PHYSICAL: STRATIFICATION AND WATER MOVEMENTS
(read: pp 39-44; 50-56 in Dodson)

"In spring the water of the pond is like blue wool, endlessly tossing. The heavy, cold water has sunk to the black bottom of the pond and, struck by this weight, the bottom water stirs and rises, filling the pond's basins with wild nutrition. . ."

(Mary Oliver 1991, as quoted by Dodson)

VERTICAL STRATIFICATION IN LAKES

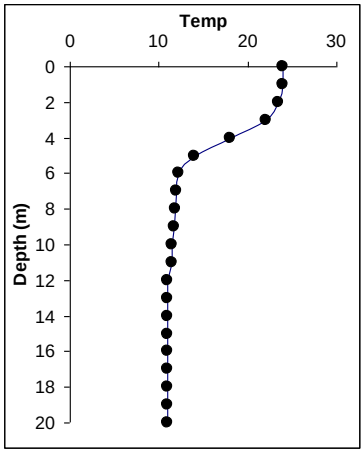
Stratification—The study of layers

Temperature
Lakes often exhibit strong stratification of temperature due to density differences of water. Remember that temperature and salinity are the predominant factors that cause density differences in water. Thus, water that is 4 degree C will sink, and warmer (and colder) temperatures will rise. Salty water will sink.

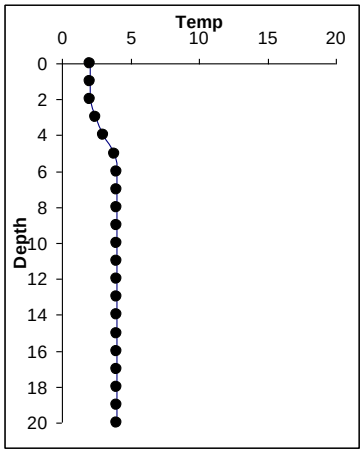
Key terms for lake stratification
- Epilimnion—upper layer
- Hypolimnion—lower layer
- Metalimnion—transition zone between the epilimnion and hypolimnion
- Thermocline—found within the metalimnion, this is the depth where temperature changes the most rapidly.
- Isothermal—the same temperature from top to bottom

Three example temperature profiles:

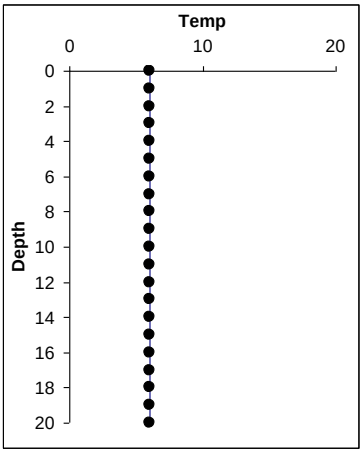
Stratification



Reverse stratification



Isothermal



Isopleth plots are common and useful ways to graph temperature profiles across an entire season.

Stratification is influenced by:

- Time of year
- Lake depth
- Fetch
- Topography
- Solutes

Annual mixing patterns:

- Dimictic—stratifying twice per year, once during summer and once under the ice (reverse stratification)
- Monomictic—stratifying once per year. This can be stratifying during the summer in lower latitude lakes or stratifying during summer in high latitude lakes.
- Amictic—Always stratified and not mixing, often due to permanent ice cover.
- Polymictic—Frequently mixed. Often shallow lakes and tropical lakes.
- Meromictic—Lakes that don't mix due to chemicals, especially salt.

Global climate change strongly impacts these seasonal patterns in stratification and mixing. Specifically, scientists have observed lakes are thawing earlier and freezing later now than over the last 100+ years. How would expect that these seasonal changes would influence the seasonal dynamics of lakes?

WATER MOVEMENTS

Water movements occur across multiple scales, ranging from microscopic diffusion to km-scale waves or currents.

Two main factors cause water movements:

- Wind
- Gravity

Diffusion—random and small-scale movement of water molecules

Types of water movements

- Laminar flow—Smooth flows that move water without mixing it.

- Turbulent flow—Chaotic flows that result in mixing

Whether or not flows are laminar or turbulent depends on the velocity of the water movement

TWO KEY NUMBERS FOR UNDERSTANDING WATER FLOWS

1. **Reynolds number**

This ratio of viscosity to inertia forces considers scale and velocity differences in estimating whether currents or movements will be laminar or turbulent.

$R_e = ((V_1 - V_2) * (\text{distance or size}))/\text{kinematic viscosity}$

V equals velocities of the two currents or movement of an object.

$R_e < 1$, viscosity forces dominate
$R_e < 500$, flow will be laminar
$R_e > 200$, flows will be turbulent

2. **Richardson number**

Ratio of turbulent wind mixing and water's resistance to mixing

R_i is proportional to density differences/wind speed

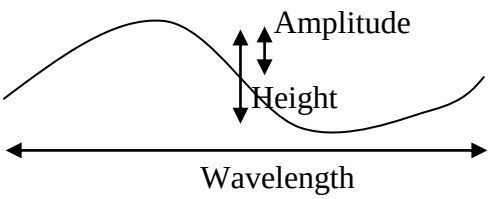
Horizontal Currents

Movement of water across the lake
Caused by:

- Wind—drives water movements of about 2% of wind speed
- Water inputs such as lakes or streams

Periodic Movements
Can be defined by:

- Amplitude
- Period—time for complete cycle
- Frequency—inverse of period
  Number of waves over time.



TYPES OF WATER MOVEMENTS INCLUDE:

Surface waves

Maximum wavelength is related to fetch

$$h = 0.105 * fetch^{½}$$

where h = maximum wave height and fetch are in cm.

Foam streaks

Foam is the frothy mixture of air water and organic compounds.
Cause of these streaks of foam is debated. One theory is that they are caused by Langmuir spirals, patterns of upwelling and downwelling in the mixed layer.

Seiches

Rocking of water basins due to strong winds starting and then stopping.

- **Internal—**wave along the thermocline of a lake. Large magnitude, low frequency.

- **External (surface)**—wave along the surface of a lake. Low magnitude, higher frequency.