Section 2, Module 2: Phylogeny and its applications – Teacher copy

The Mountain Pepper is a well-known plant species native to Australia. It is distributed from Tasmania to Victoria and Southern New South Wales, having been extensively used by Aboriginal people for its food and medicinal properties. During colonial times, the plant was promptly identified as an efficient source of vitamin C, used to treat scurvy, and was a popular spice for cooking. Today, Mountain Pepper has commercial use, being imported to Japan for constituting one of the ingredients that makes wasabi. The figure below shows a short section of the Angiosperm clade, which includes the order to which Mountain Peppers belong.

Tasmannia lanceolata, Mount Donna Buang, Victoria, Australia
Image source: Wikimedia commons

Phylogeny of ancient spice clade Magnoliids

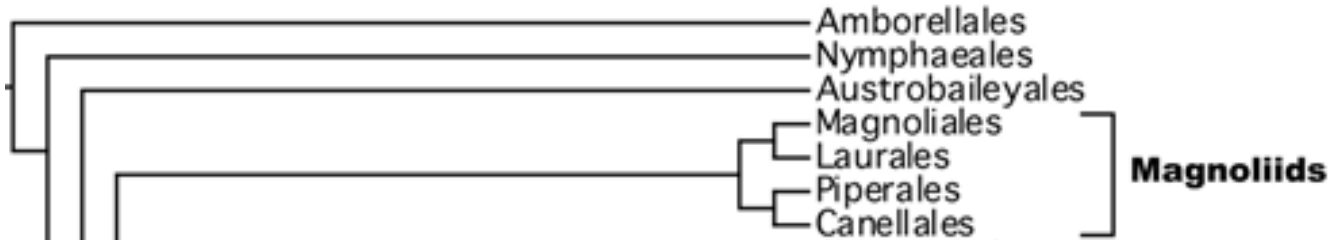


Figure 1: Current phylogenetic tree of Angiosperms, depicting the Magnoliids and all of its Orders.

Due to its valuable properties, there is an interest in identifying other plant species that might be similar to the Mountain Pepper. Knowing that related species tend to present similar properties, a scientist wants to find which plant previously understudied would most resemble the Mountain Pepper. For the investigation, the scientist chooses Nut Meg, Bay leaves, Black pepper and the Giant Water Lily looking to find whether they group together based on their chemical and molecular similarity. The plant species chosen by the scientist and their respective uses are summarised in Table 1.

Table 1: Well-known Angiosperms across the globe and native to Australia

Common name	Uses	Species	Order
Nut meg	Spice	*Myristica fragrans*	Magnoliales
Bay leaves	Spice	*Laurus nobilis*	Laurales
Black pepper	Spice	*Piper nigrum*	Piperales
Australian native pepper	Spice/ herbal remedy	*Tasmannia lanceolata*	Canellales
Giant water lily	Ornamental	*Victoria amazonica*	Nymphaeales

Given that the Orders of all plant species shown in Table 1 are present in Figure 1, you are to find which Order correspond to which plant. To assist with your investigation, you will be provided two sets of data: The first will be the DNA sequences of each plant species (Table 2). The second will be their chemical properties (Table 3). Using the data you have available, construct the phylogenetic tree for these species and then indicate to which Order each of the plants are likely to belong.

Table 2: Hypothetical DNA sequences for phylogeny

Species	DNA sequence									
Nut meg	**A**	**C**	**T**	**T**	**G**	**G**	**A**	**C**	**T**	**C**
Bay leaves	**A**	**C**	**T**	**C**	**G**	**G**	**C**	**C**	**T**	**C**
Black pepper	**C**	**C**	**A**	**A**	**G**	**G**	**G**	**G**	**A**	**C**
Australian native pepper	**T**	**C**	**G**	**A**	**G**	**G**	**T**	**T**	**A**	**C**
Giant water lily	**G**	**G**	**G**	**C**	**T**	**A**	**C**	**A**	**G**	**T**

Table 3: Chemical characteristics

Species	Chemical character 1 Piperitone	Chemical character 2 Myristicine	Chemical character 3 Sabinene
Nut meg	YES	YES	YES
Bay leaves	NO	NO	YES
Black pepper	YES	YES	YES
Australian native pepper	YES	YES	YES
Giant water lily	NO	NO	NO

Question 1

Counting the number of similarities between the different plant species, fill out the table below to organise your data. Species with highest similarity index (number of similar data) should be more related to each other.

