Levels of Biological Organisation
(hierarchy of increasing complexity)

Biosphere
Ecosystem
Community
Population
Organism

Organ system
Tissue
Cell
Subcellular component
Molecules in biological systems (incl. genes)
Levels of Biological Integration

- Ecosystem
- Organism
- Cell

The only true levels of integration in biology.

- True level: total environment of all levels below and a structural & functional component of next level above.

- Prediction at one level requires knowledge and consideration of next true level above.
Forest Genetics: Pattern & Complexity

- Interacting set of “species”: if one forces a periodic or chaotic pattern by its own density dynamics, then all members of the set must develop responses to the interactive biotic environment.
- Forest–level pattern an emergent effect of independent, lower level elements; each population and species doing its own thing.
- Or pattern emerges as a consequence of strong functional interactions among the elements.
- Species assemblages not random associations – are selected, have +/- interactions supporting their existence.
- Genes in individuals not random operators that happen to produce whole trees; they are assembled because they function together.
Genes: Selfish or Environmentally Aware?

- All function derives from genes; higher levels of biological organisation “mere outgrowths that carry gene effects”?
- Gene effects emergent properties of molecular processes; also partly determined by developmental, population & ecosystem processes.
- No genotype without an environment ~ genotype defines environment.
Evolutionary Effects

Climate Change Stressors ➔ Impact Mechanisms ➔ Biodiversity Impact

- Increased Average Annual Temperature ➔ Range and Abundance Shifts
- Changes in Precipitation Patterns ➔ Phenological Changes
- Selection Pressure: Individuals with higher genetic capacity for adaptations are favoured, others are extirpated ➔ Loss of Genetic Diversity
- ➔ New Community Assemblages
Genetic Variation

- Genetic diversity within species enables adaptation to changing environments.
- Ultimate source of biodiversity at species and ecosystem levels.
- How do species adapt to heterogeneous environments, especially when environments are rapidly changing?

- Genetic variation: clinal (continuous) & racial (discontinuous).
- Most wide-ranging forest tree species have racial variation.
- Genetically distinct infraspecific populations.
- Physiological or phenological differences (functional traits related to survival, growth, reproduction).
Adaptive Strategies

Trade-off between selection for high **growth** potential vs. selection for **hardiness** (high cold tolerance)

Each tree species has different life **history strategy**.

- white spruce: regeneration on a variety of seedbeds, shade tolerance, slow steady growth, extreme cold tolerance, abundant small light seeds that disperse widely & different **genetic architecture**.

**Specialists** ↑ genetic differentiation
- physiological processes attuned to a small range of environments
- phenotype controlled by genotype
- environmental variability & change accommodated by genetic variation.

**Generalists** ↑ phenotypic plasticity
- physiological processes attuned to a broad range of environments
- phenotype controlled by environment
- environmental variability & change accommodated by phenotypic variation.

>> **Individualistic responses to change**

Most B.C. conifers are genetically specialised; Pw and Yc are plastic.
Prediction

Genetically specialised species will respond to climate change by differential survival of the races or genotypes best suited to future conditions.

- … but change could be happening too fast for evolution to keep up, at least in species—like trees—with long generation times
- adaptation rate negatively related to generation time (i.e., reproductive age), positively related to within-population genetic diversity
Predictions

Climate warming will ultimately exceed the adaptive capacity of many of our conifers because:

- populations locally adapted: cc causes conditions to deteriorate throughout species’ range, not just at margins; will push many populations beyond their physiological limits of temperature or moisture tolerances
- mortality induced by extreme climatic events >> losses of genetic diversity
- rate of change too fast for adaptive tracking response by tree species with long generation times and life-spans

These factors will lead to significant genetic erosion and forest decline for several forest generations.

Long-lived specialists will have to migrate to survive, moving if possible to where suitable environments exist.
Prediction

Generalists with lots of phenotypic plasticity will respond to climate change by “attempting” to ride it out within the bounds of their plasticity.

- Individuals of highly plastic species can tolerate wide range of environments, may be less sensitive to climate change.

- Eventually—when changes become intolerable—they too will have to evolve, or migrate but maybe not as far to survive.

