Biology 4415
Evolution

NAME:________________________________

Exam I

To the intelligent man or woman, life appears infinitely mysterious.
But the stupid have an answer for every question.
—Edward Abbey

1. Fill in the blanks! Use one letter per blank, and don't skip any blanks. When you're done, the ***first letters of each word***, read downwards, will give you the answer to this question:

In 1860, "Darwin's Bulldog", Thomas Henry Huxley, locked horns in public debate with a well-known Anglican bishop, one of the best public speakers of his time, who was opposed to the idea of evolution. What was his name? (20 pts.)

S M I T H	Economist who proposed *laissez-faire* capitalism (and influenced Darwin)
A L L E L E S	Different forms of a gene at one locus
M O R G A N	Scientist who first mapped genes onto chromosomes, using fruit flies
U C A	Football team with a decent chance of upsetting Tulsa this weekend, which would make us 5-0 going into Southland Conference play. Go Bears!
E P I S T A S I S	Interaction between genes at several loci
L Y E L L	"Father of Modern Geology" and deviser of *uniformitarianism*
W E I S M A N N	19^{th} century scientist who theorized about "germ plasm" and "intracellular pangenes"
I M M I G R A T I O N	One of the factors that will knock a population out of Hardy-Weinberg equilibrium
L A M A R C K	First person to come up with a theory of how evolution might happen

B E A G L E — Charles Darwin sailed on the ship *HMS* __.

E U G E N I C S — The idea that humans should apply artificial selection to themselves

R A N D O M   M A T I N G — One of the criteria for the Hardy-Weinberg equilibrium

F I T Z R O Y — Captain of the ship Darwin sailed on

O R I G I N — Darwin's most famous book, __ *of Species.*

R E C E S S I V E — Allele whose presence may be masked by the presence of another allele of the same gene

C O D O N — A group of three nucleotide bases that codes for one amino acid

E R A S M U S — First name of Charles Darwin's grandfather, the poet, inventor, and evolutionary theorizer

. . . and the name of the infamous bishop, nicknamed "Soapy Sam" for his legendary slipperiness in debate, was Bishop

"S A M U E L   W I L B E R F O R C E"

2. For each of the following case studies or examples below, write a couple of sentences explaining the general concept or principle that is illustrated. (5 pts. each; 20 pts. total)

a. On Tuesday, Sept. 23, 2008, the *New Orleans Times-Picayune* reported that Louisiana state legislator John LaBruzzo (R–Metairie) had a plan to pay poor women to be surgically sterilized. LaBruzzo was also working on a plan to offer tax breaks and/or other financial incentives for college-educated, high-income people to have more children. (I'm not saying that this is a good idea, and you may not approve either. Just explain what concept, mentioned in lectures, this is an example of.)

This is an example of eugenics; LaBruzzo is applying artificial selection to humans by trying to keep those with presumably poor genes from breeding and encouraging those with presumably good genes to breed. [This assumes that poverty, education, etc. are governed by genes in the first place, which they probably aren't, at least not in any simple and straightforward way. I didn't say LaBruzzo's plan was a good idea -- or that it would work as he probably intends. . .]

b. Zhang and Gerstein's recent study of the human genome (*Nucleic Acids Res.* 31(18): 5338-5348) focused on mutations in a certain set of pseudogenes. Point mutations that altered T to C or C to T, or A to G or G to A, were roughly twice as common as point mutations that altered A to C or T, G to C or T, T to A or G, or C to A or G.

These are point mutations -- but what I wanted you to notice most of all was that this is an example of mutational bias, with transitions (purine to purine, or pyrimidine to pyrimidine) more common than transversions (purine to pyrimidine or pyrimidine to purine).

c. Beetles have two pairs of wings: the first pair forms a hardened, stiffened covering over the abdomen called the *elytra.* When the elytra opens, the second pair of wings can unfold and be used in flight. However, in the leathery ground beetle *Carabus coriaceus*, the elytra is fused together and cannot open. Nonetheless, there is a second pair of wings underneath the elytra, even though these can never unfold and are never used in flight.

The hindwings of this beetle are vestigial structures. They had a function in the beetle's ancestors but apparently have no function now.

d. John Ray was a 17th-century English clergyman and botanist who wrote that his studies of living things "serve not only to demonstrate the Being of a Deity, but also to illustrate some of his principal attributes; namely, his infinite Power and Wisdom." He also wrote that "the Adapting all the Parts of Animals to their several Uses, the Provision that is made for their Sustenance. . . are evident Demonstrations of His Sovereign Wisdom."

