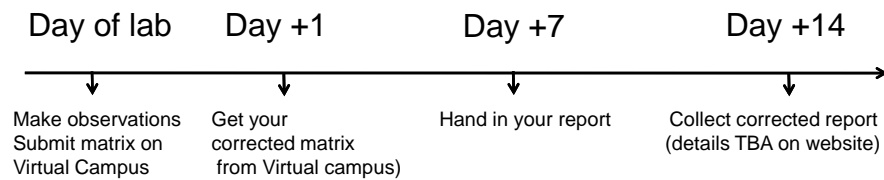


Vertebrate Phylogeny

LAB4 TIMELINE



Objectives

Lab outline and objectives:

- understand terminology associated with cladistic analysis
- make detailed observations concerning 12 morphological characters in nine different species of euchordates
- Polarize data using the lamprey as an outgroup



Objectives (continued)

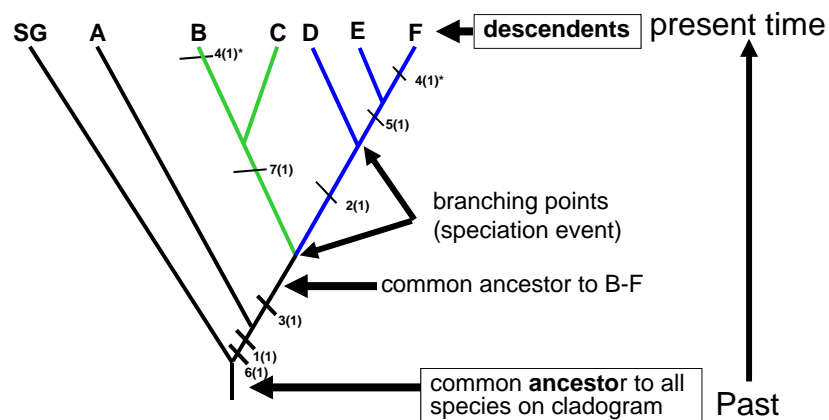
- express phylogenetic information regarding the evolution of the vertebrates in a cladogram
- recognize homoplasies and postulate whether they are the result of convergence or reversals
- postulate a hypothesis regarding the evolution of endothermy in vertebrates



BIO1130 – Organismal biology

Terminology

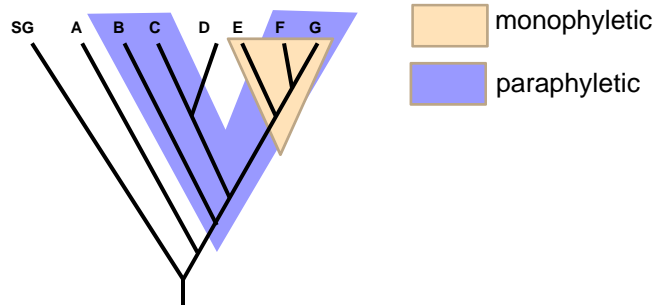
Cladogram: Branching diagram that presents the relationship between different groups based on the distribution and transmission of derived characters.



BIO1130 – Organismal biology

Terminology (cont'd)

Monophyletic group: group that includes the common ancestor to this group plus all its descendants (also called 'clade').



BIO1130 – Organismal biology

Terminology (cont'd)

- **Character:** any morphological, biochemical or behavioural feature that can be observed.
- **Homologous characters:** 2 characters are **homologous** if they derive from a structure present in a distant, common ancestor. Only these characters are informative to define monophyletic groups.
- **Character states (or evolutionary stages of a character):**
 - Ancestral or **plesiomorphic** (also called general, primitive)

↓ transformation

 - Derived or **apomorphic** (exclusive, advanced)



BIO1130 – Organismal biology

Terminology (end)

Homoplasy: phenotypic similarity among different species that is not inherited from a common ancestor (non-homologous similarity):

- Convergence: similar feature appearing in several species that do not share a common ancestor (ex. wings in insects and birds).
- Reversal: when a derived character reverts to a more ancestral state within a group of species (ex: Loss of limbs in snakes)

Principle of parsimony: the simplest solution is more likely to be correct (=the cladogram involving the less transformation steps is more likely to represent the actual chain of events).



