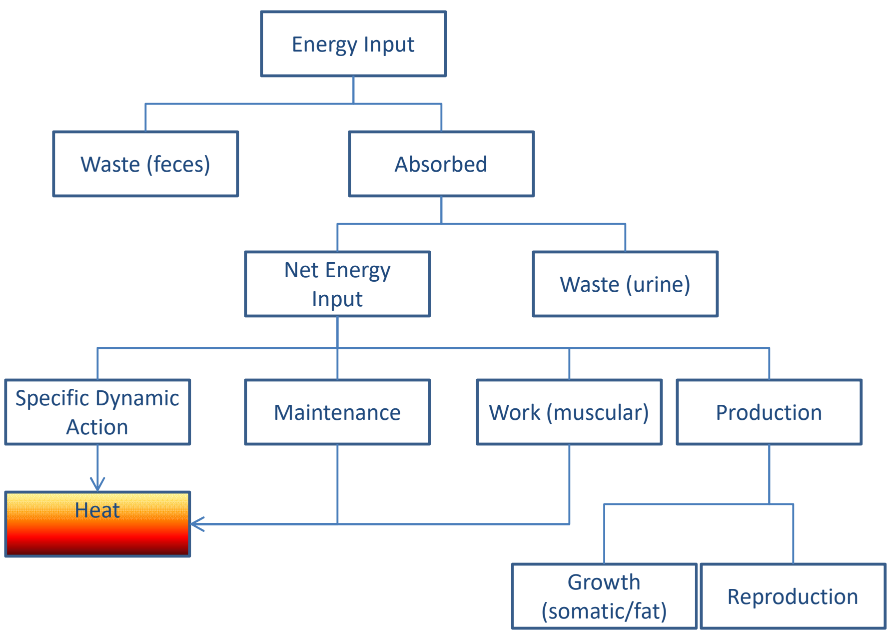
Metabolism and Energetcis

- Simple energy budget
  - Calories ingested = Calories used + growth
- Currency is typically (kilo)calories
  - 1 calorie ↑ 1 g water 1 C^{o}
  - 4.2 Joules
- Problems
  - Not all ingested calories are equal
  - Calories use variable due to many factors
  - Different categories of growth, also with environmental inputs

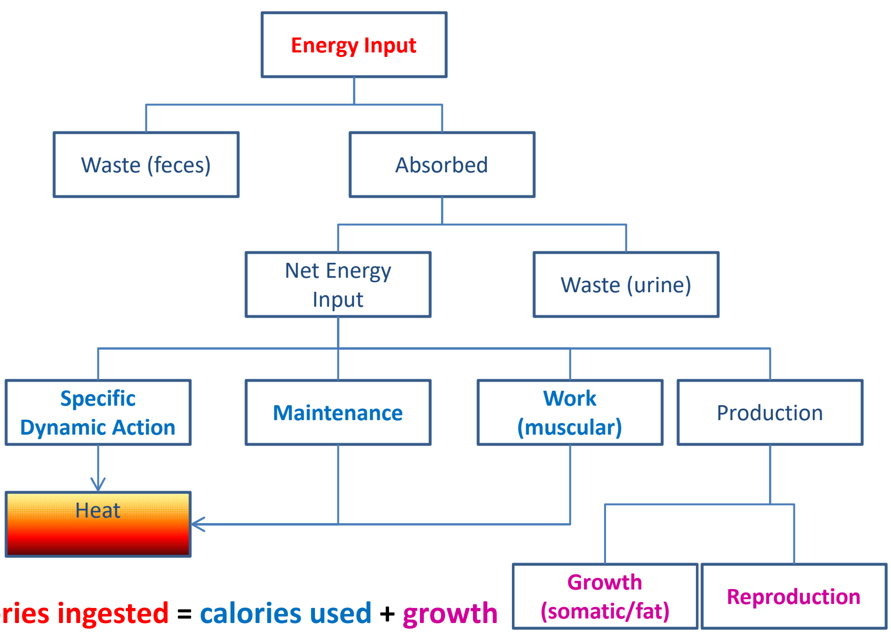
Metabolism and Energetics



Metabolism and Energetics

- Metabolism
  - Cellular – ATP production
  - Organismal – total calories spent, cumulative over many categories
- **Specific Dynamic Action** - calories spent digesting food, above basic metabolism
- **Maintenance** – variety of basic cellular processes (includes osmoregulation)
- **Work** – Muscle activity
- **Production** – anything increasing the mass of the organism, protein synthesis, **lipogenesis** (**Acetyl CoA** → lipid)

