Introduction to Gymnosperms

- Group of seed bearing plants that contain conifers, cycads, Ginkgo, and Gnetales.
- Currently comprised of a little more then 12 families, 83 genera, 1000 species. (compared to 300k angiosperms species.)

Pinus merkus

Cycas rumphii

Diversity and classification

- Distributed over all continents except Antarctica.
- 2/3s of all gymnosperms are conifers.
- Among each genera 34 are monotypic, 22 only have 2-5 species, and only 3 harbor more then 100 species (*Cycas, Pinus* and *Podocarpus*)
- Nearly half of the major genera occur in Asia and Australia.

Phylogeny and evolution

- Divergence between gymnosperms and angiosperms are dated to be about 300-350 mya.
- The 5 main lineages separated from each other during the late Carboniferous to late Triassic (311-212 mya)
- While many species such as *Ginkgo biloba* are living fossils,due to pulses of extinction and specialization most living gymnosperm species are much younger then though to be.
  - Cycads are not much older then 12 million years old
  - Suggests a coevolution between living cycads and their insect pollinators. This is due to the fact they occupy diverse habitats and show evidence of making adaptive shifts.
  - Sharp cooling/ drying at the end of the Eocene(56-33.9 mya) may of caused extinction of several conifers and cycads due to them normally occupying warmer and wetter environments

Phylogeny and Evolution cont.

- Due to these climate changes older lineages of gymnosperms are mostly found in the southern hemisphere.
  - This is due to the milder wetter habitats in the southern hemisphere.

Ginkgo biloba

Phylogenetic position of Gnetales

- Group of plants that are one of the major unsolved problems of gymnosperms.
- Gnetales are composed of three isolated genera *Ephedra*, *Gnetum*, and *Welwitschia*.
- Over the years 5 hypotheses have been formed to which group is their sister clade, and still being argued over today.

Welwitschia mirabilis

Phylogenetic position of Gnetales

- Hypothesis #1(A) Anthophyte Hypothesis.
  - This hypothesis assumes Gnetales to be the sisters of angiosperms.
  - Supported by some morphological, anatomical and reproductive characters such as net-veined leaves, vessels in the wood, double fertilization and simple, unisexual flower like structures.
  - Later studies prove that these characteristics between the two are NOT homologous or due to parallel evolution due to backings from molecular studies.
  - Studies only found that they were weakly linked together by their ribosomal DNA. Also to be though that the link between the due could be completely due to paralogus copies (due to HUGE genomes).
  - Regardless of all this very interesting that it is at all supported by the slowing evolving ribosomal DNA.

