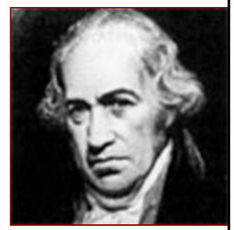
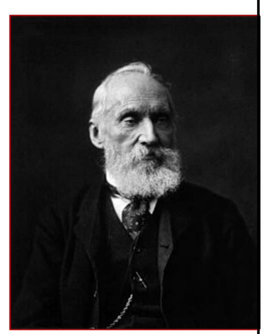
Temperature

- **Daniel Gabriel Fahrenheit** (1686 – 1736)
  - Fahrenheit scale determined by three reference points
    - 0 °F – mixture of water, ice, and ammonium chloride
    - 30 °F – water at the point of surface ice
    - 96 °F – human body temperature
    - 600 °F – boiling point of mercury
    - 180 °F – point at which water boiled above the freezing point
  - Later modified from 32 to 212 °F with 180 °F divisions between reference points.
- **Anders Celsius** (1701 – 1744)
  - Celsius temperature scale based on 1742 reference points
    - 0 °C – freezing point of water at one standard atmosphere
    - 100 °C – boiling point of water at one standard atmosphere
    - 100 equal divisions between each point.



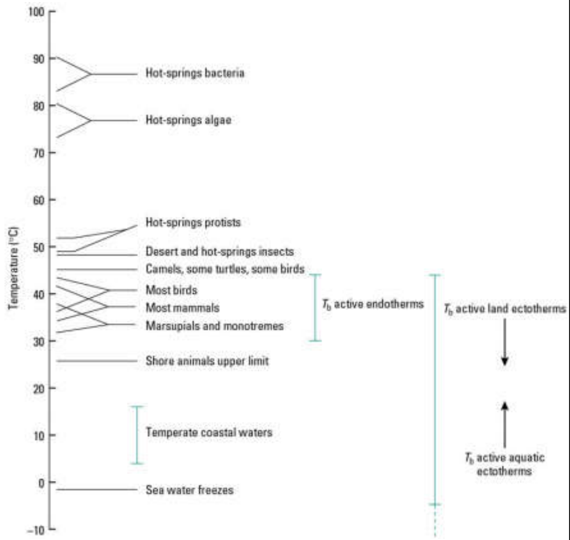
Kelvin

- **William Thomson,** 1st Baron Kelvin (1824 – 1907)
  - **Absolute zero** - theoretical basis of temperature and kinetic energy within the framework of thermodynamics
  - 0 °K – kenetic energy = 0
  - 0 °K = -273 °C
  - Volume = 0



Temperature

- Life exists from -260 C° to 90 C°
- Thermal properties of water
  - Heat of vaporization (2260 J/g) – energy to change liquid water to gas at same temperature
  - Heat of fusion (334 J/g) – energy required to change solid water to liquid
  - Heat capacity

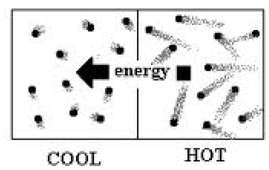


Aquatic vs. Air Temperatures

- Dramatically different thermal environments on land and water
- Air
  - Low conductance
  - Low thermal inertia
  - High variability
  - No lower bound
- Water
  - High conductance
  - High thermal inertia
  - Low variability
  - Low end buffered by freezing point

Temperature

- Stress induced by high vs. low temperature are physiologically different
- Variability in temperatures often more stressful than high or low
- As temperature increases:
  - Molecules move faster
  - Number of collisions between molecules increases
  - Kinetic energy (E_k) transformed into heat from friction
  - Volume increase