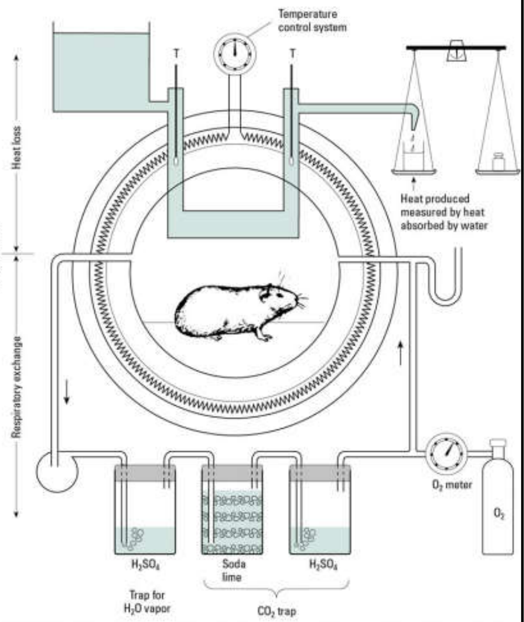
Metabolism and Energetics



Calories ingested = calories used + growth

Metabolism and Energetics

- Most metabolism energy winds up as heat
  – Even muscle activity ~ 80% internal friction
- Metabolism measured as
  – Heat given off
  – Oxygen consumed
  – CO_2 released



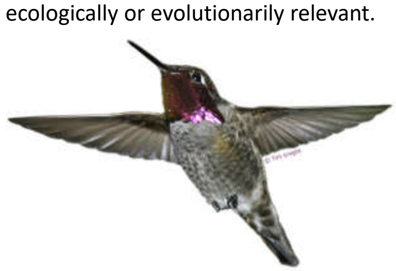
Metabolism and Energetics

Time and Energy budgets

Costly behaviors – 8% of time spent getting nectar, 32% of energy

Energy saving behaviors - 46% of time spent night roosting, only 9% of energy expended

Metabolism is fairly easy to measure in the lab. Lab measurements are not always ecologically or evolutionarily relevant.



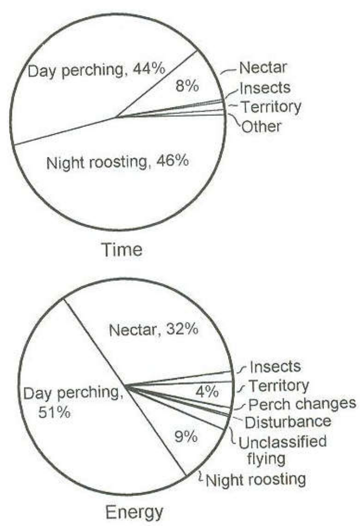
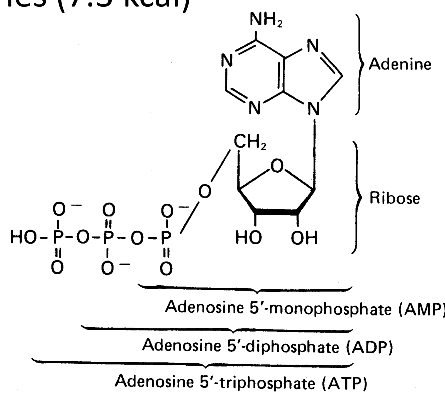


