Read each question carefully.

Make sure you answer everything each question asks. Each part of each question is worth an *equal* fraction of the question's point value.

Read the question carefully! Don't answer something different from what I ask for!

Always be as specific as possible! Use information from other questions (especially the figure questions in the back!) to help you. There's nothing untoward about using the material on the exam itself to help you answer a particular question.

Work within the limits of the data. Your ability to assess what is supported by data is explicitly what I'm testing here (and in your project, and just generally in this class).

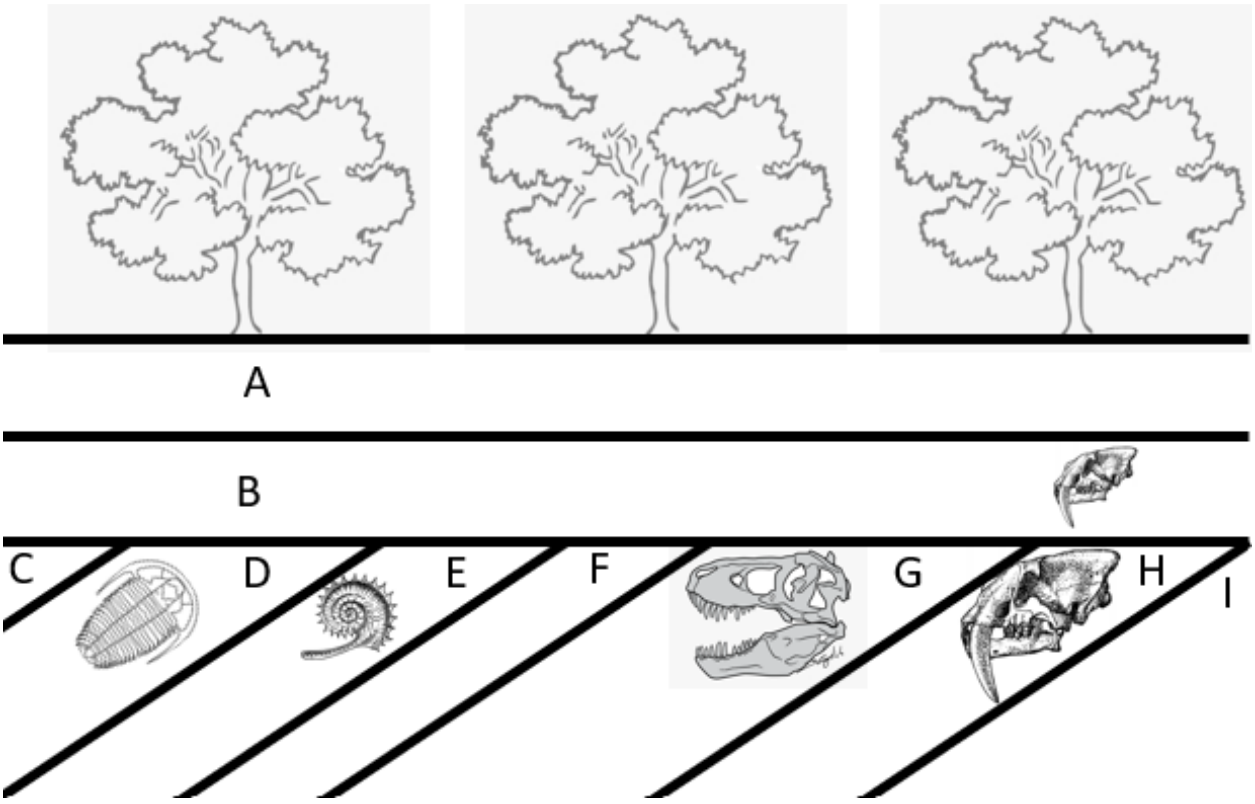
Assume anything stated in the question is true.

