*Your coolest friend approaches you with an interesting biological problem, and asks for your help making sense of it, "So I've got these drawings of some rare creatures from a far away region of the world. All I have are these old drawings by a guy named Camin, so I'm calling these creatures "Caminalcules". Apparently he travelled to this area back in the 70's and saw and carefully documented the physical traits of these animals. He also noted where he saw each creature, and made notes about finding more specimens in several sections of rock. I have his drawings, his map, and his geological sections, and I can show them to you here. Another guy, Gendron, published a phylogeny back in 2000, but I don't think it's right. I've made an attempt at making a new taxonomy, a hierarchical grouping, of the creatures. I've divided them into five small groups I'm just calling c, t, e, x, & z. I've further grouped those five into bigger groups: Blue group is z/x, Green group is z/x/e, Orange group is c/t, and the Gray group is all of them except for one I can't quite place.*

**1.** (2 points) Help your friend by:

(1a) Determining what big group (colored box) the unknown creature best fits in and explaining why.

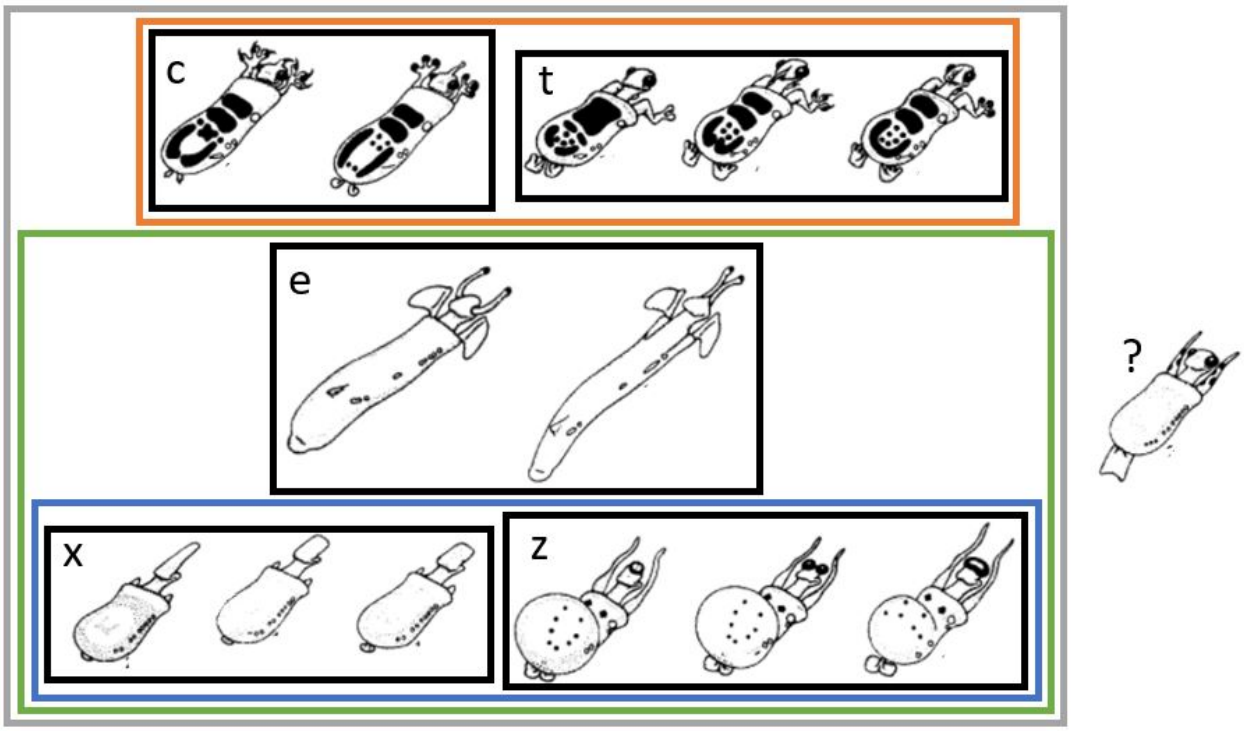
(1b) Determining how many times paired eyes evolved (i.e., are the paired eyes seen in the orange box homologous to, or convergent with, the eyes seen in groups e and one member of group z).

(1c) Identifying at least four traits that have probably evolved convergently, again assuming this set of groupings is correct.

(1d) Proposing an alternative grouping that would have less convergence.

