Expressions of Growth

- Absolute growth = $Y_2 – Y_1$
- Absolute growth rate = $(Y_2 – Y_1) /(t_2-t_1)$
- Relative growth = $(Y_2 – Y_1)$ $/y_1$
- Relative growth rate = $(Y_2 – Y_1)/[y1 /(t_2-t_1)]$
- Instantaneous growth rate or specific as %
- $G = (\ln Y_2 – \ln Y_1) /(t_2-t_1)]$

Physiological and Biochemical Indices

- Protein synthesis
- RNA : DNA ratio : (DNA relatively constant, RNA varies with protein synthesis)
- Condition Factors, HIS
- Proximate contents - water, lipid, protein, carbohydrate, ash

Proximate Composition

- What does it mean?
- What about carbohydrates?
- What about energy content?

What about thermal relationships to growth

- We know temperatures affect body processes
- Different species may have different life history stages that use different temps?
- What are some examples?

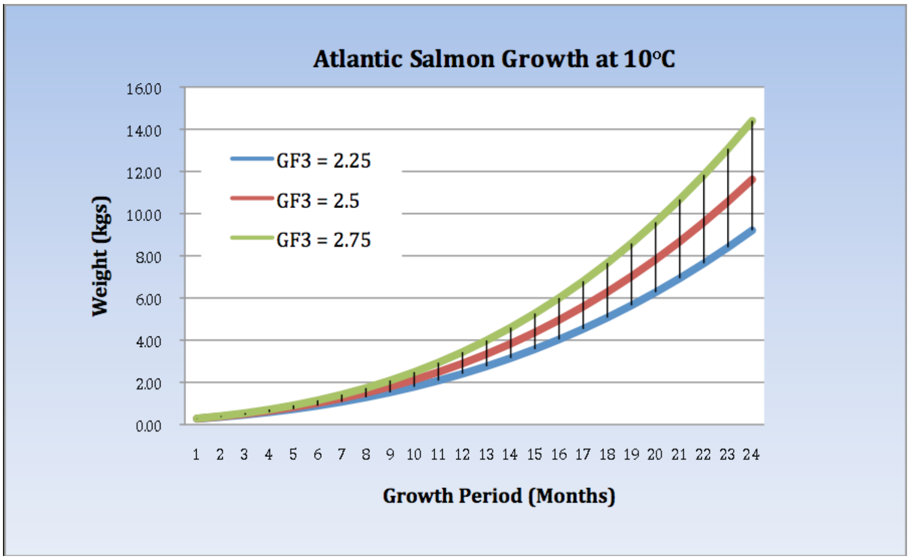
Thermal growth coefficient

- Degree days approach to growth.
- Assumptions have limitations
- It works if the relationships are the same for different temperatures.
- If growth in length is constant over all time

Thermal growth coefficient

- Degree days approach to growth.
- T is temperature in °C, and t is time
- Degree day = T X t
- $\sqrt[3]{Wt} = \sqrt[3]{W_0} + [(T/1000) \times t]$
- Length weight relations $W \sim L^3$
- Solve for time t
- $W_t = \{\sqrt[3]{Wt} = \sqrt[3]{W_0} + [(T/1000) \times t]\}^3$

Thermal growth coefficients can be different



Production Aquaculture Versus Conservation Aquaculture ?

- Fast- efficient
- Slower and efficient
- ????