1. (1 point) *You are sitting on a park bench with your coolest friend, when they turn to you and say, "I've been thinking that a good definition for evolution would be the change in frequency of heritable characteristics within replicators. This does make me wonder, though, about one specific example. I saw a funny picture on Twitter the other day. Then later that day, I saw that other people had reposted that same picture, but now with a variety of captions. Some of the specific captions got reposted a lot, while others seem to have been posted once then never again. A week later I am still seeing this image with captions being posted again and again. It seems like the image is replicating itself by having people post repost it, vaguely like how a virus can't replicate itself but can get other cells to replicate it. Do you think this is evolution?"* How do you answer your coolest friend? The friend here is describing a meme and a meme is a literal example of evolution; the word "meme" was coined by an evolutionary biologist in a book on evolutionary biology to discuss how ideas can evolve. Really, any answer that isn't a flat-out 'no' could get at least some partial credit. Here I was looking mostly for open-thinking and critical engagement.

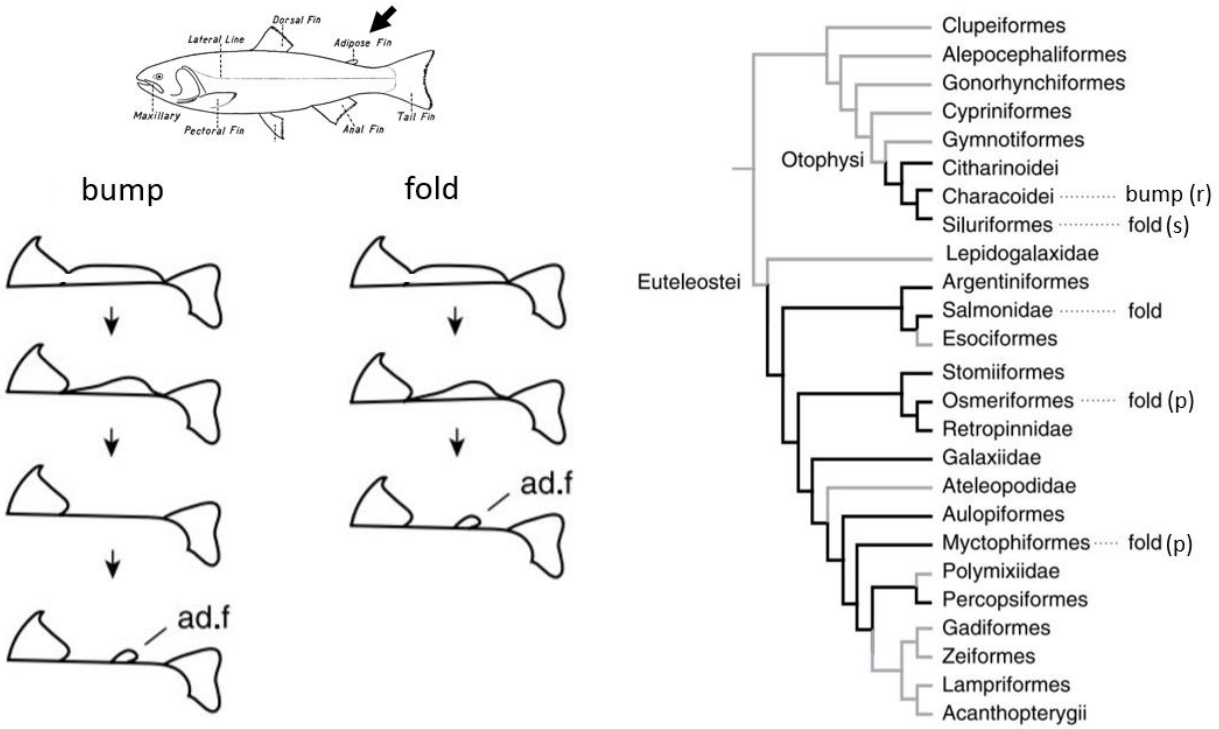
2. (1 point) *A cancerous tumor is a population of cells within a person's body that have gone "rogue" due to the unique mutations they've accumulated. These rogue cells divide and proliferate, and in so doing accumulate additional mutations (heritable changes) creating different cell lineages* within *the tumor. These different intratumor lineages can vary in the rate of cell division, the ability to metabolize nutrients, the recognizability to the immune system, and just about every other aspect of the cell.* What does the above information imply about how the cells of a tumor respond over time to a specific treatment? That the population of cells in the tumor can adapt and evolve in response to treatments. If a treatment is too specific, there may be cells that evade it, increasing their frequency and preventing the same treatment from being used effectively in the future for that individual. Conversely, it also means that you can impose alternative pressures on the tumor to render it less malignant (called evolutionary treatments and becoming more common).

