Protein Function and Evolution

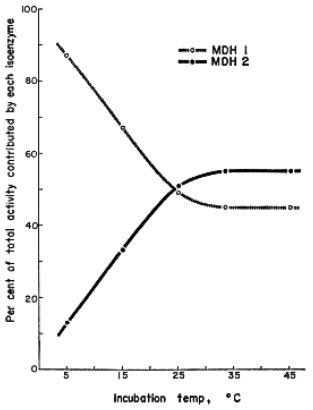
- **Allozyme** – distinct forms of proteins that catalyze the same reaction
  - Typically different alleles of the same gene.
  - **Isozymes** may be different genes that catalyze the same reaction.
  - Isozyme and allozyme variants often have different thermal properties.
  - Changing expression of variant forms allows for fine tuning of metabolic processes to different temperatures.

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/isozymes
- **Long term** (evolutionary)
  - Selection for allozymes optimized for different temperature

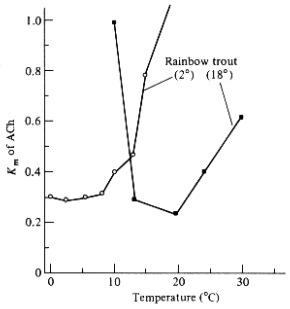
allozymes examples – short term

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



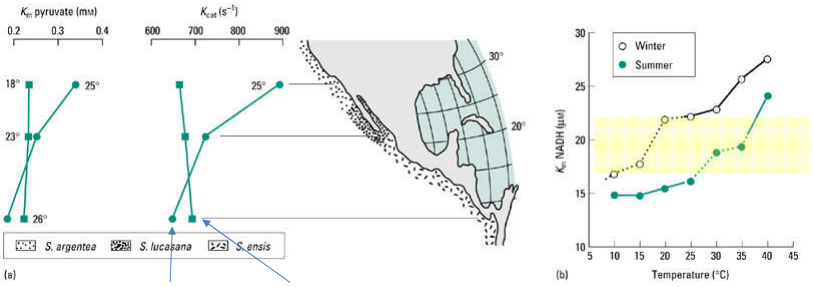
Allozyme example – medium term

- 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



Allozyme example – medium+long term

K – enzyme activity rates.

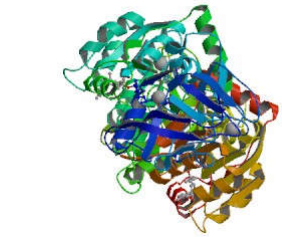


Enzyme activity for all three populations at 25 C

Different forms of enzyme ensure activity rate is constant at mean environmental temperature.

Within a species, different forms produced seasonally ensure rate (K) is constant at range of temperatures experienced summer vs winter (--- experienced temperatures)

LDH by latitude



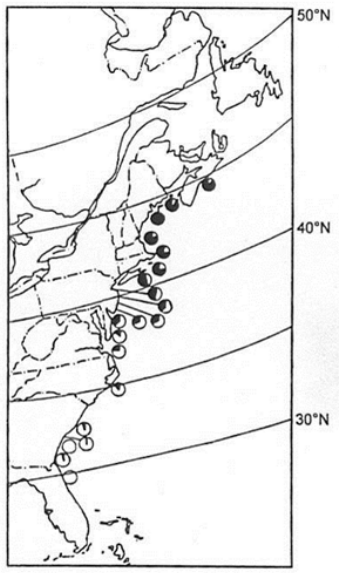
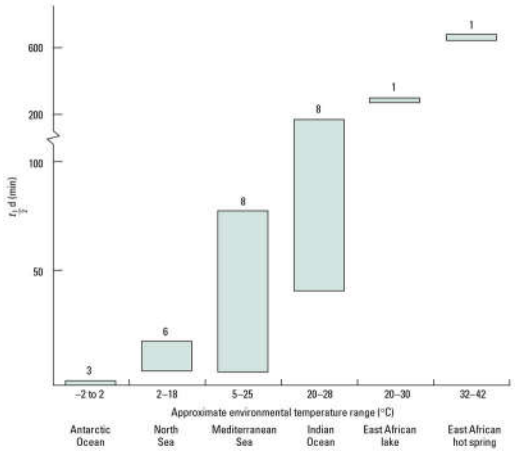


Figure 4.13 The relative frequencies of two alleles of lactic acid dehydrogenase in *Fundulus heteroclitus* along the East Coast of North America. Source: Modified from Place and Powers (1979).