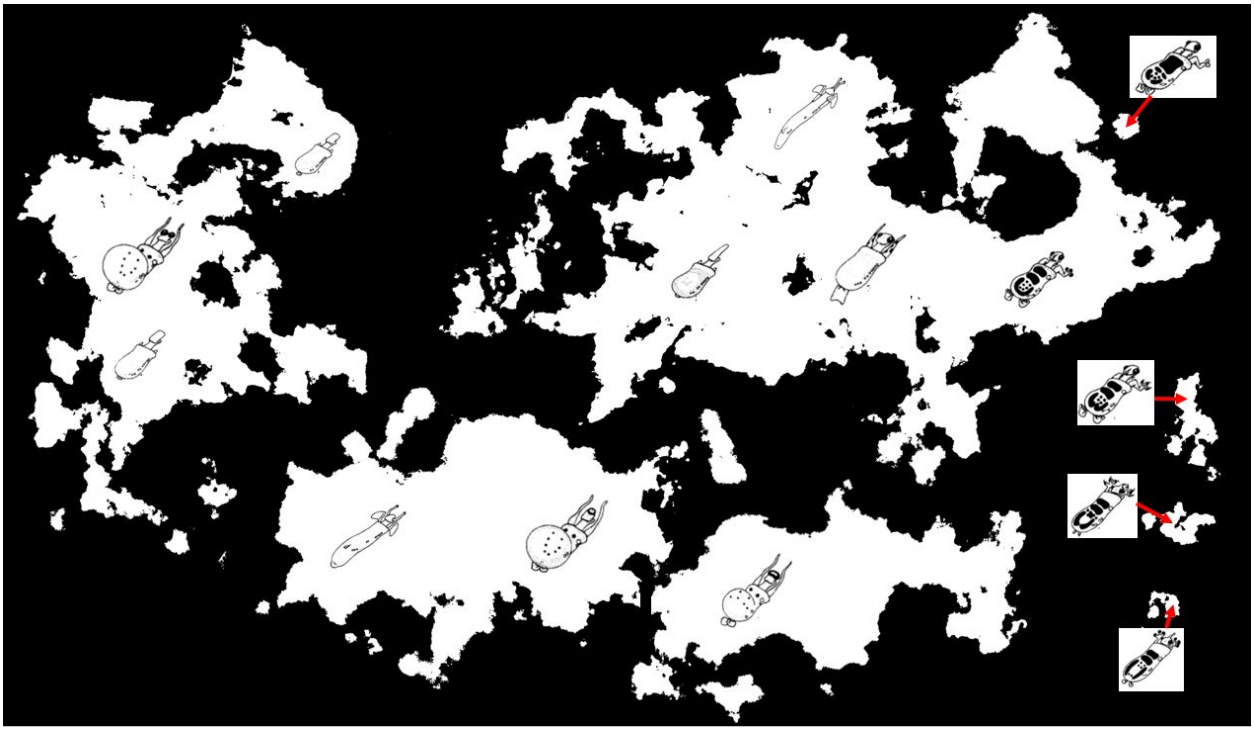
**2.** (1 point) Help your friend by finding (a) the *most likely* example of dispersal and (b) the *most likely* example of vicariance on the map.

**3.** (2 points) Help your friend by determining the relative age of the fossils by organizing the rock layers (A - Y) from oldest to youngest. There may be uncertainty with regards to some layers, so make sure you are clear with your friend! You also need to be pretty clear about how you determined the relative age of these layers, so that your friend can better understand how to do it on their own in the future.