3. (1 point) *I have both arms and legs. My arms and legs both have a skeletal arrangement of one bone, followed by two bones, followed by a series of small bones, followed by five radiating sequences of 19 bones. The muscles are arranged similarly, with flexor and extensor compartments and similar patterns of nerve branching throughout. Developmentally, both derive from a combination of cells from the lateral plate and hypaxial somites and both are triggered as a result from a cascading series of* Tbx, Wnt, Bmp, Fgf, *and* Shh *gene signals. The distribution of "has arms and legs" is extremely consistent across species.* Is my arm homologous to my leg? This is a concept called serial homology. The answer is "yes, to an extent." For now it's sufficient to note that they satisfy all of the requisite conditions, so there's some substantial degree of homology between them. Later, in the evo-devo section, we'll discuss how the legs are actually descended from the arms. But you don't need to know that for this question.

An alternate way to think about this question: homology is a description of fundamental sameness between biological structures (due to shared ancestry). It also comes in degrees, with structures homologous to various extents. A good way to come around on this question is to think of it transitively: a human's arm and a chimp arm are VERY homologous. Further, under the criteria we have, a chimp's *leg* is *to some degree* homologous with a human's arm. Thus human arm = chimp arm $\approx$ human leg, so there's a degree of sameness (some degree of homology) between a human arm & leg.



4. (1 point) *Above is a diagram showing the bedrock under a particular forest, with fossils known from each layer (trilobite in D, ammonite in E, dinosaur in G, advanced mammals in H and B) indicated. Assume each layer a fossil occurs in represents the full duration each fossil species lived.* (a) What is the youngest layer of rock? (b) What is the oldest layer of rock? (c&d) Propose an explanation for anything strange observed in this particular sequence of strata. A, C, the rocks representing C-I were overturned by tectonic activity and have actually flipped upside-down. Based on lecture, I told you quite explicitly that trilobites occur before dinosaurs, and that advanced mammals occur after dinosaurs. So you should have had a good handle on the rock order.



5. (1 point) (basically) *All ray-finned fish have dorsal fins and tail fins. Some species of fish possess an extra fin, called an "adipose fin" though this is not a technical term, between the dorsal & tail fins (see diagram at top left). In fish, early on in development, a large median fin develops along the entire length of the fish's, and as the embryo grows, this fin degenerates in places and leaves the tail and dorsal fin behind. In some fish (Characoidei), the adipose fin emerges as a "bump"* after *the median fin disappears (see above, left). In other fish the adipose fin develops as a remnant of the median fin fold that never degenerated. The adipose fins of fish also have anatomical differences with some possessing bony plates ("p"), slender rays ("r"), others sharp spines ("s"), and others possessing no connection to any bone at all (e.g., in Salmonidae). The diagram above shows a large number of fish groups with a description of the development and anatomical relationships of the adipose fins in those groups that possess one.* (a) Based on the developmental data (left figure), is this fin in Characoidei homologous to the same fin in Salmonidae? (b) Based on the anatomical data (connection to bones, indicated with r/s/p), is the fin in Osmeriformes homologous to the fin in Myctophiiformes?

(a) The developmental data imply at least two (probably three +) separate origins (one from the median fin, one from some other group of cells). So the Characoidei would have an adipose fin that may not be homologous to the other groups, which (given the distribution of taxa) mean that the siluriform fin is probably distinct from the other fold-based adipose fins. (b) The anatomical data is consistent with several different origins, with osmeriiforms and myctophiforms having one origin, salmonids another, and siluriforms a third, in addition to the characoid fin also being distinct. Or it's consistent with rapid functional evolution! Regardless, the anatomical evidence also strengthens the idea of (at least) three origins with silurifoms and characoids have non-homologous adipose fins as their anatomy *and* development differs. (n.b., for what it's worth, it is very likely the case that siluriforms and characoids have homologous adipose fins, but based solely on the limited data shown here, it'd be hard to draw that conclusion)

However, none of these data are strong enough to be conclusive (e.g., characoid and siluriform fins could be homologous, and their anatomy and development could have changed for functional reasons). Further, the consistency of the distribution of the trait on the tree conflicts with the other evidence (did not need to note this for full credit, but it is shown in the data).