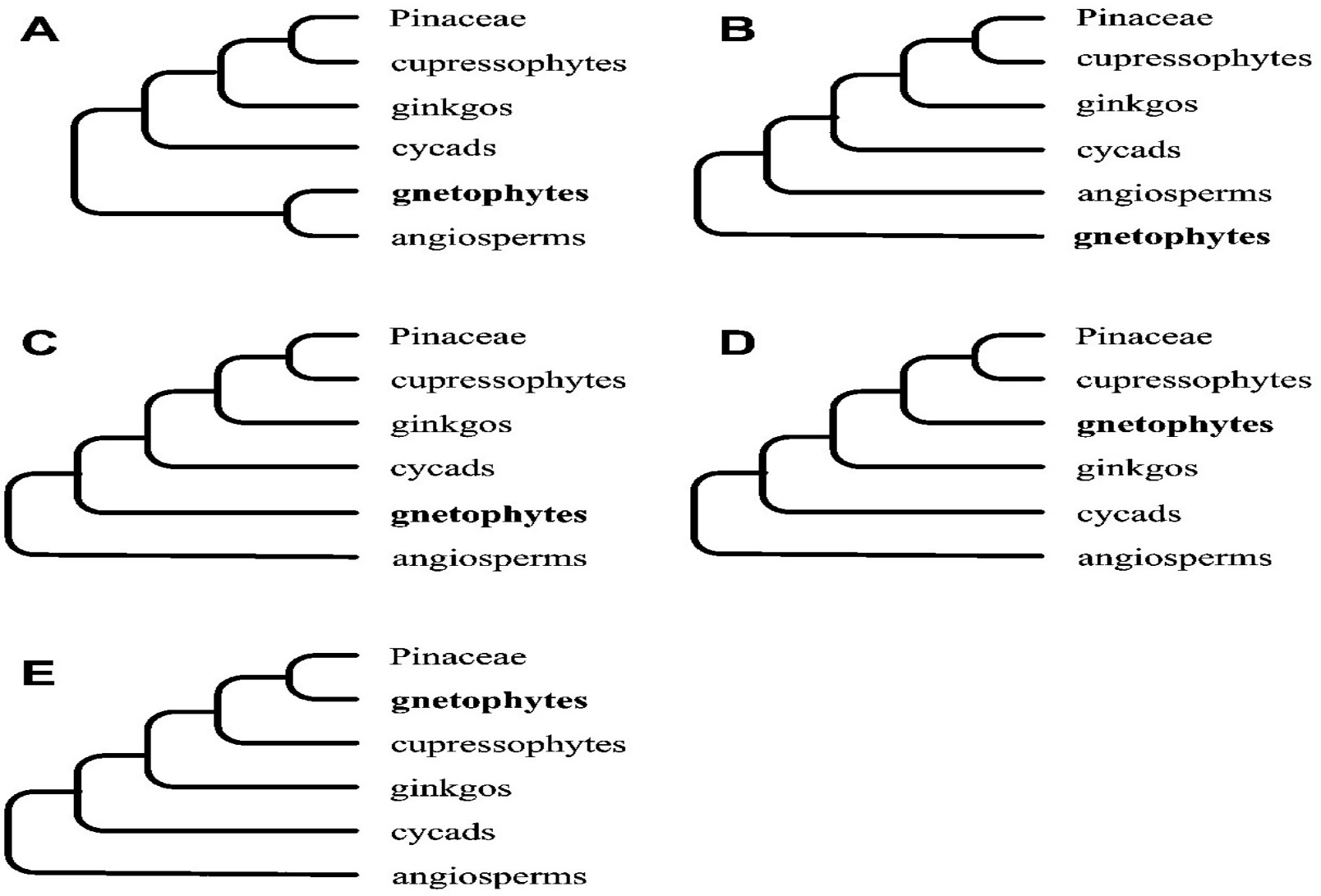
Phylogenetic position of Gnetales

- Hypothesis #2(B) (Gnetales-other seed plants) and #3(C) (Gnetales-other gymnosperms)
  - When comparing Chloroplast DNA to each other using a maximum parsimony (MP) method we get Gnetales as a sister group to all other seed plants.
  - However when using Expressed sequence tags with MP we get Gnetales as a sister group to all other gymnosperms.
  - Currently neither hypothesis is widely accepted due to the fact that the MP method is easily affected by long branch attraction then maximum likelihood and Bayesian inference.
  - This is due to the fact that the data sets used contained too much missing data due to the large evolution/extinction history of seed plants.

Phylogenetic position of Gnetales

- Hypothesis #4(D) (Gnetales sister to conifers) and #5(E)(Gnetales sister to Pinaceae)
  - When basing the study on nucular ribosomal DNA as well as the mitochondrial *rps3* gene we get Gnetales as sister to conifers.
  - However when eliminating bias in data analyses we finally get Gnetales as sister to Pinaceae.
  - Gnetales as sister to Pinaceae is currently the most supported hypothesis due the loss of many genes as well as similarity in their chloroplast genomes.

Phylogenetic position of Gnetales



Molecular evolution

- One of the best studied group of land plants. Among the 83 genera of gymnosperms, the genome size has been estimated for 344 species.
- A very interesting feature of gymnosperms is the narrow variation range of chromosome numbers from 2n=14 to 66 in wild plants.
- Another feature is that all congeneric species have the same basic chromosome number except for a distinct few.
- There is karyotype conservation across species and genera. IE: None or very few chromosomal translocation were observed.
- Chromosomes are extremely large (length of metaphase chromosome is 6.4um-16.2um in *Pinus)*
- With this the mean genome size of gymnosperms is much larger then angiosperms. 1C=18.08pg to C=5.9 picograms
- Lastly polyploidy is exceedingly rare in gymnosperms.

