Assume anything stated in the question is true. If your answer to a question involves contradicting something stated in that question or its background information...it isn't the right answer.

Read each question carefully.

These questions are tricky. Plot out your answer before you start writing; you're welcome to draft answers on scrap paper or annotate questions to get your thoughts in order.

Make sure you answer everything each question asks. Each part of each question is worth an *equal* fraction of the question's point value. If a part of a question is labeled, for example, c+d, then one answer is required but it counts as two parts of the question.

Read the question carefully! Advice so nice I put it twice! Don't answer something different from what I ask for!

Work within the limits of the data. Sometimes the data are ambiguous and it is correct to say, "you can't tell from these data" because that's just the way the world works. Sometimes the answer might be "nothing" or "none"! Don't try and guess what you think I want, just answer each question with what you really think the answer is.

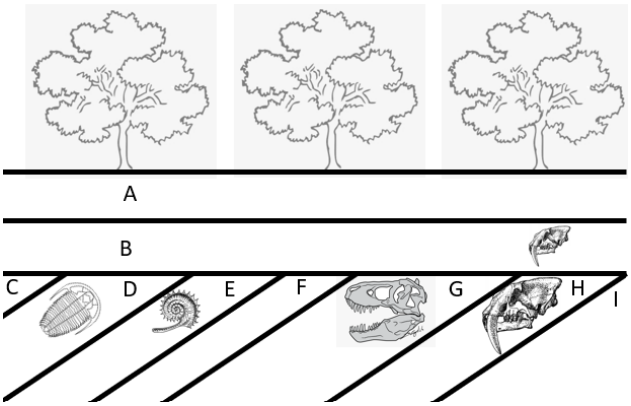
Also, **ask me questions!** If something is unclear or confusing, and you ask me about it, I may be able to clarify it. The worst I can do is say, "sorry, I can't answer that question", but most of the time I can give you some sort of clarity. Always worth trying!

1. (1 point) *Prions are infectious proteins–strange macromolecules that, when they encounter another protein with the same sequence of amino acids, will change the folded structure of that protein to match the prion. The newly formed prion will then subsequently change any compatible proteins it encounters into more of the same prions. Prions originate from a mutated nucleic acid sequence that produces the original protein, which then misfolds. The same amino acid sequence can misfold in multiple ways to produce prions that have different affinities and properties. Once the first prion forms, it can then spread about a body, or even between bodies, producing more copies of itself by misfolding the proteins it encounters. The most well-known prion disease is called "mad cow disease" but prions are associated with diseases in humans (e.g., Kuru, fatal familial insomnia) and other animals (chronic wasting disease) Interestingly, prions were first identified as infectious proteins because UV light treatments, which kill nucleic-acid based pathogens, had no ability to sterilize something infected with prions.* (a) Which of the criteria for evolution by selection do prions fail to satisfy? (b) Can the gene sequence that produces a prion in the first place evolve? (c + d) Can prions evolve after they've been produced, even without any nucleic acids involved?

a) None

b) Yes

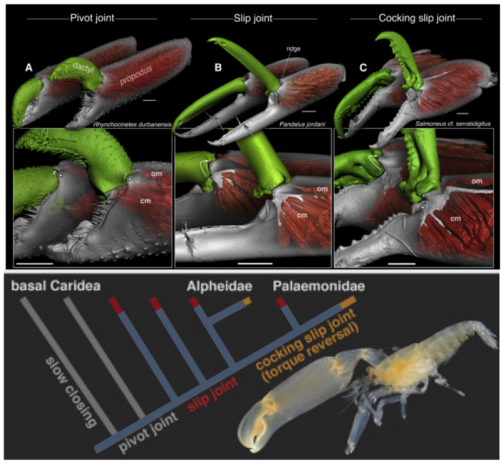
c+d) Yes



2. (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, modern(ish) 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) A (b) C

(c+d) The layers C-I were overturned by tectonic activity and are now upside-down. You can tell because trilobites are older than dinosaurs, and dinosaurs are older than mammals.