BIO1130 – Organismal biology

Lab 4 – Procedure

Three phases:

- 1- Conduct a series of morphological observations (12 characters) on 9 animals
- 2- Record observations in table format (matrix) using the lamprey as a sister group or outgroup
- 3- Carry out a phylogenetic analysis of your data and construct a cladogram



BIO1130 – Organismal biology

An example of phylogenetic analysis

- Observations regarding 9 characters were made on 8 species of fish (one of these was chosen as the sister group SG)



BIO1130 – Organismal biology

Observations Matrix

Group or species

characters

Character	Branchial chamber	Reproduction	Scales	Number of dorsal fins	Parental behaviour	Orientation of mouth	Position of eyes on the head	Teeth	Caudal fin
Species	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SG*	Slits	Eggs	Absent	1	No	Dorsal	Dorsal	Present	Round
A	Operculum	Viviparous	Present	1	Yes	Terminal	Dorsal	Present	Pointed
B	Operculum	Viviparous	Present	1	Yes	Terminal	Dorsal	Present	Square
C	Operculum	Eggs	Present	2	No	Terminal	Lateral	Absent	Pointed
D	Operculum	Eggs	Present	1	No	Terminal	Lateral	Absent	Pointed
E	Operculum	Eggs	Absent	1	No	Ventral	Dorsal	Present	Round
F	Operculum	Eggs	Present	1	No	Ventral	Dorsal	Present	Pointed
G	Operculum	Viviparous	Present	2	Yes	Terminal	Dorsal	Present	Square



BIO1130 – Organismal biology

Polarization using the outgroup comparison

- The character **state** found in the sister group is coded as "0" by definition (ancestral)
- If the ancestral **state** of a character is also found in species within the ingroup, enter a "0" for these species.
- If the character **state** is different from the sister group, it is apomorphic and is coded as "1"
- If two apomorphic states are present, they are coded by 1 and 2 (irrespectively of which one is 1 or 2).



BIO1130 – Organismal biology

Recoding the character matrix = polarisation of characters

Character	Branchial chamber	Reproduction	Scales	Number of dorsal fins	Parental behaviour	Orientation of mouth	Position of eyes on the head	Teeth	Caudal fin
Species	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SG*	Silts	Eggs	Absent	1	No	Dorsal	Dorsal	Present	Round
A	Operculum	Viviparous	Present	1	Yes	Terminal	Dorsal	Present	Pointed
B	Operculum	Viviparous	Present	1	Yes	Terminal	Dorsal	Present	Square
C	Operculum	Eggs	Present	2	No	Terminal	Lateral	Absent	Pointed
D	Operculum	Eggs	Present	1	No	Terminal	Lateral	Absent	Pointed
E	Operculum	Eggs	Absent	1	No	Ventral	Dorsal	Present	Round
F	Operculum	Eggs	Present	1	No	Ventral	Dorsal	Present	Pointed
G	Operculum	Viviparous	Present	2	Yes	Terminal	Dorsal	Present	Square

Characters ▶	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Species ▼	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SG	0	0	0	0	0	0	0	0	0
A	1	1	1	0	1	1	0	0	1
B	1	1	1	0	1	1	0	0	2
C	1	0	1	1	0	1	1	1	1
D	1	0	1	0	0	1	1	1	1
E	1	0	0	0	0	2	0	0	0
F	1	0	1	0	0	2	0	0	1
G	1	1	1	1	1	1	0	0	2