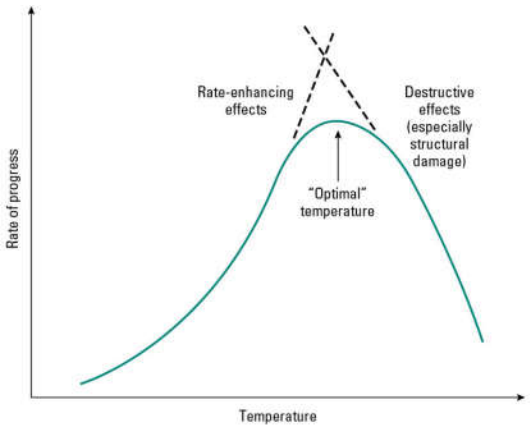
Allozyme example – long term evolutionary change

- Lactate dehydrogenase in *Fundulus* populations along the east coast
- Fig 8.3 – **thermal stability** of enzymes by habitat



Temperature effects

- **High temperature**
  - Cellular damage
  - Structural damage to proteins (recall 4° structure)
  - "runaway" reactions
- **Low temperature**
  - Reduction of vital processes (rate enhancement response)
  - Freezing → ice crystal formation → no fluid water

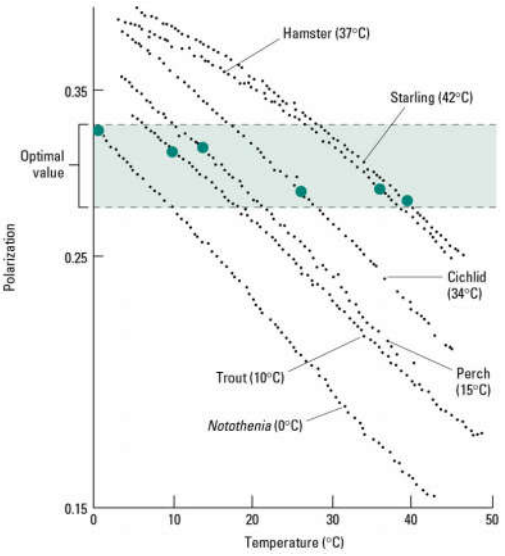


Membranes

- **Homeoviscous Adaptation** – membrane "fluidity" a function of temperature and ratio of saturated and unsaturated fatty acids

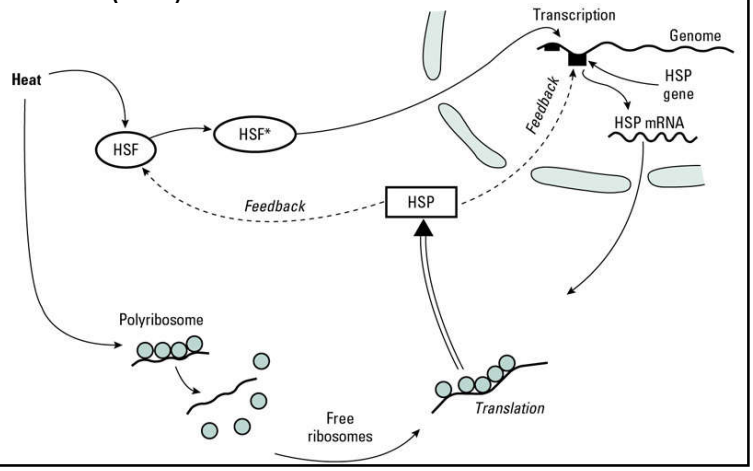
Table 8.3 The ratio of saturated to unsaturated fatty acid residues in three phospholipids from cell membranes in brain tissues of various vertebrates acclimated to different temperatures.

Species	Body temperature (°C)	Phospholipid		
		Choline	Ethanolamine	Serine inc
Arctic sculpin	0	0.59	0.95	0.81
Goldfish	5	0.66	0.34	0.46
	25	0.82	0.51	0.63
Desert pupfish	34	0.99	0.57	0.62
Rat	37	1.22	0.65	0.66

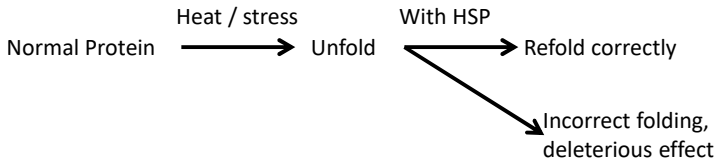


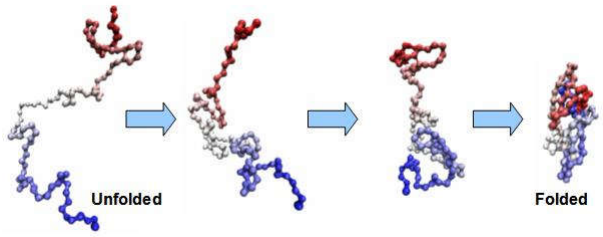
Stress Proteins

- **Heat Shock Proteins** (HSP)
- Produced in response to a variety of stressors
- "Chaperone molecules" that facilitate correct protein refolding.
- **Heat Shock Factor** (HSF)



Stress Proteins





HSP and **Heat Hardening**

- HSP production protects against heat damage (**heat hardening**).
- How long do HSP last?
- Why not always have HSP in production?

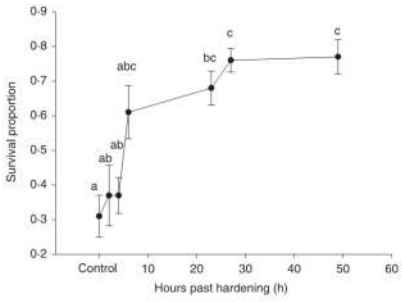


Fig. 2. Survival proportion after 60 min exposure at 37·4 °C (24 h of recovery; means ± SE). Survival was measured at different times (h) elapsed between heat hardening and exposure to heat shock. The control hour treatment did not receive any prior heat hardening treatment.