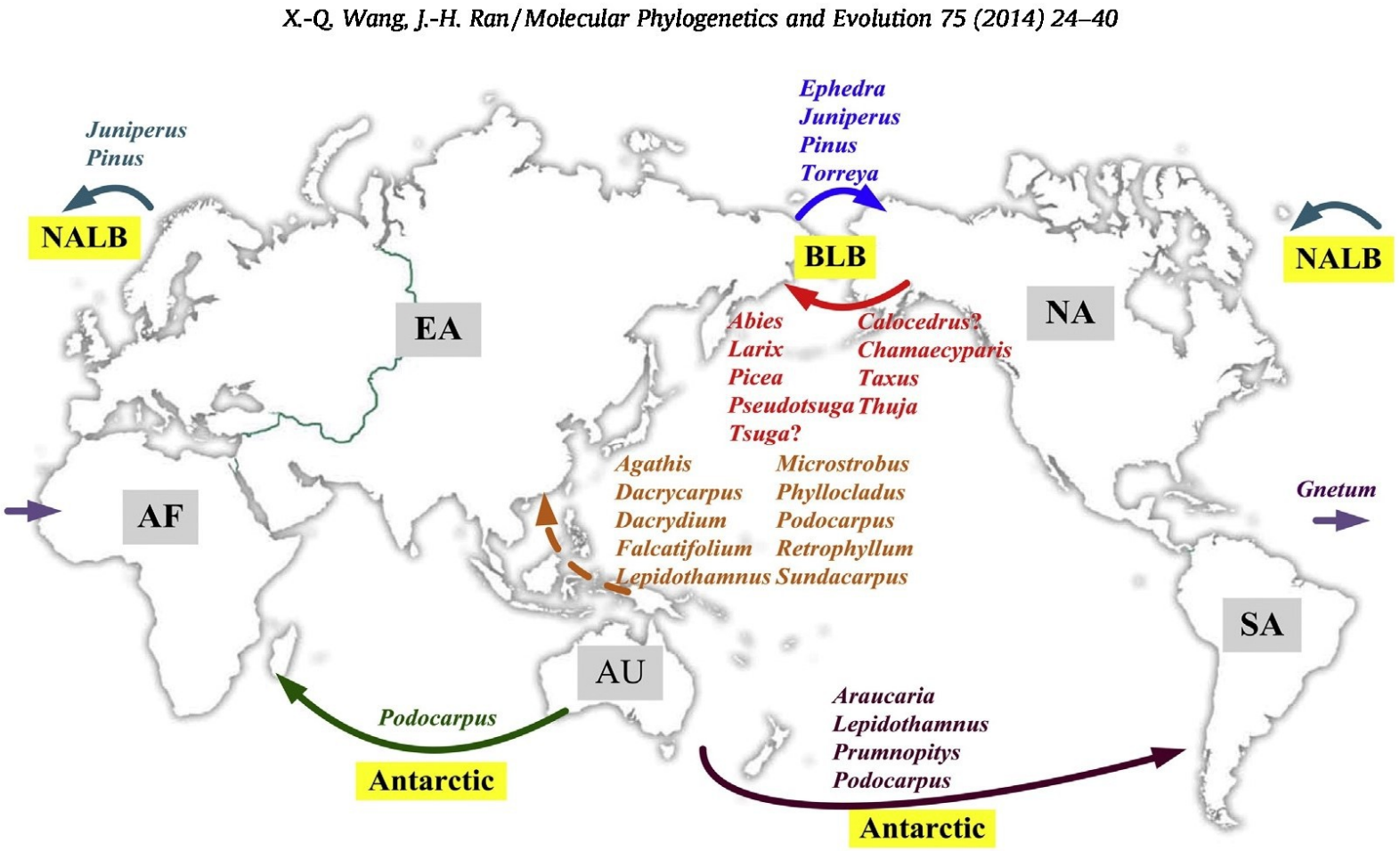
Effects of genome facts

- Due to their large genome, efforts to create a genome bank are very limited.
- Possible reasons for having such a large genome
  - Unlike angiosperms, polyploidy or chromosome duplication is not the cause.
  - Could be explained by expansion of retrotranspons(transportable DNA elements) Shown in that 75% of a conifer genome could be just repetitive elements of noncoding DNA.
  - Even with all their noncoding DNA, gymnosperms were found to have a slower evolution rate then angiosperms, but when taking generation time into account evolutionary constraints could be similar between the two.

Biogeoraphy of gymnosperms

- Due to their old age, gymnosperms provide a opportunity to show what exactly happened during the break-up of Pangea.
- However as mentioned before, most living gymnosperms were found to be much, much younger then the break up of Pangea.
- But the family Cupressaceae s.l. being old enough does give a accurate enough description of the breaking of Pangea.
  - This is because the family occurs in all continents except Antarctica.
  - Using this knowledge following the fossils of Cupressaceae's subfamilies (Callitroideae for south, Cupressoideae for north) we can use it to determine the split between Laurasia and Gondwana.

Inferred dispersal routes of some gymnosperms with intercontinental distributions.



Biogeographic difference between 2 hemispheres

- Vicariance and dispersal events played important roles in present distribution of conifer's in the southern hemisphere.(All southern hemisphere gymnosperms can be traced back to Australia)
- While in the northern hemisphere dispersal via land bridges(such as the Bering Land Bridge and the North Atlantic Land Bridge) much more then vicariance affected the northern hemisphere.
  - This created a “bidirection” dispersal between new-world (North America) and old world (Asia). Much of this migration is backed up by molecular phylogeny.
  - With this split, the gymnosperms distributed in each Hemisphere are very different. This is attributed to the southern hemisphere having very short times for long range dispersion when the continents were “linked” together BUT having wet/warm environments and the northern hemisphere having longer periods where dispersion was possible BUT much cooler,colder,drier climate that many of the older lineages of gymnosperm could not survive