Critical concepts and learning goals: Below are some fundamental concepts that form the core of the science needed to understand the fields of paleoceanography and paleoclimatology. These concepts do not cover everything that you will learn, but rather form a foundation of fundamental principles and ideas. Topics are arranged in the order of their first main appearance during the course.

Greenhouse effect: Explain the radiative physics behind the GH effect, and relate it to Earth’s radiative balance. Calculate the blackbody temperature of the Earth.

Thermohaline circulation: Explain why (and what) energy is required for the THC, and under what conditions deep waters may form.

Insolation: Distinguish between insolation and the solar constant, and describe why and how modern insolation varies spatially and temporally.

Orbital theory: Describe the geometry and periods of the three dominant orbital parameters that affect Earth’s climate.

Stable isotope fractionation: inorganic: Explain the pertinent molecular thermodynamics behind inorganic isotopic fractionation. Predict the relative enrichment/depletion of a solid/liquid/gas as a function of temperature.

Rayleigh fractionation: Explain why and how the isotopic composition of a cloud evolves as precipitation proceeds. Calculate the isotopic composition of rain as a function of the fraction of vapor remaining in the cloud.

Spectral analysis: Explain why spectral analysis is useful in paleoclimatology, and describe the basic concept behind Fourier theory.

Radiometric dating: Describe the fundamental requirements and assumptions involved in radiometric dating. Derive the generic age equation from first principles.

Factor analysis: Describe the concept and basic mathematical approach behind factor analysis, as it relates to planktonic assemblages.

Gas age-ice age difference: Explain why the bubbles/clathrates in an ice core have a different “age” than their surrounding ice. Predict how this age difference varies with snow accumulation rate.

Marine carbonate chemistry: Describe the speciation of DIC in seawater. Predict the direction of $p$CO$_2$ change with changing alkalinity and total DIC.

Weathering feedback: Write an equation illustrating the effect of silicate weathering on atmospheric CO$_2$. Explain the need for a negative feedback in the tectonic-scale carbon cycle.

Numerical modeling: Describe the need for, and basic structure of, numerical climate models. Explain the concepts of parameterization, boundary conditions, and sensitivity tests.

Hysteresis: Explain the concept of hysteresis, and how it relates to deep water formation and rapid climate change. Construct a hysteresis diagram of NADW strength as a function of freshwater flux.

Stable isotope fractionation: organic: Explain how organic fractionation differs from inorganic. Predict how the isotopic composition of a nutrient pool changes with primary productivity.