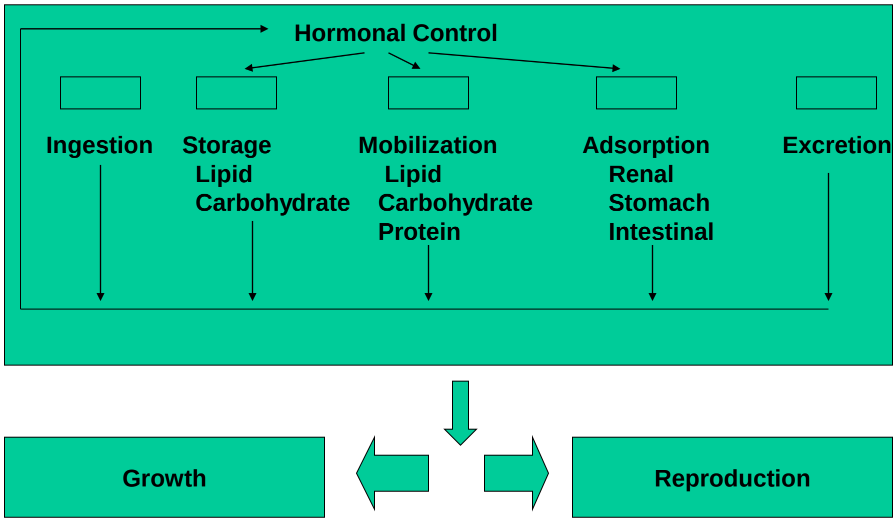
Temperature and Physiology Effects are Evident

- Individual
- Population
- Community
- Evolutionary processes

Bioenergetics Growth, Nutrition

Some approaches to understanding the dynamic processes of feeding, digestion, somatic growth, reproduction, excretion

Energetics – Processes



Energy Budgets

Intake (I = Income)

- **Macronutrients**
  - **Carbohydrates**
  - **Lipids**
  - **Proteins**
- **Micronutrients**
  - **Vitamins**
  - **Essential**
    - **Fatty Acids**
    - **Amino Acids**
    - **Sugars**

Energy Use (E = Expenditure)

- **Respiration**
- **Osmoregulation**
- **Movement**
- **Feeding**
- **Digestion**
- **Reproduction**

IF

I = E Growth = 0

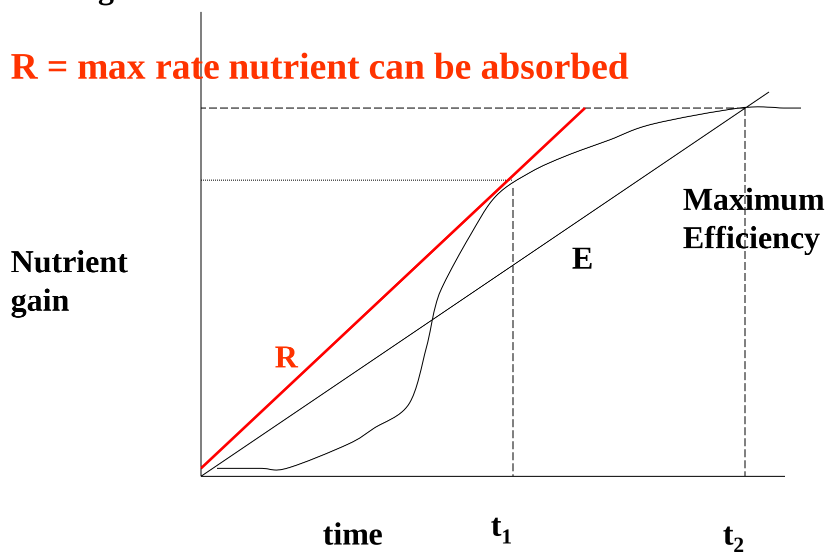
I < E Growth = -

I > E Growth = +

Specific Growth or Absorption Rates, Gut Reactor Models

- Feed conversion ratio, conversion efficiencies
- d tL/dt or d wt/dt or d protein elaborated/protein ingested/dt
- Considers Gut Evacuation, Transit and Intake Parameters