BIO1130 – Organismal biology

Color-coding your matrix makes it easier to read

Characters-> Species ▼	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SG	0	0	0	0	0	0	0	0	0
A	1	1	1	0	1	1	0	0	1
B	1	1	1	0	1	1	0	0	2
C	1	0	1	1	0	1	1	1	1
D	1	0	1	0	0	1	1	1	1
E	1	0	0	0	0	2	0	0	0
F	1	0	1	0	0	2	0	0	1
G	1	1	1	1	1	1	0	0	2



BIO1130 – Organismal biology

Building the cladogram

3 basic rules:

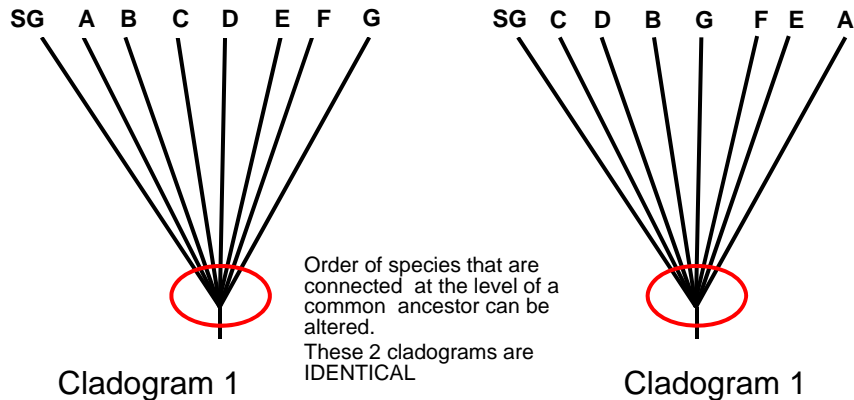
1. The cladogram presents the distribution of derived characters
2. Species that possess the same derived character(s) must be regrouped (monophyletic groups)
3. When several solutions are possible, you must choose the one that requires the lowest number of transformations (parsimony)



BIO1130 – Organismal biology

Step 1

- Initial cladogram. No resolution



BIO1130 – Organismal biology

Step 2

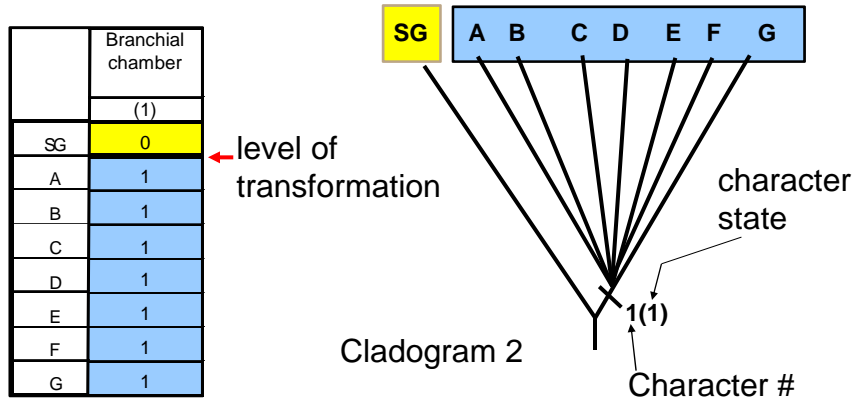
- Refine cladogram progressively by adding transformations of characters.
- Begin with binary characters that define large monophyletic groups (= lots of “1”, no “2”)

Characters-> Species	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SG	0	0	0	0	0	0	0	0	0
A	1	1	1	0	1	1	0	0	1
B	1	1	1	0	1	1	0	0	2
C	1	0	1	1	0	1	1	1	1
D	1	0	1	0	0	1	1	1	1
E	1	0	0	0	0	2	0	0	0
F	1	0	1	0	0	2	0	0	1
G	1	1	1	1	1	1	0	0	2