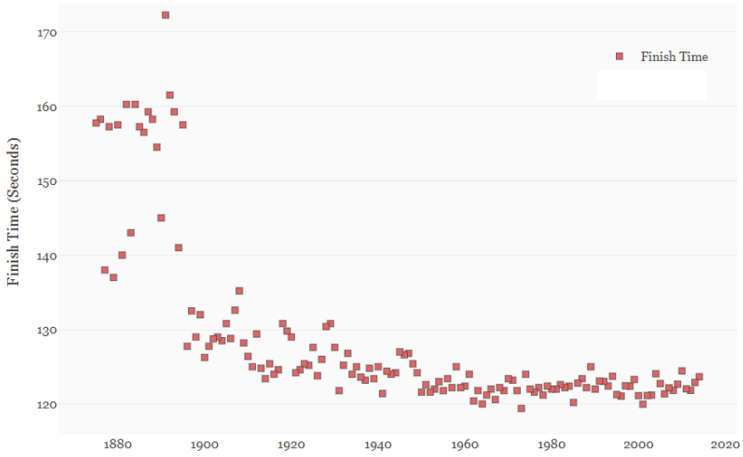
3. (1 point) *Pistol shrimp are amazing. They have specialized giant claws, with an elaborate joint that allows them to be cocked like a pistol. These small shrimp do not use their claws to grab things as other crustaceas do, though. Instead, the upper portion of the claw (the dactyl) is held upon under tension and can be "fired" also like a pistol. The dactyl snaps shut so fast, a jet of water is fired out. The snapping of this shrimp is one of the loudest sounds produced in nature, and the water forced forward from it's claw can kill a small fish several centimeters away (quite far for such a tiny shrimp!). Two clades (Alpheidae and Palaemonidae) have shrimp with these specialized snapping claws, and* ***none*** *of the other 50,000+ species of Crustacea have anything like this. The above diagrams show shrimp claw anatomy, and both Palaemonidae and Alpheidae with the cocking slip joint have essentially identical anatomical structures to produce this joint. Developmental and genetic data show that the joints are formed by the same cells using the same genes in the two different groups. These claws which are anatomically, genetically, and developmentally-identical and found* only *in these two small groups of shrimp are* ***not*** *completely homologous.*

(a) What is the best evidence that the special claws in these two shrimp groups are *not* completely homologous?

(b) Given that the common ancestor of the two types of shrimp did not have this special joint, what else do these data tell us about that ancestor?

(a) The distribution across taxa is not consistent.

(b) The basis or *potential* for this joint must be shared/homologous



4. (1 point) *The Kentucky Derby is a horse-race held every year in Kentucky. Lots of very wealthy people spend a truly obscene amount of money preparing for it. Horses that win the Kentucky Derby and other high-profile races are then used as studs, and are rented to horse-breeders to father the next generation of horses for, again, absurdly high amounts of money. The Kentucky Derby involves* ***many horses running at different speeds.*** *The fastest horse, the one that runs the track in the least time, is the winner.* ***A winning horse will father many more foals than a losing horse****, and even a losing horse will father many more foals than one that did not qualify for the race. A ton of money and effort has gone into breeding the fastest possible horses. Above are data showing winning time around the 1.25 mile long track since the late-1800's. Although training, equipment, and jockey techniques have all chanegd over the decades, these changes have been too slight to have a noticeable impact on horse speed.* ***Differences in speed in elite race horses can be assumed to be genetic.***

(a) Based on the above data, if I took wild horses and began racing them & bred only the winners, would their speed increase over the next few generations?

(b) Based on the above data, if I took a bunch of recent Derby winners and began racing them, then bred only the winners, would their speed increase over the next few generations?

(c & d) Propose a **single** explanation for your answer in (b) consistent with the above data & information.

(a) Yes (b) No

(c) The question text tells you that there's variation (not all horses win), and differential replication based on that variation (winners get bred). But the race times aren't changing! That leaves only the heritability of speed as a potential issue. Despite speed being stated as being genetic, and despite speed clearly having evolved in the past, you should be able to recognize now that *something has gone wrong with heritability of speed.* What, exactly, has happened to heritability here is coming soon to a lecture near you...

5. (1 point) *Your coolest friend, while relaxing with you on the quad, says, "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. Are my arms homologous to my legs?"* How do you answer your coolest friend?

The answer is "yes, to an extent." A hard "no" got no credit, and a hard "yes" with no qualification or explanation got half credit. It's sufficient to note that arms & legs 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 (the jargon term for this is *serial homology* but you don't need to know that to answer 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. There is "sameness" here!

A third 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. So human arm = chimp arm $\approx$ human leg, meaning that there's a degree of sameness (some degree of homology) between a human arm & leg.