ancestral populations of beach mice had dark brown fur, what could have happened to explain the occurrence of light-colored coastal sub-species?

The purpose of this activity is to have students brainstorm the spectrum of proximate and ultimate cause for the change in mouse fur color amongst *P. polionotus* subspecies. This was debriefed with a short general class discussion.

Part II (Slides 20-22) – Show the three slides sequentially, allowing students to respond to each part, first.

- What can you tell me about the MC1R protein?
  - Write three things down.
- Do you think there are any differences between the MC1R protein of dark haired mice and the MC1R protein of light haired mice? If so, what?
  - Write something down.
- Do you think there are any differences between the *mc1r* allele of dark haired mice and the *mc1r* allele of light haired mice?
  - Write something down.

4. Mini-lecture on the R allele and the C allele at the *mc1r* locus (slides 23-29). Emphasize DNA → RNA → Protein, the nature of the single base substitution mutation, and the consequence of the mutation to the cell.
5. Mini-lecture on plausible mechanism for an observable relationship (slides 30 -35). This slide set sets up the discussion on the relationship of genotype and phenotype to begin Day 2.

### ***Day Two (Entire 80 minute class period)***

#### **Student Activity 3**

Students are given the mouse karyotype handout. They are told that the gene encoding the MC1R protein is located at position 127,548,960 – 127,652,210 on Chromosome 8 (in *Mus musculus*).

Students work as individuals (but may consult a neighbor) to draw representations of Chromosome 8 in a mouse that is RR, CC, and RC. Further, they are to show them both before and after DNA replication, and to show them aligned at metaphase of mitosis, and metaphase I of meiosis.

Debrief with white board explanations (student volunteers). Then we revisit slide 35.

6. Mini-lecture/class discussion to explore genotype/phenotype relationships at the *mc1r* locus in mice (slides 36-43). In this set we show how Hoekstra et al. scored coat color phenotypes. It is a complex task. Finish off by going through the rhetorical questions on slides 42 & 43.

#### **Student Activity 4: Clicker Q (Slide 44)**

#### **Student Activity 5: Small Group Exercise**

Students work in groups of four to predict the allele frequencies of the six populations represented in slide 45. Debrief with slide 46.

7. Wrap up Genotype/Phenotype Relationships with statement in slide 47.

#### **Student Activity 6: In Class Exercise on Mouse Evolution (Slides 48 & 49)**

Students work in teams of four to devise an evolutionary scenario that led to the two present day populations shown, given the initial ancestral population. This activity emphasizes changes in population sizes over time, vicariance, and how a mutation works at a population level.

Debriefed with student volunteers at the board putting numbers on circles, and defining genotype and phenotype frequencies.

### ***Day Three (20 minutes to begin an 80 minute class session)***

8. Mini-lecture on ecology and selection pressure on the mice (slides 50 – 58).

#### **Student Activity 7: Games and Sims.**

Students download and play at their tables one of the games associated with this Case.

Minute Paper as follow-up:

What was the point of the game? Was it fun/useful?

#### **Student Activity 8: Two Clicker Questions to Wrap up (Slides 59 & 60).**

Debrief each one. The second one generates multiple answers.

## SSE 2013 PDUE/K12 Workshops

### Peromyscus Beach Mice Lessons – Objectives and Study Questions

1. Describe the cell biological and biochemical bases for differences in hair color in mice.
  - describe key differences in the biochemical pathways leading to eumelanin and pheomelanin synthesis
  - describe the roles of key enzymes/proteins (how differential regulation of these enzymes leads to different phenotypic outcomes)
  - describe the MC1R protein and its role in signal transduction across the melanocyte cell membrane
  - describe amino acid differences in the R67 and C67 variants of the MC1R protein
  - describe nucleotide sequence differences in *mc1r* alleles, and how they lead to differences in the MC1R proteins that they encode
2. Define “allele frequency” and contrast it with phenotype frequency.
3. Describe two *Peromyscus* populations on the basis of both their phenotype frequencies and genotype frequencies.
4. Understand that variation in coat color is not randomly distributed in *Peromyscus* beach mouse subspecies and populations.
5. Describe how differential predation could explain these differences in distribution, and explain how this represents an example of evolution by natural selection.
6. Describe an evolutionary scenario in which an ancestral population of *Peromyscus* mice, with almost exclusively dark-coated individuals, give rise to two descendant populations of mice, one of which has predominantly light-coated individuals. Include time frame, geographic localities, population sizes, and genotype frequencies of each population in your description.