BIO1130 – Organismal biology

Adding the first character on the cladogram



Syntax: **X(Y)** X=character number - Y=character state



BIO1130 – Organismal biology

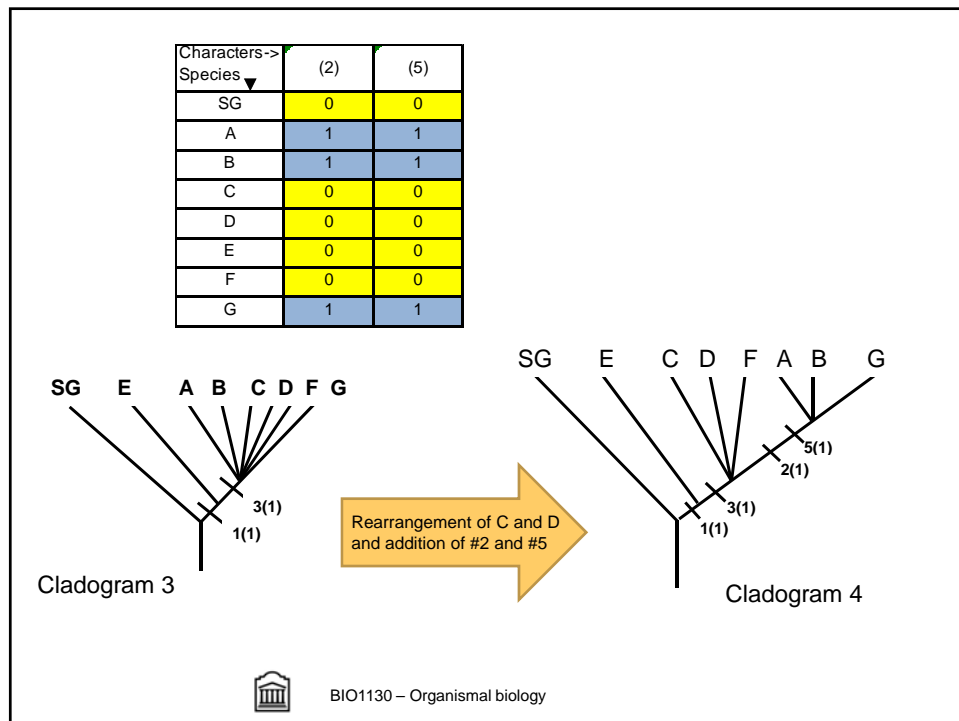
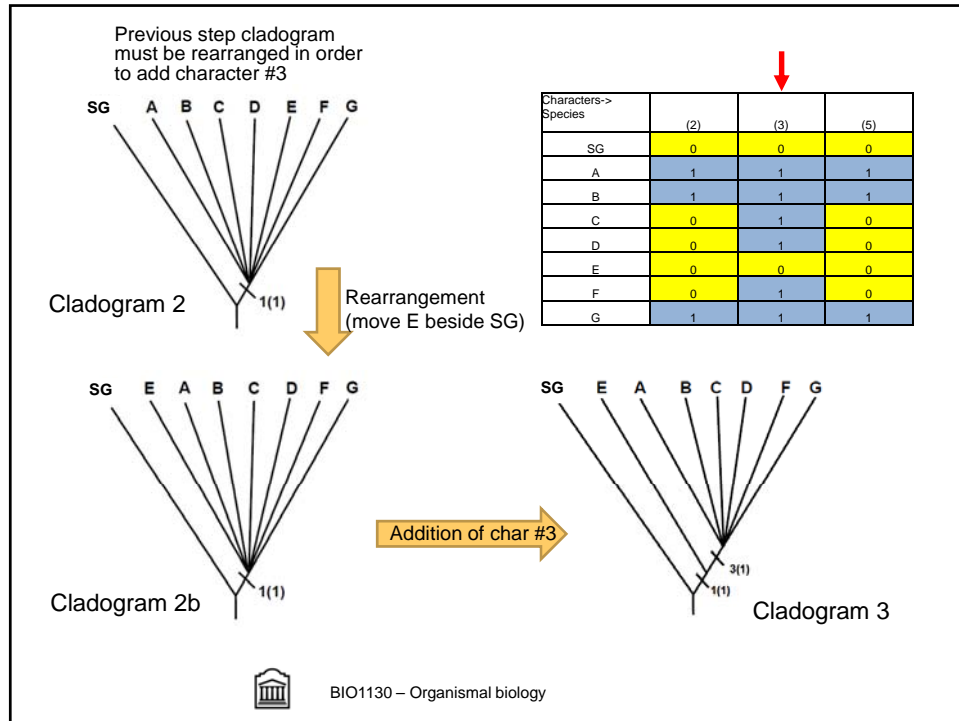
Step 3

