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Mutation Frequency

Background

A mutation is a change in an organism's DNA. Most mutations originate as copying errors. If a mutation happens in a reproductive cell (e.g., egg or sperm), it can be passed to offspring. This is a source of new alleles.

New point mutations (single-base substitutions) happen at a relatively constant rate—though the rate differs between organisms. For people, everyone has about 38 new single-base mutations that were not present in their parents. That's one mutation for every 83 million bases—with each generation.

Because mutations happen at a consistent rate, it's possible to predict how often a new allele of a particular gene will come along, and even how often a specific single-base mutation will happen.

To make a rough calculation, you need to know just 3 things:

1. Mutation rate – How often do errors occur?
2. Population size – How many individuals are in the population?
3. Reproductive rate – How many offspring are born in each new generation?

Fur color in rock pocket mice

Rock pocket mice live in dry, rocky habitats in the southwestern United States and northern Mexico. Some rock pocket mice have light tan fur, and others have dark brown fur.

Scientists know that a gene called MC1R influences fur color in these mice. To have dark fur, a mouse needs just one copy of a 'dark' MC1R allele.

Based on genetic variations found in nature—some in rock pocket mice, some in other animals—scientists know that there are at least 10 different bases in the MC1R gene that when mutated will generate a dark fur allele.

Some rock pocket mice have light fur, and others have dark fur.

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Question

In a population of light-colored mice, how often will a pup be born with a new MC1R allele that gives it dark fur?

Information you will need

- There are 20 possible bases in MC1R where mutations will cause dark fur (10 bases x 2 alleles).
- Mutation rate = 1 mutation for every 185 million (185,000,000) bases (this also means that for a single base, it will be mutated once in every 185 million offspring.)
- The population has 5,000 female mice.
- Female mice give birth to at least 5 pups/year.
- 1 million = 1,000,000

Calculate

1. Multiply: (mutation rate) x (number of possible dark mutations)

1 out of 185 million x 20 = 20 out of 185 million = 1 out of 9.3 million (9,300,000)

Divide: One out of every ____9.3 million____ pups will have a mutation that gives it dark fur.

2. How many pups are born each year?

5,000 female mice x 5 pups/year = 25,000 pups/year

3. Assuming the rock pocket mouse population stays the same size, how often will a pup with dark fur be born (once every how many years)?

9,300,000 pups / 25,000 pups per year = 372 years

4. Rock pocket mice have been living in New Mexico for at least 500,000 years. In that time, about how many pups could have been born with **new** dark fur alleles?

500,000 years / 372 years = 1,344 mice

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Mutation frequency in *E. Coli*

E. coli is a type of bacteria that lives in the lower digestive tract of people and warm-blooded animals. Most strains of *E. coli* are harmless or even helpful, but a few can cause illness.

Like for many bacteria, the mutation rate in *E. coli* is quite low compared to mammals like the rock pocket mice. Yet between strains of *E. coli*, many genes vary in as many as 50% of their DNA bases.

Question

Why is there so much genetic variation among *E. coli* bacteria?

Information you will need:

- The mutation rate in *E. coli* is 1×10^{-10} (or 1 out of every 10 billion bases copied).
- The *E. coli* genome is about 5 million bases long.
- *E. coli* bacteria reproduce by copying their DNA and dividing in two. In the human gut, they divide about once/day.
- The human colon has an enormous population of bacteria: about 3.8×10^{14} individuals. About 0.1% of these are *E. coli* bacteria, or an average of about 380 billion individuals.

1. Use the genome size and the mutation rate to calculate:

(1 mutation x 10^{-10} bases) x (5 x 10^{6} bases/cell) = 5 x 10^{-4} mutations/cell = $\frac{5 \text{ mutations}}{10{,}000 \text{ cells}}$

One out of every ____2,000____ new bacteria will have a mutation.

2. Use the number of E. coli in the human gut and the answer from number 1 to calculate:

$\frac{380 \text{ billion}}{2{,}000}$ = 190 million -or- (3.8 x 10^{11}cells) x (5 x 10^{-4} mutations/cell) = 19 x 10^{7} mutations

Each day in a person's colon, ____1.9 x 10^{8}____ new *E. coli* bacteria will have a mutation.

3. There are about 7 billion people on earth. Across the human population, how many new E. coli bacteria will have a mutation each day?

(1.9 x 10^{8} mutations/person) x (7 x 10^{9} people) = 13.3 x 10^{17} mutations

Answer: 1.33 x 10^{18} bacteria will have a mutation

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