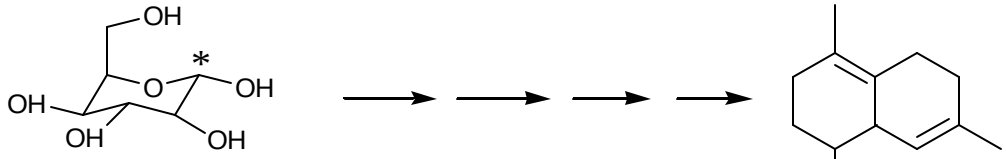
Biology 407b Plant Secondary Metabolism

Assignment No. 4 Terpenoid Biosynthesis

Solutions

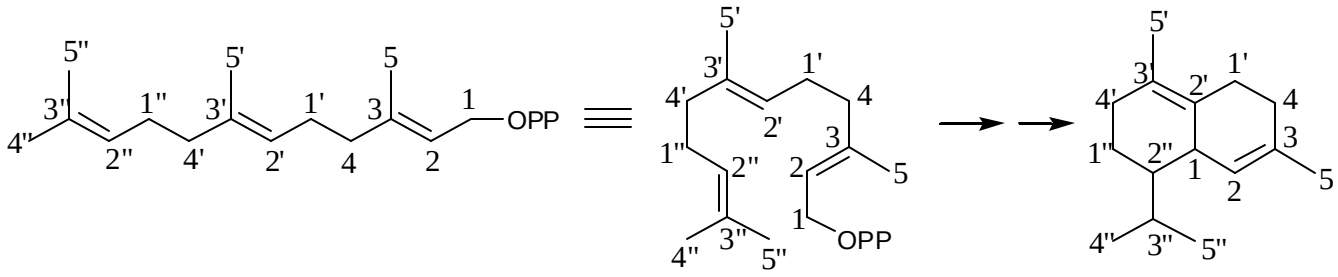
1. Predict the ^{13}C-labelling patterns of δ-cadinene derived from isoprene units synthesized via the mevalonic acid and deoxyxylulose phosphate biosynthetic pathways when [1-^{13}C]-glucose is the only carbon source (i.e., you only need to show the two labelled compounds, and not how you derived their labelling). [3 marks]



[1-^{13}C]-glucose

δ-cadinene

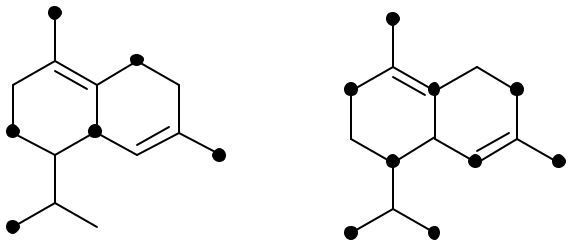
Solution: We know from labelling experiments that the mevalonate pathway yields 2,4,5-[^{13}C]-IPP, while the deoxyxylulose phosphate pathway yields 1,5-[^{13}C]-IPP, when 1-[^{13}C]-glucose is available as a carbon source. Therefore, in order to predict the labelling in δ-cadinene (a sesquiterpene), you have to track the carbons coming from three IPP units. This is shown below:



Farnesyl Diphosphate

δ-cadinene

From this point it is a simple matter of designating each appropriate carbon in the final compound:



Deoxyxylulose-derived δ-cadinene

Mevalonate-derived δ-cadinene

Note that for the deoxyxylulose-derived δ-cadinene, carbons 4" and 5" are indistinguishable.

2. Which of the labelling patterns depicted in your answer from Question 1 would most likely be found in plants administered [1-^{13}C]-glucose? Why? [2 marks]

Since δ-cadiene is a sesquiterpene, it would be expected that it would have the mevalonate-derived labelling pattern, since sesquiterpenes are only synthesized in the cytoplasm, i.e., the compartment in which the mevalonate pathway operates. The simplest explanation for the apparent sub-cellular compartmentation of the biosynthesis of the major classes of terpenoids involves the targeting of specific enzymes to plastids, while leaving others to carry out their metabolic conversions in the cytoplasm. Thus, while GPP- and FPP synthases are active both in the cytoplasm and plastids, the other major synthases and cyclases involved in terpenoid biosynthesis are expressed in either the cytoplasm or plastids, but not both. Specifically, you would expect squalene synthase to be localized to the cytoplasm. Similarly, the cyclases that utilize FPP as substrate (e.g., *epi*-aristolochene synthase, vetispiradiene synthase, δ-cadiene synthase, etc.) are also cytoplasmic. In the plastid, on the other hand, GGPP synthase is the major enzyme that utilizes FPP as a substrate. Its presence in the plastid, along with the **absence** of sequiterpene cyclases ensures that no sequiterpenes are synthesized in the plastids. Instead, monoterpene cyclases (e.g., pinene cyclase) diterpene cyclases (e.g., casbene synthase, taxadiene synthase, abietadiene synthase, copalyl diphosphate synthase) and phytoene synthase are **exclusively** active in the plastids. Presumably, all of the plastid-active terpenoid enzymes are synthesized with a plastid targeting signal peptide that ensures that they are delivered to the appropriate compartment.

Note, however, that there are exceptions to this general trend. The biosynthesis of gibberellins, for example, takes place in both the plastid (i.e., synthesis of *ent*-kaurene) and the cytoplasm (elaboration of the gibberellin ring structure by ER-bound and soluble enzymes).