- Use the same reasoning to add characters 3, 5 and 2 on the cladogram

	<div> <div></div> <div></div> <div></div> </div>								
Characters-> Species	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SG	0	0	0	0	0	0	0	0	0
A	1	1	1	0	1	1	0	0	1
B	1	1	1	0	1	1	0	0	2
C	1	0	1	1	0	1	1	1	1
D	1	0	1	0	0	1	1	1	1
E	1	0	0	0	0	2	0	0	0
F	1	0	1	0	0	2	0	0	1
G	1	1	1	1	1	1	0	0	2



BIO1130 – Organismal biology



Characters 7,8 and 4 give contradictory information

- 7 and 8: regroup D and C
- 4: groups C and G

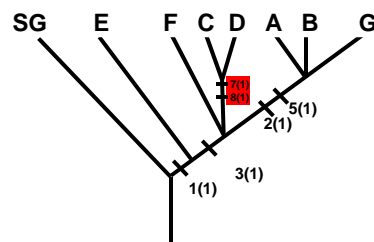
Characters-> Species	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SG	0	0	0	0	0	0	0	0	0
A	1	1	1	0	1	1	0	0	1
B	1	1	1	0	1	1	0	0	2
C	1	0	1	1	0	1	1	1	1
D	1	0	1	0	0	1	1	1	1
E	1	0	0	0	0	2	0	0	0
F	1	0	1	0	0	2	0	0	1
G	1	1	1	1	1	1	0	0	2



BIO1130 – Organismal biology

Observing the cladogram from the previous step allows to add 7 and 8 with no ambiguity

Characters-> Species	(4)	(7)	(8)
GF	0	0	0
A	0	0	0
B	0	0	0
C	1	1	1
D	0	1	1
E	0	0	0
F	0	0	0
G	1	0	0

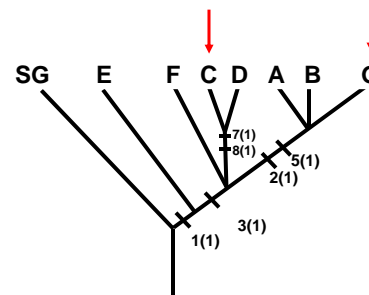


BIO1130 – Organismal biology

Character 4 does not define a monophyletic group: it's a homoplasy

- Is it the result of reversal or convergence event?