This is straight-up natural theology: the idea that the complexity of nature must imply a powerful and intelligent Designer, presumably God; and that man can understand God by studying God's creation. [Some students mentioned Paley here -- but Paley didn't invent natural theology; the idea goes back at least to the Bible (Luke 12:24-28; Proverbs 6:6-8; etc.). Paley did popularize natural theology and explain it very clearly and well in his book <u>Natural Theology</u>. But others, including John Ray, had expressed the same idea earlier.]

3. There is evidence for a human gene that affects the blood's ability to carry oxygen. There are two alleles; persons that are homozygous or heterozygous for the autosomal dominant allele (call these the *BB* and *Bb* genotypes) average 6-10% higher oxygen saturation than persons that are homozygous recessive (*bb*).

In a sample of 698 Tibetan women living at high altitudes (about 13,000 feet / 4000 meters), women with the *BB* genotype had, on average, 3.79 children that survived to adulthood. Women with the *Bb* genotype averaged 3.58 surviving children, and women with the *bb* genotype averaged 1.69 surviving children.[1] This difference is entirely due to differences in infant mortality; a woman's genotype had no effect on how many children she gave birth to.

a. In one village, there are 37 *BB* individuals, 21 *Bb* individuals, and 22 *bb* individuals. Estimate the allele and the genotype frequencies after one generation. (10 pts.)

starting frequency of BB = 37/80 = 0.463
starting frequency of Bb = 21/80 = 0.263
starting frequency of bb = 22/80 = 0.275

frequency of B=[(37 x 2) + 21] / 160 = 0.594. Call this p.
frequency of b=[(22 x 2) + 21] / 160 = 0.406. Call this q.

w_{BB} = 3.79/3.79 = 1.00
w_{Bb} = 3.58/3.79 = 0.945
w_{bb} = 1.69/3.79 = 0.446

To predict the effect of selection, first calculate w-bar:

$p^2w_{BB} + 2pqw_{Bb} + q^2w_{bb}$ = w-bar. Plug in the numbers, and you get

w-bar = 0.352 + 0.456 + 0.0735 = 0.882.

Now divide all terms through by w-bar, and you get:

new frequency of BB = p^2w_{BB} / w-bar = 0.399
new frequency of Bb = $2pqw_{Bb}$ / w-bar = 0.517
new frequency of bb = q^2w_{bb} / w-bar = 0.0833

BIG DIFFERENCE between starting and new, right?

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[1] Beall, C. M., Song, K., Elston, R. C., and Goldstein, M. C. 2004. Higher offspring survival among Tibetan women with high oxygen saturation genotypes residing at 4,000 m. *Proceedings of the National Academy of Sciences of the USA* **101**: 14300-14304.

b. Estimate the allele and the genotype frequencies after another generation. (10 pts.)

You have to recalculate p and q to do this -- because p and q will have changed because of natural selection. Which is really the point. . . So from the previous problem, you know that:

frequency of BB = p^2w_{BB} / w-bar = 0.399
frequency of Bb = $2pqw_{Bb}$ / w-bar = 0.517
frequency of bb = q^2w_{bb} / w-bar = 0.0833

new frequency of B = 0.399 + (0.517/2) = 0.658. Call it p.
new frequency of b = 0.0833 + (0.517/2) = 0.342. Call it q.

w_{BB} = 3.79/3.79 = 1.00
w_{Bb} = 3.58/3.79 = 0.945
w_{bb} = 1.69/3.79 = 0.446

To predict the effect of selection, first calculate w-bar, and you get:

w-bar = 0.432 + 0.425 + 0.0522 = 0.909

Now divide all terms through by w-bar, and you get:

new frequency of BB = p^2w_{BB} / w-bar = 0.475
new frequency of Bb = $2pqw_{Bb}$ / w-bar = 0.468
new frequency of bb = q^2w_{bb} / w-bar = 0.0574

Now answer any two of the following four questions, each of which is worth 20 points.