Tip: Before counting the number of similarities between the different plant species, convert all information into numbers to make the comparison easier!

Species	DNA sequence									
Nut meg	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Bay leaves	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**0**
Black pepper	**1**	**0**	**1**	**2**	**0**	**0**	**2**	**1**	**1**	**0**
Australian native pepper	**2**	**0**	**2**	**2**	**0**	**0**	**3**	**2**	**1**	**0**
Giant water lily	**3**	**1**	**2**	**3**	**1**	**1**	**1**	**3**	**2**	**1**

Species	Chemical character 1 Piperitone	Chemical character 2 Myristicine	Chemical character 3 Sabinene
Nut meg	1	1	1
Bay leaves	0	0	1
Black pepper	1	1	1
Australian native pepper	1	1	1
Giant water lily	0	0	0

Molecular similarity matrix for the DNA sequences

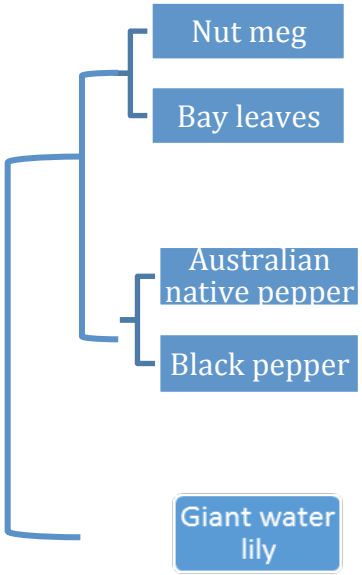
	Nut meg	Bay leaves	Black pepper	Australian native pepper	Giant water lily
Nut meg	X				
Bay leaves	8	X			
Black pepper	4	5	X		
Australian native pepper	4	4	6	X	
Giant water lily	0	2	0	1	X

Chemical similarity matrix for the chemical properties

	Nut meg	Bay leaves	Black pepper	Australian native pepper	Giant water lily
Nut meg	X				
Bay leaves	1	X			
Black pepper	3	1	X		
Australian native pepper	3	1	3	X	
Giant water lily	0	2	0	0	X

Question 2

Construct the phylogenetic tree of your plant species using the data provided. You should group plants with highest similarity index together, and then plot similar groups with each other following the example in Figure 1. Then, state to which Order each plant species is likely to belong. Remember: All species must be vertically aligned in your phylogenetic tree, showing that they are all existing (not extinct) species!



Question 3

Based on the information of your phylogenetic tree, which plant species is most likely to present similar properties to the Mountain Pepper? Explain your answer.

Besides having similar chemical properties for the chemicals analysed, the black pepper is also the most closely related plant species to the mountain pepper. That means that the black pepper has a higher likelihood to share similar properties with the native Australian plant, if compared to the other species analysed in this investigation.

Question 4

Suppose the scientist has decided not to use the commercially available plant species to replace the Mountain Pepper, but instead looked for other Australian native species that shared similar properties with it. Comment on at least two ways the scientist could find this other native species.

1) The scientist could find a list of other native Australian species of the Order Canellales and look for the species that share similar environmental pressures to the mountain pepper.
2) The scientist could use ethnobotany to investigate which other plants Aboriginal people used for same or similar effects as of the mountain pepper's.

Question 5

How do the chemical properties of species contribute to making your phylogenetic tree? Do you consider this type of data to be as important as the DNA sequence? Discuss how it is possible for nutmeg to be more chemically similar to the Australian native pepper than to bay leaves.

Chemical properties are found to be somewhat conserved across closely related species, serving as one of the sets of data that can inform a phylogenetic tree. This is mostly because metabolic pathways tend to be similar among related species. However, environmental pressure ultimately shapes the essential chemical properties of organisms that live in such environments, selecting against the ones that do not exhibit determined characteristics. Therefore, although there are phylogenetic links regarding chemical properties, they are not as strong as DNA evidence. It follows that DNA sequences are more relevant when building a phylogenetic tree than chemical properties. Even though the nutmeg is more closely related to bay leaves than to the Australian native pepper, it may present more similar chemical characteristics to the latter than to the former, perhaps due to the similarity between environments that nutmegs and Australian native peppers inhabit.

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