Characters Species	(4)
GF	0
A	0
B	0
C	1
D	0
E	0
F	0
G	1



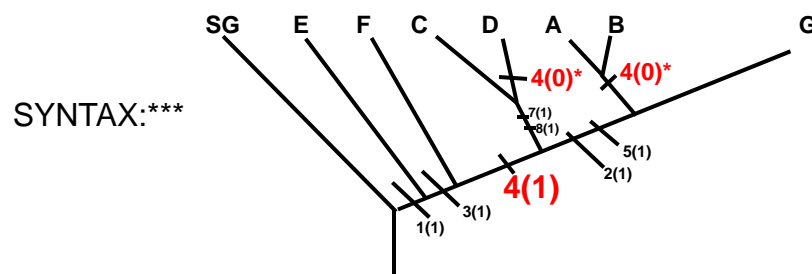
Cladogram 5



BIO1130 – Organismal biology

Scenario I: Reversal

C and G inherited 4(1) from their common ancestor: reversal on D, E and F



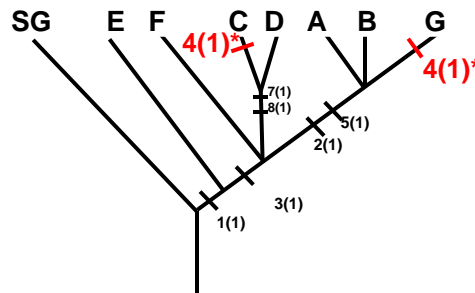
→ Implies 2 reversals: on D and ancestor of E and F



BIO1130 – Organismal biology

Scenario II: Convergence

- 4(1) appeared independently on C and G



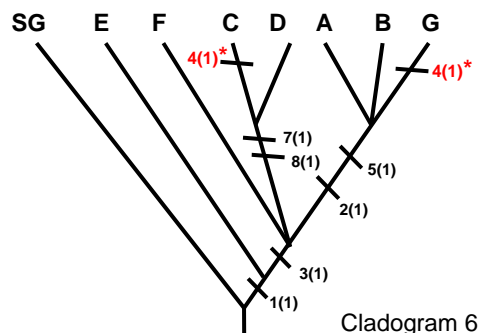
Implies: 1 convergence event



BIO1130 – Organismal biology

Convergence is more parsimonious

The convergence hypothesis is more parsimonious.
This results in the following cladogram:



Cladogram 6



BIO1130 – Organismal biology

Let's now consider a character with more than two states, such as character 6.

Characters-> Species	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SG	0	0	0	0	0	0	0	0	0
A	1	1	1	0	1	1	0	0	1
B	1	1	1	0	1	1	0	0	2
C	1	0	1	1	0	1	1	1	1
D	1	0	1	0	0	1	1	1	1
E	1	0	0	0	0	2	0	0	0
F	1	0	1	0	0	2	0	0	1
G	1	1	1	1	1	1	0	0	2



BIO1130 – Organismal biology

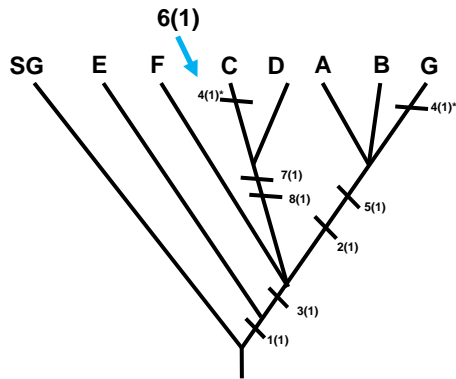
- Three sets of transformations for this trait are possible:
 - Dorsal mouth (0) >>ventral mouth (1) >>terminal mouth (2)
 - Dorsal mouth (0) >>terminal (2) >>ventral (1)
 - Terminal mouth (2)<<dorsal (0) >>ventral (1)



BIO1130 – Organismal biology

We use the information already present on the cladogram in order to determine the sequence of transformation of character 6.
Species that possess state 1 can be grouped in a monophyletic group [CDABG].

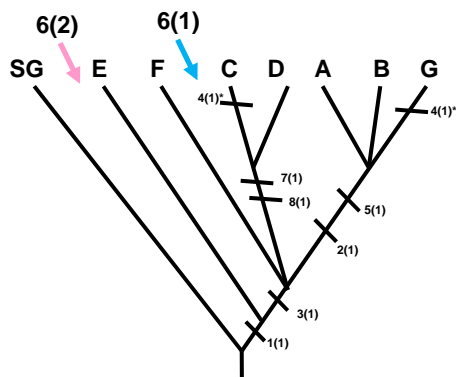
Characters-> Species	(6)
SG	0
A	1
B	1
C	1
D	1
E	2
F	2
G	1