Sibly Model from GI into Blood- ingestion to absorption, single constituent

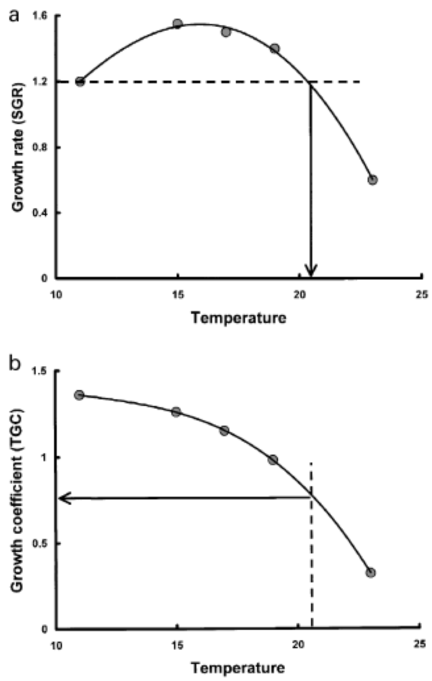


Gut Evacuation Approaches

- Malcolm Jobling – University of Tromsø, Norway.
- Scores of publications bolus with markers –
- Recent models of dilution related to aquaculture production to achieve desired flesh constituents- fish oil derivatives
- The mathematical description of this dilution

Jobling 2003

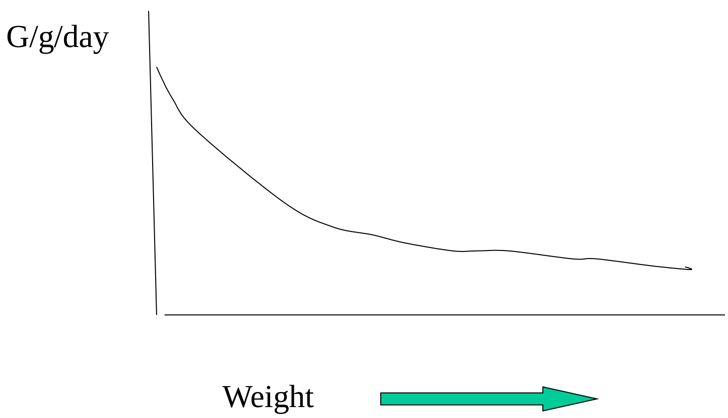
- Critical look at the thermal growth coefficient
- Does coefficient of condition remain the same over time?
- Rate of temperature affecting growth is often bell shaped for one size of fish



Influence of temperature on the growth of Baltic salmon *Salmo salar* L. (a) The growth rate - temperature relationship. The dashed line indicates that the specific growth rate (SGR) at 11 °C is the same as that at 20.5 °C {SGR =[(lnWt - ln W_0) / t]100}.

(b) The change in the thermal growth coefficient (TGC) with increasing temperature. The arrow indicates the estimate of the TGC at 20.5 1C (~0.75).

But Consumption Changes with Weight



Ecosystem and Community

- Change in quality and availability of foods, predators, timing of spawning events, migrations

Global Warming

- Effects in your lifetime
- Temperatures
- pH shifts in the oceans
- Extremes more common

Temperature and Fish Physiology

- Thermal biology dominated by constraints of respiration
- Limited solubility of O_2 in H2O
- High heat capacity of water ensures blood is equilibrated with water
- Thus heat generated by metabolism is carried to gills and lost to environment.

- Temperature determines rate of chemical reactions
- Temperature dictates point of equilibrium in reactions
- Temp affects structural flexibility components for protein and biological membranes.-
- Thus, significant changes in body temperature pose a serious challenge to maintenance of physiological functions

- Some (very few) fish are endothermic
- Most fish are isothermal with environment and must contend with variable body temperatures
- However, fluctuations are not exceptionally large compared with what can happen in the air

Poikilothermy- Ectothermy

- Most typical for fishes (inverts, reptiles, amphibians)
- Ambient conditions dictate temperature
- Behavioral adjustments (thermal refugia for summer and winter conditions)

Adjustments to Temperature Changes

- Some adaptation such as increasing surface circulation
- Evolutionary adaptation to specific environments
- Evolutional distinctions in tolerance
  - Eg polar fishes versus desert fishes
  - Antifreeze proteins

Membranes- Lipid Composition

- Phospholipid acyl chains
  - Brain fatty acids in Antarctic fish have 24 carbon polyunsaturated fatty acids
  - PUFA vs SFA ratio changes with temperature
  - Unsaturated pack less efficiently, and have lower melting points than saturated homologues
  - Increased membrane un saturation offsets direct effects of low temperature by reducing membrane order and increasing fluidity