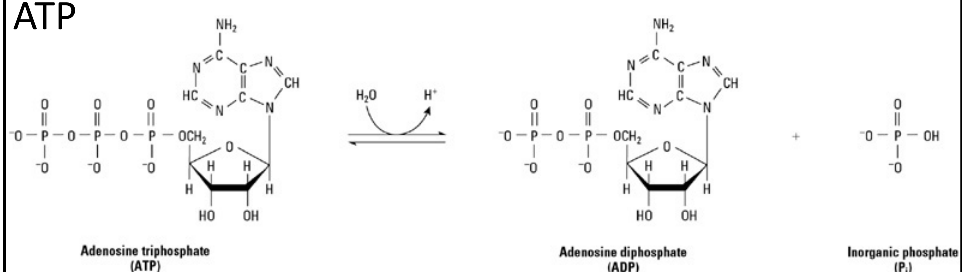
Figure 10.3 Time and energy expenditures over 24h in the field by Anna's hummingbird (*Calypte anna*). Source: Modified from Pearson (1954b).

Metabolism and Energetics

- Cellular metabolism – ATP production
  - 1 mole ATP = 7,300 calories (7.3 kcal)
- **Anabolic**
- **Catabolic**



ATP



- Drives all cellular processes
- Unstable (can't be stored in volume)
- Hydrolysis break off P, releasing energy
- Yields ADP and inorganic phosphate
- 60% of bond energy lost as heat – all metabolic processes generate heat (recall energy budgets)

ATP turnover rate

- ATP use variable by tissue, type of activity
- ATP demand may increase 100-1000 times during exercise
- Clear allometric trends

Table 6.1 ATP turnover rates during peak exercise in animals of varying size.

Species	Body mass	Muscle ATP turnover (μmol ATP g^{-1} min^{-1})
Insects		
Locust	1 g	5400
Birds		
Hummingbird	2.5 g	600
Mammals		
Mouse	7.2 g	227
Ferret	500 g	82
Wallaby	4.8 kg	57
Goat	20 kg	48
Human	70 kg	30
Eland	210 kg	32

Assuming all body mass is muscle, how many calories consumed per hour?

Locust

5400 µmol = .0054 mol * 7300 cal
= 39.42 cal g^{-1} min^{-1} *60
= 2365.2 cal h^{-1} * 1 g mass
= 2.4 kcal h^{-1}

Human

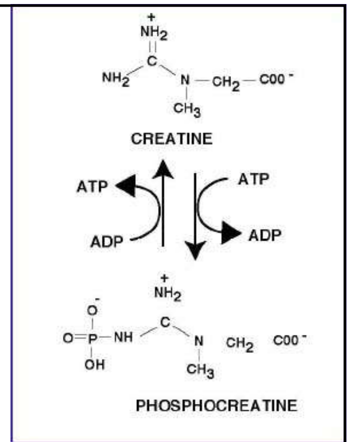
30 µmol = .00003 mol * 7300 cal
= 0.219 cal g^{-1} min^{-1} *60
=13.14 cal h^{-1} * 70,000 g
= 919.8 kcal h^{-1}

Sources of ATP

- **Phosphagen system**
  - Short term, rapid, no oxygen required
- **Anaerobic pathways**
  - Long term, slower, no oxygen required
- **Aerobic pathway**
  - Long term, slower, oxygen required

Phosphagen System

- Creatine phosphate or Arginine phosphate store P to "recharge" ADP
- Fast acting
- "Storage" of P
- High concentrations in muscle tissue
- Very short term
- No oxygen required (yet)
- Only a buffering system, no net ADP → ATP



Phosphagen System

Metabolic constraints on burst-swimming in the Antarctic teleost *Notothenia neglecta*

J. F. Dunn and I. A. Johnston

Gatty Marine Laboratory, Department of Physiology, University of St. Andrews; St. Andrews KY16 8LB, Fife, Scotland

- Phosphagen system better developed in animals showing short bursts of activity
- Often constrains capacity of other ATP sources

Phosphagen system

- Creatine serves to keep ATP levels stable.
- Typically (mammal) can supply all muscle ATP needs for 2-5 seconds.
- Must then be recharged by aerobic or anaerobic means.
- Important role in shuttling P between where ATP is produced and where it is used.