BIO1130 – Organismal biology

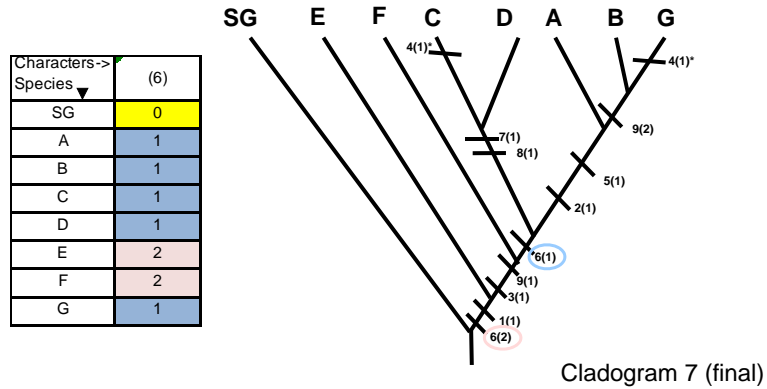
Species that possess 6(2) do not represent a monophyletic group (E+F), but the transformation to 6(2) is easy to place using the parsimony principle.

Characters-> Species	(6)
SG	0
A	1
B	1
C	1
D	1
E	2
F	2
G	1



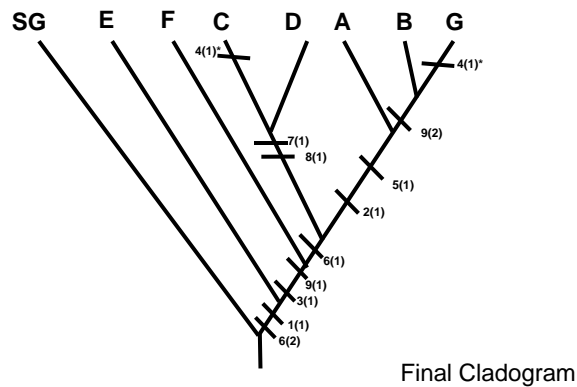
BIO1130 – Organismal biology

That's it, we resolved the sequence of transformation:
dorsal mouth → ventral → terminal
6(0) → 6(2) → 6(1)



BIO1130 – Organismal biology

This final cladogram results:



BIO1130 – Organismal biology

Before the lab

- Carefully read the manual & Prelab presentation
- Know the characters

The day of the lab:

- Arrive at 2:20 (12:50 on Friday)
- **Bring your lab coat and safety glasses**
- Attendance is mandatory



BIO1130 – Organismal biology

Assignment:

- 1- Enter your observations in the excel matrix.
- 2- Submit CODED matrix to virtual campus (instructions during the lab).
- 3- Your corrected matrix will be returned to you on virtual campus at the date indicated by your TA during the lab.
PRINT THE CORRECTED MATRIX AND ATTACH IT TO YOUR REPORT.
- 3-Hand in report one week after the day of your lab



BIO1130 – Organismal biology

Cladogram report (see **instruction file** on website for more details)

- **Report content:**
- Title page
- Assignment sheet (species and characters)
- **Printout of the corrected matrix sent back by your TA**
- Cladogram:
 - Initial cladogram with no resolution
 - **One cladogram per stage (all characters added successively to the previous step)**
 - Comment for each step including full name of added character and reasoning if a homoplasy has been added
 - Final cladogram: big, clean and annotated (species full names).
- **Conclusion:** How does endothermy (a character that hasn't been used to build the tree) fit in your cladogram? What can you conclude about its evolution in chordates?



BIO1130 – Organismal biology

Visit LabWeb for more information

Don't forget your labcoat. No labcoat = -10%

Do not wait the last minute to start your cladogram... It may be too late to contact a TA for additional help.

Section C9 lab is on DEC 1st



BIO1130 – Organismal biology