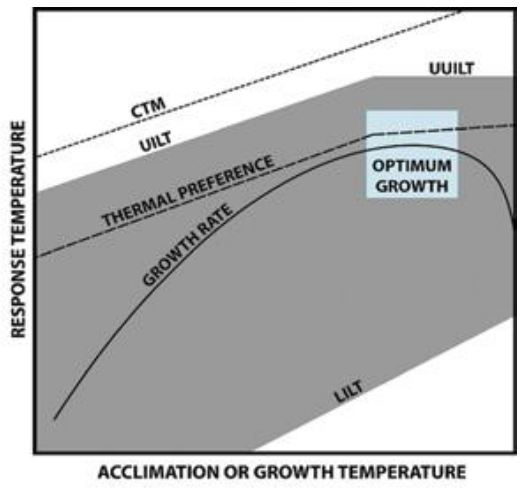
Proteins

- High heat can completely denature them, but enzyme systems are evolved for efficiency at a particular temperature range
- Rate of reactions are chemical balance sheets affected by substrate, temperature and feedback mechanisms.

Thermal Tolerances

- The main idea of this concept is the existence of so-called *pejus*-temperatures or thresholds. The suboptimal temps characterized by decreasing performance before critical temperature limits are reached at the high and low end of the thermal tolerance window.

- Hypothesized borders characterized by the transition to hypoxemia, i.e. internal (systemic) hypoxia caused by a limited capacity of oxygen supply mechanisms (ventilation, circulation) at extreme temperatures. The temperature-induced hypoxemia delineates the first line of thermal limitation and occurs in fully oxygenated waters



Critical thermal maximum (CTM; ---) ; thermal preference; lower and upper incipient lethal temperatures (LILT and UILT), are positively correlated with acclimation temperature.

Heat Shock Proteins

- Family of proteins expressed in invertebrates and vertebrates in response to wide range of biotic and abiotic stressors
- Widespread phenomenon
- Intracellular proteins among diverse organisms

HSP (proteins)

- **Named by molecular mass (kDa) as determined by SDS Page electrophoresis or other methods such as western blot.**
- **HSP 70 is one of the most highly conserved of the HSP groups**
- **Almost all studied cells have HSP**
- **The DNA sequences for HSP are more than 50% similar among bacteria yeast and drosophila.**

- **Vital role in cell. Protein assembly, correct folding, and translocation and regulating interactions between hormones and receptors.**

Elevated Temperatures

- **Heat shock proteins (HSP) expression is increased when the cells are exposed to elevated temperatures.**
- **Increase in expression is transcriptionally regulated.**
- **Up regulation of the heat shock proteins induced mostly by heat shock factor (HSF) is a key part of the heat shock response.**

Consequences

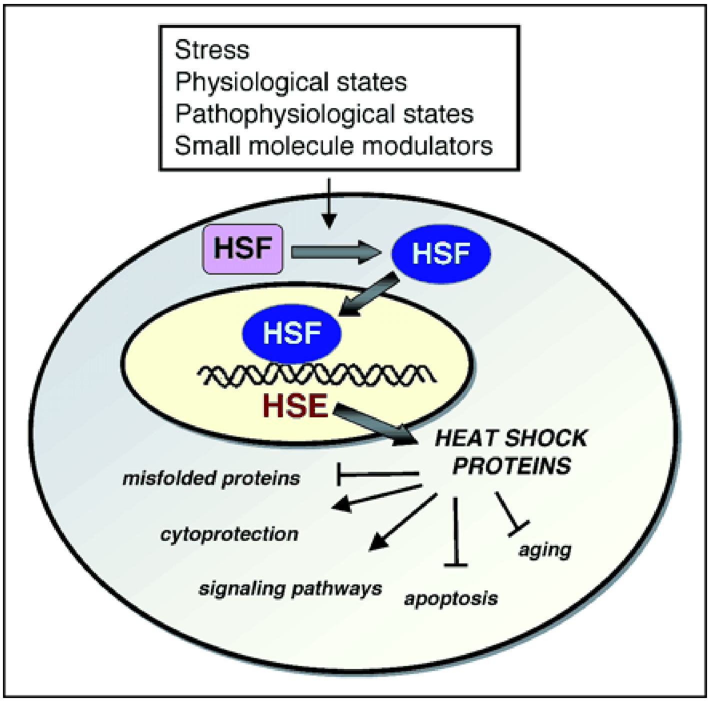
- **Heat shock proteins trigger immune response through activities that occur both inside the cell (intracellular) and outside the cell (extracellular).**