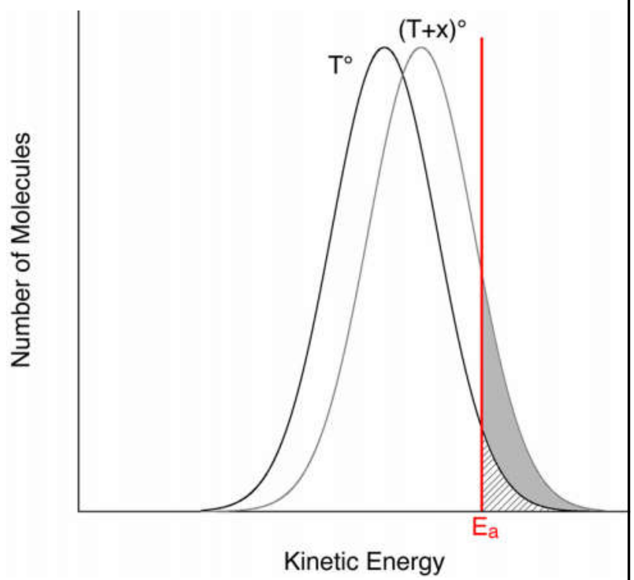


Temperature and Reaction Rates

- With a 10 C° increase in temperature, what is the change in kinetic energy (E_k)?
- 25 C° = 298 K°
- 35 C° = 302 K°
- $\frac{302-298}{298} = \frac{1\ 0}{298} = 3.35\%$
- 3.35% in kinetic energy, however a 10C increase in temperature may increase reaction rates by 100-200%, why?

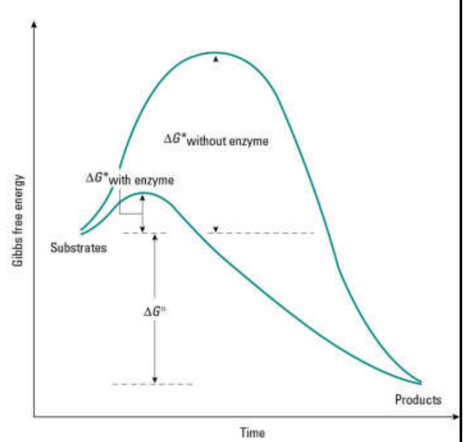
- **Energy of activation**

- **ΔT = 10°C**
- **ΔE_k = 3%**
- **ΔE_a > 100%**



Q_{10}

- A temperature quotient indicating the sensitivity of a chemical reaction or biological function.
- A temperature difference of 10°C has become a standard span over which to determine this temperature sensitivity.
- Enzyme function and reaction rates



Temperature and reaction rates

- $Q_{1\ 0} = \left(\frac{k_1}{k_2}\right)^{\left(\frac{10}{t_2 - t_1}\right)}$
- Q_{10} itself changes logarithmically

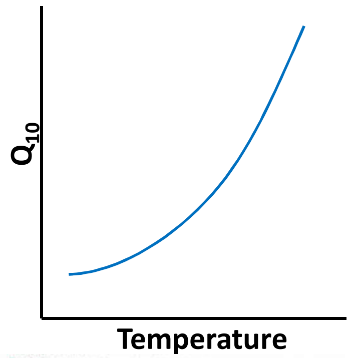
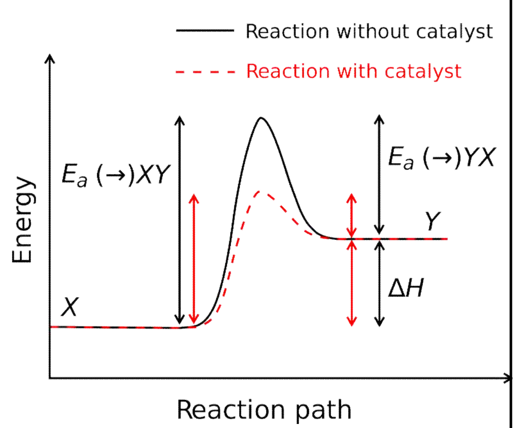


Table 8.1 Q_{10} values for a variety of reactions involved in biological processes.