**SSE2013 PDUE/K12 Workshops**  
**Peromyscus Beach Mice Exam**  
**(20 pts total)**

Name \_\_\_\_\_

1. Molecular Genetics. What is the difference between the  $R^{67}$  and  $C^{67}$  alleles? Specifically – how do their nucleotide sequences differ and what is the resulting difference in the amino acid sequences of the MC1R proteins that they encode? (3 pts)
2. Cell Biology. What is the role of the MC1R protein in eumelanin pigment synthesis in *Peromyscus polionotus* and how does MC1R operate differently in light fur vs. dark fur mouse populations? (3 pts)
3. Ecology. What role does natural selection play in determining the coat color of mice living in different *Peromyscus polionotus* populations? Briefly describe one of the studies that have been done to support this. (3 pts)
4. Population Genetics. You find a population of *Peromyscus* mice that has 200 individuals. You also find that 100 of them have dark coats, and 100 of them have light coats. In addition, you find that all of the mice with dark coats are homozygous for the  $R^{67}$  allele, while 50% of the mice with light coats are heterozygous  $R^{67}C^{67}$  (the others are homozygous for the  $C^{67}$  allele). (3 pts)

Describe this population in terms of its:

- a. phenotype frequencies
- b. genotype frequencies
- c. allele frequencies

5. Devise and describe an evolutionary scenario whereby a new Florida Gulf Coast Beach Mouse population, in which many mice have light coat colors, forms by divergence from an ancestral inland (old field) mouse population in which all of the mice had dark fur coats. Assume for this scenario that the  $R^{67}$  and  $C^{67}$  alleles at the *mc1r* locus are solely responsible for mouse coat color. (8 pts)

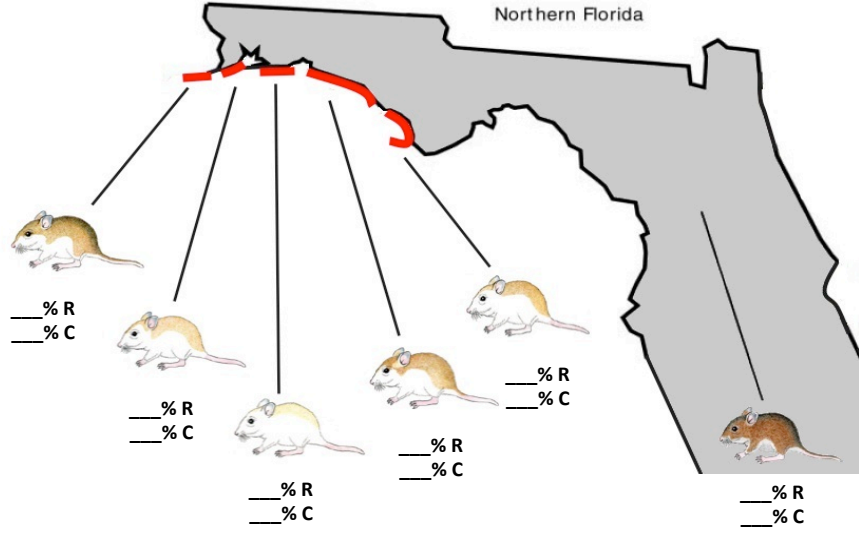
Include in your scenario *as baseline information* for your description:

- a. When and where the ancestral population lived, and its size.
- b. The locations and sizes of the present day inland and beach mouse population(s).
- c. The history of mutations in the *mc1r* gene in your populations (in which populations did they occur, and when?)
- d. The frequencies of the light and dark phenotypes, and the frequencies of the  $R^{67}$  and  $C^{67}$  alleles, in each population.

In your scenario, when, exactly, did evolution occur?