Functional Ecology 2009 doi: 10.1111/j.1365-2435.2009.01541.x

Dynamics of heat-induced thermal stress resistance and hsp70 expression in the springtail, *Orchesella cincta*

Simon Bahrndorff[1,2]*, Janine Mariën[3], Volker Loeschcke[1] and Jacintha Ellers[4]

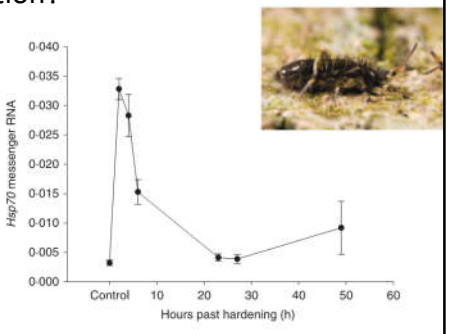
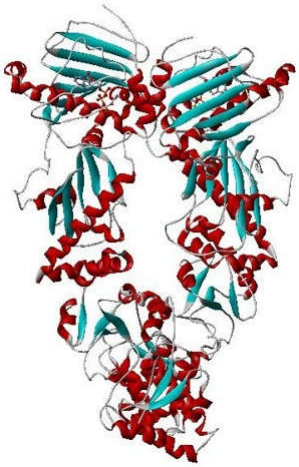
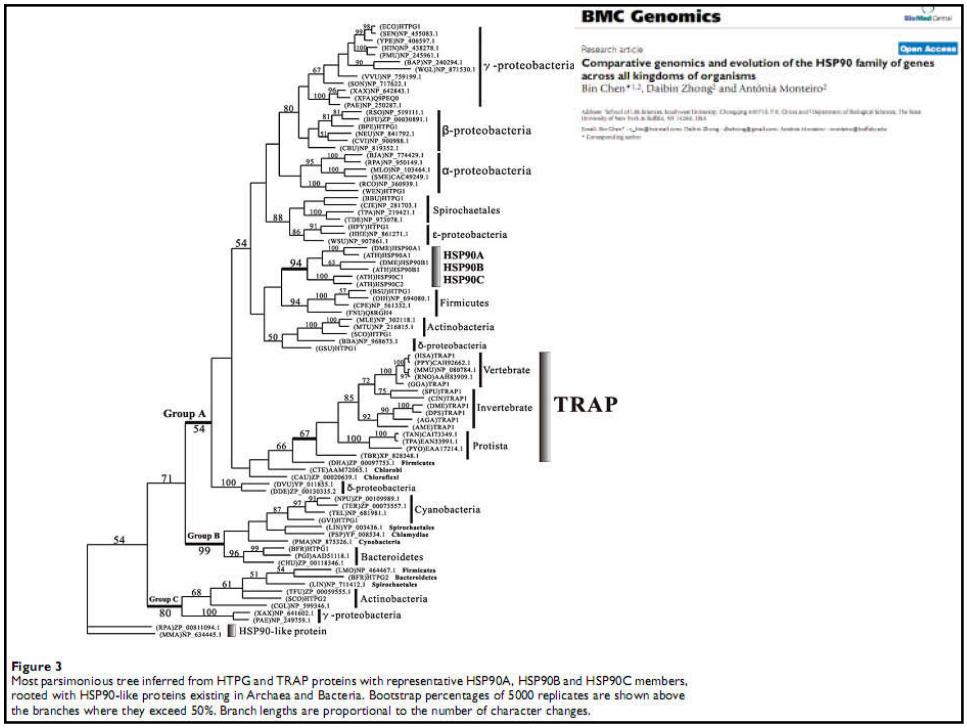


Fig. 3. Levels of *Hsp70* (mRNA) (in percentage of standard) in *Orchesella cincta* at different times elapsed after heat hardening. Means ± SE. *Hsp70* was measured at different times elapsed after heat hardening (35·4 °C for 60 min in a waterbath). After heat hardening treatment, springtails were allowed to recover for different lengths of time (2, 4, 6, 23, 27 and 49 h) at control conditions (16 °C). The control hour treatment did not receive any prior heat hardening treatment.

HSP Evolution

- HSP generally classified based on their size (kDa)
  - 10 – 100 kDa
  - Very well conserved, prokaryotic and eukaryotic
  - Eg. 90 kDa
    - 12 forms in Humans
    - Protein folding
    - Cell signaling
    - Tumor suppression
    - Prokaryote and eukaryote analogs





BMC Genomics

Research article

Open Access

Comparative genomics and evolution of the HSP90 family of genes across all kingdoms of organisms

Bin Chen*[1,2], Daibin Zhong[2] and Antónia Monteiro[2]

Figure 3
Most parsimonious tree inferred from HTPG and TRAP proteins with representative HSP90A, HSP90B and HSP90C members, rooted with HSP90-like proteins existing in Archaea and Bacteria. Bootstrap percentages of 5000 replicates are shown above the branches where they exceed 50%. Branch lengths are proportional to the number of character changes.