- If generalists handicapped by low levels of genetic diversity, as in western white pine and yellow-cedar, could be more susceptible to pathogens (like blister rust), esp. exotic pathogens, or to things like freezing damage.
pollen profiles >> major increase of cedar(s) 6,000-2,500 years ago
very little prior to that (10,000-6,000); presumably warm dry “early Holocene xerothermic interval” unfavourable
very long-lived; sporadic and slow seedling survival & establishment
yet infiltrated coastal and wet interior forests and spread to current range within a few thousand years
appears to be well-defended against insect pests and fungal pathogens
but has very low levels of genetic diversity and is highly inbred
The Ecological Theatre and the Evolutionary Play

- **Salmon**: diversity of genotypes, populations, behaviours and environmental sensitivities in response to considerable environmental variability and uncertainty.

- Evolutionary strategy of locally adapted populations works well when linked to dynamic & variable (within limits) marine environment and to availability of healthy, complex, & connected freshwater and terrestrial habitat.

- Population-specific variability in response to climate fluctuations is ultimately responsible for the resilience of the entire stock—up to a point.

- Genetic homogenization & intense selection against large fish >> big mistakes
“… think of salmon landscapes as heterogeneous “filters” of climate. The environmental conditions experienced by any individual population are produced from how the overriding climate signal is expressed in their habitat, as influenced by its geomorphic, hydrologic, and ecological characteristics. … to some extent, the regional diversity of population responses to climate change appears to derive from local adaptations of salmon populations to heterogeneity in landform and hydrologic conditions.”

Prediction

If intact ecosystems have resident species with a higher proportion of mature/old individuals and with more genetic diversity than secondary or degraded ecosystems,\(^1\)\(^2\) then both the genetically diverse species and the intact ecosystems have greater resilience.\(^3\)

- European birch has “warm year” & “cool year” genotypes that enhance seedling survival in variable environments.\(^4\) “Warm year” genotypes should increase in frequency in situ in a warming climate with a much faster response than N migration of S genotypes.\(^5\) Moreover N populations should be better adapted to their local edaphic conditions than S populations, at least initially.

PETM—Paleocene-Eocene Thermal Event
55 Ma, abrupt (onset in a few thousand years), short-lived event (signal lasts ~20,000)
caused by another runaway CO2 event (seafloor spreading, volcanism) with strong implication of a methane hydrate event
estimates are it took ~100,000 years for the oceans to absorb the CO2 as carbonate rock
Questions To Ponder

- Is the complex genetic architecture of NW tree species an inevitable consequence of physical complexity (climate, topography, physiography, landforms)? (If NW North America was flat, would the tree species be as genetically diverse?)

- Given their ecosystem role (structure & function), ecosystem services, carbon dynamics, genetics & life history characteristics, and economic significance, should most of B.C.’s tree species be of conservation concern?

- Do genes of dominant species determine ecosystem structure and drive ecosystem “evolution”? Are ecosystems emergent properties of genetic processes? Do species-level events form the only organising principle?
A 50-Million-Year-Old Fossil Forest from Strathcona Fiord, Ellesmere Island, Arctic Canada: Evidence for a Warm Polar Climate

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ABSTRACT. The remains of a fossil forest are buried within a pedogenic sequence of Eocene age (approximately 50 million years old) near Strathcona Fiord, Ellesmere Island. Large pteridophyte stumps are preserved in their original growth positions in veins of the Eureka Formation Group, a sequence of sandstones, siltstones, and coals deposited in an alluvial/lacustrine environment. The dimensions of 83 stumps were recorded and their positions plotted on a plan of the exposed area of coal.

The fossil stumps are roughly conical in shape, up to 1.6 m high and with roots spreading up to 5 m in diameter. They are closely spaced on the coal, some only 1 m apart. A density of 1 stump in 27 m² (367 stumps/km²) was calculated for this forest. The stumps represent large forest trees that grew in freshwater, swampy conditions between large river channels. Their buttressed roots provided extra support in the waterlogged peat. The rivers periodically shifted their courses, flooding the forests and burying them under clays and sands.

Wide growth rings in the fossil wood, in addition to evidence from associated sediments and vertebrate faunas, indicate favorable growing conditions in a mild, cool/warm temperate climate with high rainfall. Palaeoclimatic studies suggest that the forest lay close to its present high-latitude position during the Eocene. Such a forest is therefore evidence that the Eocene polar climate was much warmer than today and that the trees were able to tolerate a polar sunlight regime of continuous summer sunlight followed by months of winter darkness.

Key words: fossil forest, Tertiary, Canadian Arctic, palaeoclimate, Ellesmere Island, pteridophyte, Eureka Sound Group.