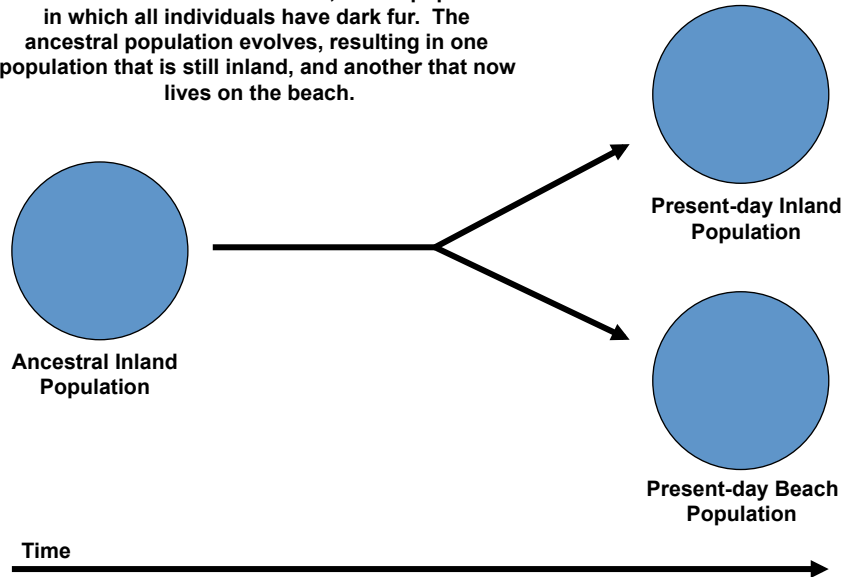
5.12a

# Predict Allele Frequencies



## In Class Exercise on Mouse Evolution

Scenario: Start with an ancestral, inland population in which all individuals have dark fur. The ancestral population evolves, resulting in one population that is still inland, and another that now lives on the beach.



## In Class Exercise on Mouse Evolution: Questions for Student Teams to Consider

- When did the ancestral population live? How big was it (number of individuals)?
  - What were the *mc1r* genotype frequencies? The *mc1r* allele frequencies?
- How big is the present day inland population (number of individuals)?
  - What are the *mc1r* genotype frequencies? The *mc1r* allele frequencies?
- How big is the present day beach population (number of individuals)?
  - What are the *mc1r* genotype frequencies? The *mc1r* allele frequencies?
- Where along the timeline did an R → C substitution in MC1R occur?

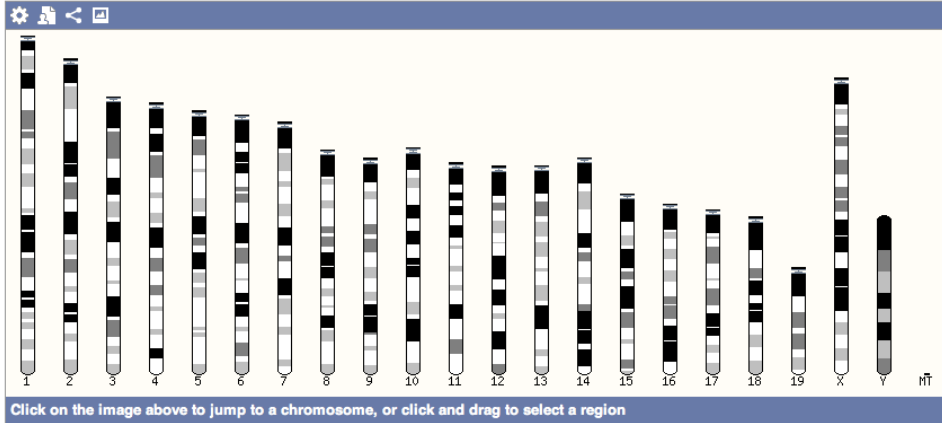
**Clicker Q1****The C → T substitution at position 199 of the *mc1r* gene:**

- A. arose by a mutation in the beach mouse populations in response to a need for protection from predation.
- B. leads to the failure of melanocytes to make an MC1R protein.
- C. arose by a mutation then increased in frequency because it was selectively advantageous in the beach mouse populations.
- D. had no effect on the beach mouse populations.
- E. produced an alternate allele that was detrimental to mice on the white sand beaches

**Clicker Q2****What was the reason for the lighter coat colors of the mice on the white sand beaches?**

- A. Owls and other carnivores prey on beach mice that do not carry the mutant allele.
- B. A substitution of cysteine for arginine at position 67 of the MC1R protein.
- C. A substitution of thymine for cytosine at position 199 of the *mc1r* gene nucleotide sequence.
- D. The failure of melanocytes to lay down melanin pigment in the cortex of hairs of the lighter colored beach mice.
- E. The poorer binding affinity for  $\alpha$ -MSH and the lower amount of cAMP produced by individuals with the mutated MC1R protein.

# House Mouse Karyotype (Mus musculus)



## Summary

Assembly:	GRCm38.p1, Jan 2012
Database version:	71.38
Base Pairs:	3,480,528,190

Chromosome 8 is approx. 130,000,000 bp