**QUESTION 1**

Using the table that follows, do the following:

* Treat the lancelet as the outgroup.
* Draw all of the possible trees depicting the possible relationships among these taxa.
* Map the characters onto each tree.
* Determine which trees fit the data best by calculating the tree length, i.e. total number of evolutionary changes on the tree.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Taxon** | **Jaws** | **Vertebrae** | **Paired Fins** | **Pouched Gills** | **Skull** |
| **Lancelet** | Absent | Absent | Absent | Absent | Absent |
| **Hagfish** | Absent | Absent | Absent | Present | Present |
| **Lamprey** | Absent | Present | Absent | Present | Present |
| **Shark** | Present | Present | Present | Absent | Present |
| **Goldfish** | Present | Present | Present | Absent | Present |

Some studies have suggested that hagfish and lampreys are more closely related to each other than to other vertebrates. Is this clade supported by these data?

If it were supported, what would it imply regarding the evolution of vertebrae?

Recent embryological studies have demonstrated that vestigial vertebrae are present in hagfish embryos. If we score hagfish as having vertebrae, how does that change your results?

**QUESTION 2**

Using the table that follows, do the following:

* Treat the shark as the outgroup.
* Draw all of the possible trees depicting the possible relationships among these taxa.
* Map the characters onto each tree.
* Determine which trees fit the data best by calculating the tree length, i.e. total number of evolutionary changes on the tree.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Taxon** | **True Bone** | **Internal Nostrils** | **Limbs** | **Waterproof Skin** |
| **Shark** | Absent | Absent | Absent | Absent |
| **Lungfish** | Present | Present | Absent | Absent |
| **Salamander** | Present | Present | Present | Absent |
| **Lizard** | Present | Present | Present | Present |
| **Dog** | Present | Present | Present | Present |

The following two characters relate to the evolution of breathing mechanisms in vertebrates. Map them onto your most parsimonious phylogeny. Based on your results, where did the important changes in breathing mechanisms evolve?

|  |  |  |
| --- | --- | --- |
| **Taxon** | **Inhalation** | **Exhalation** |
| **Shark** | Absent | Absent |
| **Lungfish** | Buccal Pump | Passive |
| **Salamander** | Buccal Pump | Abdominal Muscles |
| **Lizard** | Aspiration | Abdominal Muscles |
| **Dog** | Aspiration | Abdominal Muscles |