4. In a study of a deep-sea holothurian ("sea cucumber") called *Benthogone rosea*, Bisol and colleagues[2] found that a gene called *Est4* had three different alleles within a population. These alleles were called A, B, and C. Bisol *et al.* found that allele B was the most common, with a frequency of 0.970. A had a frequency of 0.02, and C had a frequency of 0.01. They also found out that the frequency of all heterozygotes in the population was 5.9%. Is the population in Hardy-Weinberg equilibrium? How can you tell? Show all work. . .

If you have three alleles with frequencies p, q and r, then the HW equation is given by

$(p + q + r)^2 = 1$

which is

$p^2 + q^2 + r^2 + 2pq + 2pr + 2qr = 1$

Each of these terms represents the frequencies of a certain genotype: the frequency of the AA genotype is p2, of the AB genotype is 2pq, of the AC genotype is 2pr, and so on. The predicted frequencies of all the heterozygotes add up to:

$2pq + 2pr + 2qr$

Plug in the numbers, and the predicted heterozygote frequency is 0.0388 + 0.0004 + 0.0194 = 0.0586, or 5.86%. Since the actual frequency of heterozygotes is 5.9%, the population is in Hardy-Weinberg equilibrium.

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[2] Bisol, P. M., Costa, R., and Sibuet, M. 1984. Ecological and genetical survey on two deep-sea holothurians: *Benthogone rosea* and *Benthodytes typica*. *Marine Ecology Progress Series* **15**: 275-281.

5. The young Charles Darwin was a great admirer of the writings of Rev. William Paley, writing later in life that at one time he almost had one of his books memorized. Darwin's actual views came to be very different from Paley's, and yet we can still measure Paley's influence on Darwin's work. What was Paley noted for, why did it influence Darwin—and how is it that Darwin's own conclusions came to be so different from Paley's?

Paley was noted for his presentation of natural theology -- the idea that the complexity of living things proved the existence of a God who designed them, and so that you could learn about God by studying the complex things God created. First, this gave religiously devout people a reason to study nature -- it's ultimately the reason why Darwin as a college student, studying for the ministry, could take so many courses in science. Secondly, Paley drew attention to the complex adaptations that animals and plants have to their surroundings. Darwin was very impressed by the adaptations, but showed that they can be explained in other ways than a single Designer.

6. Imagine you're studying the genetics of a population of some organism, which has one gene with two alleles. . . and you find that the population consists of 63% heterozygotes. Is the population in Hardy-Weinberg equilibrium? Show all work. Any equation of the form $ax^2 + bx + c = 0$ may be solved by using the quadratic formula,

$$x = \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a}$$

If a population is in H-W, then the frequency of heterozygotes (for any gene with two alleles) is equal to 2pq. So if this population is in H-W, then

$2pq = 0.63$

Since $q = 1-p$, then

$2p(1-p) = 0.63$

which you can expand and rearrange into a quadratic equation,

$-2p^2 + 2p - 0.63 = 0$

Plug the numbers into the quadratic formula, which I gave you, and the roots are:

$p = \{-25.166, 1.2517\}$

But since it's a p must fall between 0 and 1 -- it can't be negative, and it can't be 1.25, because that would mean that 125% of the alleles were p, which isn't possible. So the population cannot be in H-W equilibrium.

7. Fellow scientist Georges Cuvier gave the eulogy at Jean-Baptiste Lamarck's funeral—which remains unsurpassed in the history of science for its sheer bitchiness. Cuvier referred to Lamarck's theories as "resembling the enchanted palaces of our old romances, which vanished into air on the destruction of the talisman to which they owed their birth." Cuvier also said that "A system established on such foundations may amuse the imagination of a poet. . . but it cannot for a moment bear the examination of any one who has dissected a hand, a viscus, or even a feather." And yet, in the late 1800s, there came to be an entire "Neo-Lamarckian movement" of scientists who revived Lamarck's ideas on evolution. Why?

Lamarck's ideas became popular again because they seemed to solve some problems that Darwin's theory could not. Neither Darwin nor anyone else at the time (except Mendel, but no one paid much attention to him) understood where variation came from and how it was inherited. In Lamarck's theory, organisms create their own variation and cause themselves to adapt, through "use and disuse of parts". Lamarckian evolution can also, in theory, happen very rapidly -- the giraffes can all stretch their necks and pass on that stretching to their babies, instead of waiting around for a long-necked variant to be born. This made neo-Lamarckian evolution attractive to those who felt that the Earth wasn't old enough for the slow, plodding, gradual process of natural selection to have generated all the diversity of life on Earth.