	Temperature (°C)	Q_{10}
Physical reactions		
Diffusion	20	1.03
Biochemical reactions		
Cytochrome reductase (possum)	>20	1.5
	<20	2.5
Pyruvate kinase V_{max} (rat)	>25	1.7
	<25	3.2
Hemoglobin coagulation	60	13.8
Physiological reactions		
Anemone oxygen consumption	5	2.0
	15	2.3
Crayfish heart rate	5	2.4
	15	1.6
	25	0.8
Crustacean gill movements	5	3.8
	15	1.7
Beetle oxygen consumption	10	2.4
	20	2.1
Insect thermal induction of diapause	20	1.4
Torpid mammal oxygen consumption	10	3.7
	20	4.1

Arrhenius Equation

- $k = Ae^{\frac{-E_a}{RT}}$
- Where
  - K – reaction rate
  - A – molecular collision constant
  - T – temperature (absolute, kelvin)
  - R – gas constant



Protein Function and Evolution

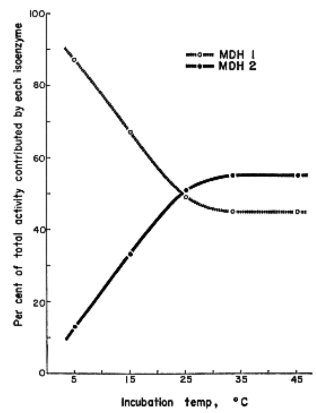
- **Allozyme** – distinct forms of proteins that catalyze the same reaction
  - Homologous
  - May be different alleles of one gene or different genes
  - May have different thermal properties
  - Isozyme vs allozyme

Response to temperature change

- **Short term** (pre-acclimation, seconds)
  - Change effective concentration (compartmentalize, activate through phosphorylation)
- **Medium term** (acclimation, days or weeks)
  - Production of different allozymes
- **Long term** (evolutionary)
  - Selection for allozymes optimized for newer temperature

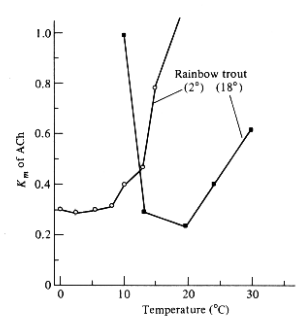
allozymes examples – short term

- Compensate for temperature change by modifying the effective concentration
  - Activation
  - Compartmentalization
  - Ligand allosteric effects

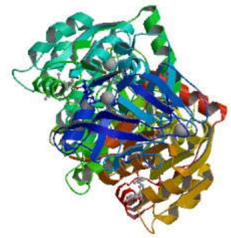


Allozyme example – medium term

- Carp – acclimation to cold changes the ratio of myosin ATPase forms, increasing muscle contraction speed at cold.
- Allozyme expression may vary by tissue type
- Typically there are Allozymes present with a range of optima, ratios change with acclimation
- Do not typically have allozymes that are either on or off



LDH by latitude



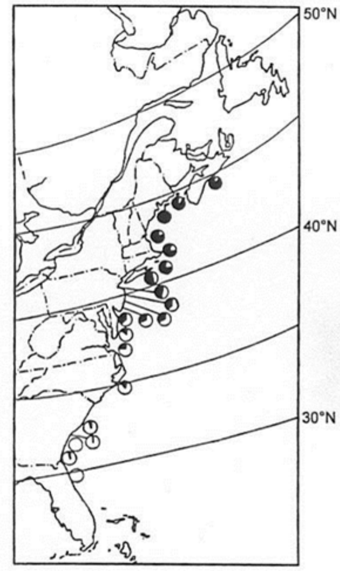


Figure 4.13 The relative frequencies of two alleles of lactic acid dehydrogenase in *Fundulus heteroclitus* along the East Coast of North America. Source: Modified from Place and Powers (1979).