Intracellular

- **Normal functions of heat shock proteins inside the cell (such as helping proteins fold, preparing proteins for disposal, etc.)**
- **HSPs end up binding virtually every protein made within the cell. Thus, they represent a 'library' of all the proteins inside the cell.**
- **HSP bind to normal peptides and abnormal peptides (infectious diseased, old, cancerous).**

Extracellular

- **Extracellular HSPs are one of the most powerful ways of sending a ‘danger signal’ to the immune system in order to generate a response that can help to get rid of an infection or disease.**



Viral Infections (possible link to fever repair?)

- **Viral infection induces Hsp expression.**

Oxidative Stress

- **Immune cells release nitric oxide and superoxide in the attack on invading cells.**
- **Host cells express Hsps to protect against oxidative damage.**
- **Pathogens also mount a protective response with massive overproduction of Hsps.**

Emotional and Physical Stress

- **When rats are physically restrained, their vascular endothelial cells express elevated levels of Hsp70. The response has been linked to an abrupt increase in blood pressure.**

- **Elevated Hsp70 expression protects against cardiac failure. Hearts of transgenic mice that express elevated Hsp70 sustain less damage.**

Neural Receptors

- **Some evidence that mechanism transports Hsps from support cells to neurons during stress.**

Model for Regulation (Proteo toxicity model)

- **Denatured or foreign proteins are potent inducers**
- **HSP 70 is key sensor and mediator of events leading to further production.**

Cell Lines

- **Many proteins are expressed in different fish cell lines, including RTG, and H, CHSE, FHM**

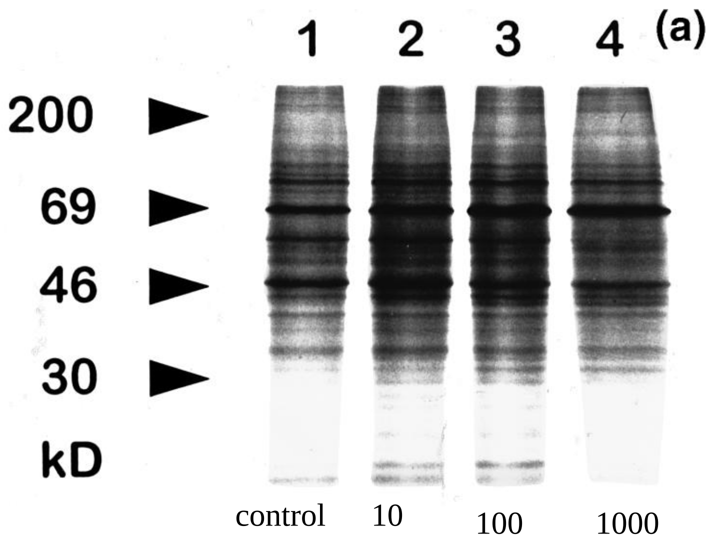
Cell Lines Can Help Study

- Simple
- Excellent experimental systems

Whole Animal Studies

- **Induction in many tissues with temperature**
  - **Muscle, liver, heart, brain**
- **Induction with environmental contaminants**

Autoradiograph of CHSE cells after 3 dosages of hydrogen peroxide
From Iwama et al. 1998



Western Blot Liver Tissues infected with R. sal

From Iwama et al.