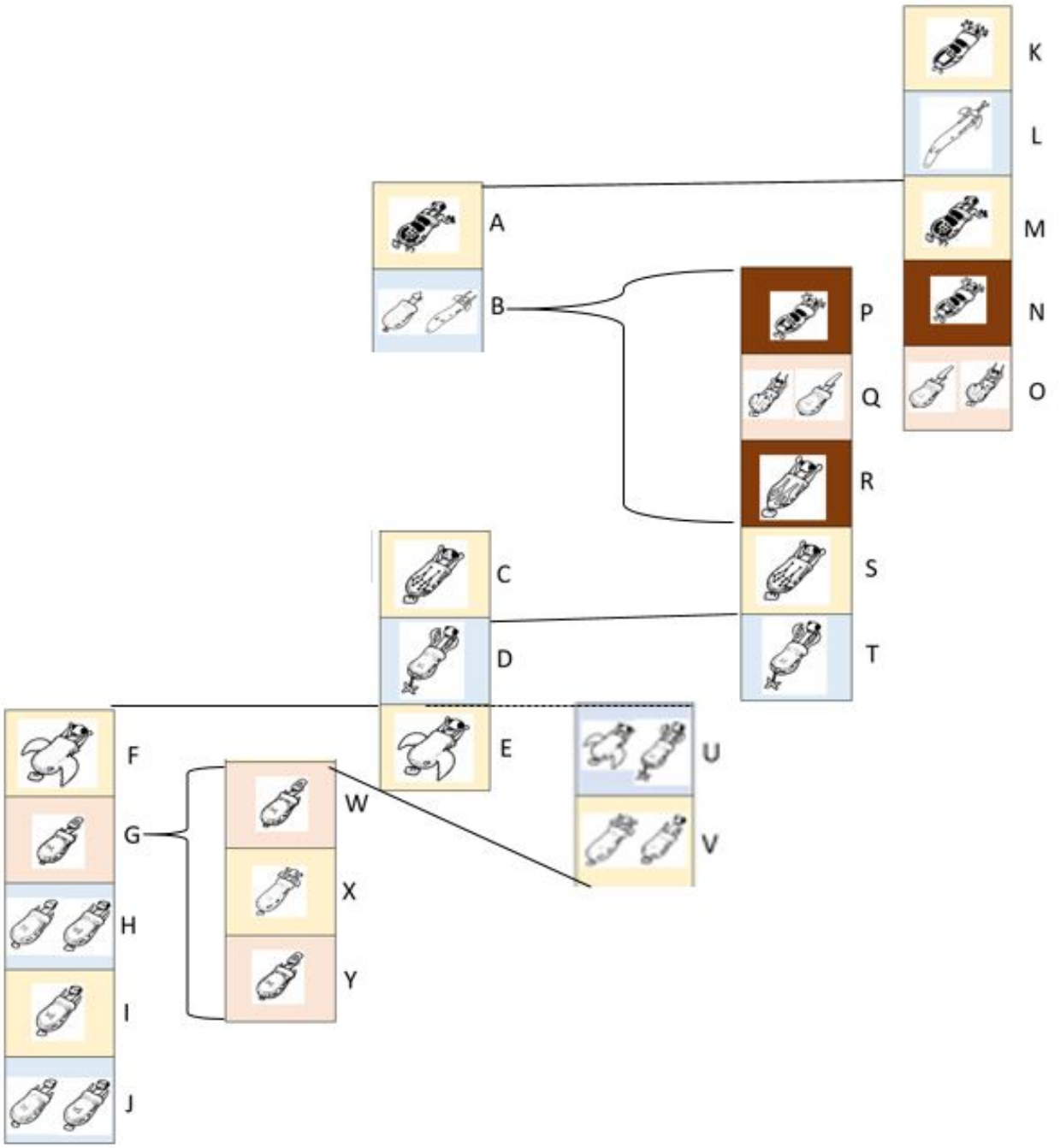

Proposed taxonomy & mystery creature

- 1a Full credit: discussed specific trait homologies and convergence when determining placement. Half credit: discussed only overall similarity. No credit: Only gave an assignment, no trait discussion. No living species can be the ancestor of other living species, so a common error was to call this living species an "ancestor". We can't be sure of how traits evolved, but some explanations are more likely than others, especially given the patterns seen in the fossil data from part 3. Must use everything!
- 1b Full credit: Homologous based on consistent trait distribution (only group x lose eyes, although some in z fuse them). Common ancestry works here, too (same thing). Half credit: homologous for any other reason OR convergent with a pretty good justification (eyes seem to change a lot in this group, maybe they evolve quickly!). No credit: No good justification. Best answer here involves reference to the fossil data in Question 3: paired eyes were there from the start!
- 1c Many options. The key is that convergent traits need to be (1) shared by at least two species and (2) have not been present in their common ancestor. Since we can't know for sure what was or was not present in the common ancestor, as in a & b we must stick with the most likely explanations. That is, the fused eyes seen in two members of group z *could have* evolved separately, but more likely it evolved once (especially given the map!). Some examples: shortened neck (c, e); dorsal spots (c/t and z); elongated forward appendages (z and c/t); bifurcated tail into appendages (z and c/t), lost rear appendages (e & x); other possibilities
- 1d x [ z [e [ct] ] ] is the least convergent grouping, BUT any grouping you give where you specifically address and discuss the convergences your new grouping gets rid of & mention at least one new one it creates, you got full credit. Bringing in the biogeographical data here is also a good idea.



Biogeographic map of observations

Dispersal obvious from island members of orange group, vicariance most likely in the division of z group members on the southern continent (there is a narrow strait that seems to have cut the continent in two, no other clear possibility for vicariance really on this map)




Set of stratigraphic columns with fossil occurrences. Rock layers are colored by environment type, but that rascal Camin didn't include a key!

Explanation of grading: (1 point) a (mostly) correct sequence. (1 point) At least four ambiguities described below discussed. Trans/regress sequences. Blue = lime, yellow = sand, red =terrestrial, brown = mud.
Order: $J \to I \to H \to G = (W/X/Y) \to F = E(V \to U) \to D = T \to C = S \to R \to Q = O \to P = N \to M = A \to L \to K$ (youngest).
Key things:

◦ Layer A correlates to layer M, so there's some missing time between A & B
◦ Layer B is somewhere between S/R/Q/O/P/N, but canont be mapped to a specific other layer. It represents some unique time/environment situation that wasn't present in the other areas.
◦ Layer G correlates to Y/X/W entirely. That is, G doesn't correspond to just one, but rather all three layers–or, to put another way, there's no way to tell whether G = W or G = Y, so you have to treat it as a single correlation
◦ Layer U complicates things greatly. E/D/F/T all have one of the two species seen in U. D and T are the same environment as U, so the E/F species truly seems to be absent from D/T. But it's unclear if the D/T/U species occurs in the environment of E/F. If you place U somewhere specific, equivalent to F/E is most defensible.
◦ Layer V is older than U & younger than W, but like B, cannot be directly correlated to another layer.