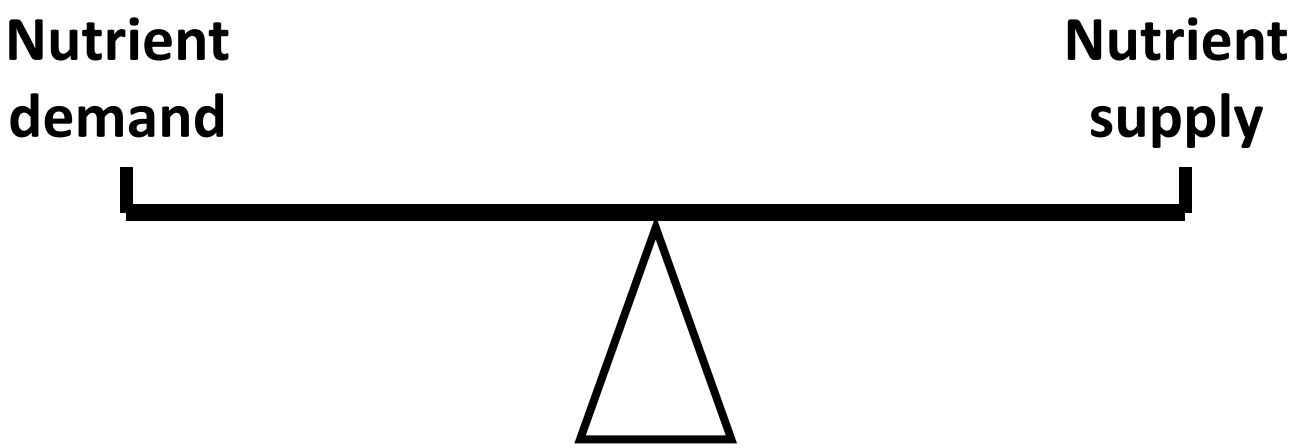
Nutrition

- Range of diets eaten*
- Nutritional requirements
- How does an insects gain the required nutrients



Evolutionary

Day to day

Feeding type: Plant/Animal associated morphology and physiology

Life history stage: Reproductive/non reproductive

Dietary history: last meal(s)

Pre-ingestive choices meal type and size

Post-ingestive processing morphology of mouthparts/gut selective absorption/excretion

Nutritional requirements

Nutrition = chemicals required for growth, tissue maintenance, reproduction and all other life activities

Is the outcome of **ingestion, digestion, absorption, metabolism** and **excretion**

- Ingested
- Synthesized by the insect
- Symbionts

Macronutrients

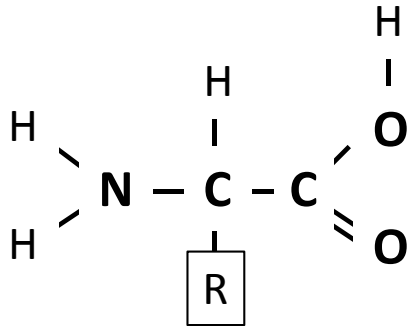
- Nitrogen (10 a.a.): proteins and amino acids
- Energy source - carbohydrate, fat, protein
- Fatty acids
- Sterols (cholesterol or plant sterols)

Micronutrients

- Vitamins (vitamins B’s, A, C & E)
- Mineral ions

Nitrogen

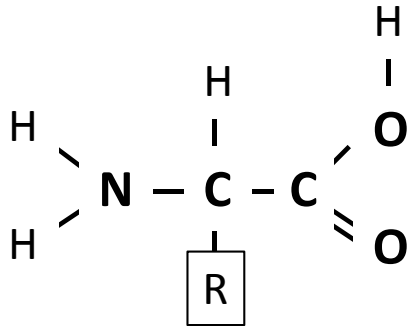
Amino acids ⟹ Proteins



- Structural purposes
- Enzymes
- Transport and storage
- Receptor molecules
- Cuticular sclerotization (aromatic amino acids)

Nitrogen

Amino acids ⟹ Proteins

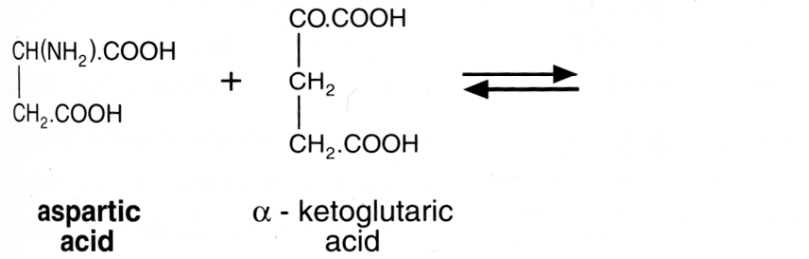


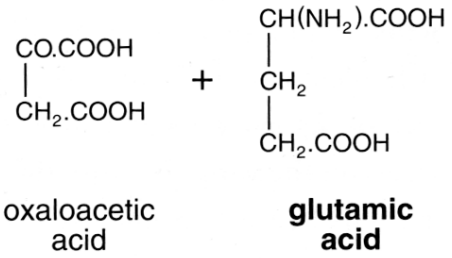
Need 20 amino acids

- 10 amino acids essential

- the other 10 can be synthesized

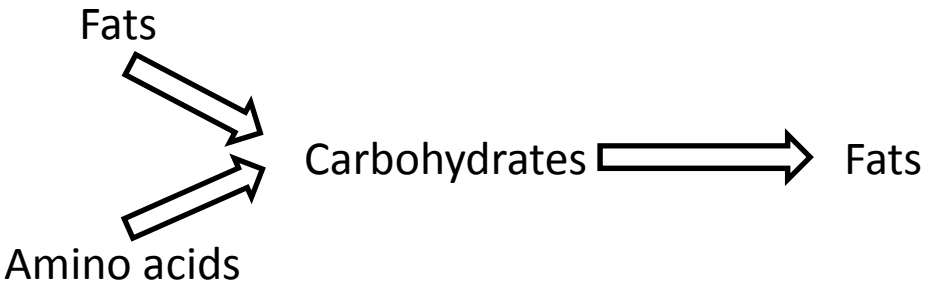
= TRANSAMINATION (transfer of an amino acid group from a pre-existing amino acid





Chapman, 1998

Carbohydrates



- Chitin
- Energy

- $(CH_2O)n$
- Simple carbohydrates (mono & di-saccharides)

  e.g. glucose, fructose, sucrose (gluc + fruc), maltose (gluc+ gluc)
- Complex carbohydrates (polysaccharides)

  e.g. glycogen, starch, cellulose

Lipids

- Fatty acids
- Phospholipids
- Sterols

- Fatty acids - $C_nH_{2n+1}COOH$
- Two forms - saturated (no double bonds) and
  - unsaturated (1 or more double bonds)
- Cell membranes
- Moulting and Reproduction
- Energy storage e.g. Long distance migration (flight)

Sterols

Cholesterol → Animals

Plant/Fungal Sterols → Plant/fungus or from symbionts

- Affects development and morphology
- Precursors of the steroid hormones
  - e.g. ecdysone
- Cellular membranes
  - Essential structural components (provides support and rigidity)

Micronutrients

Vitamins

Visual pigments

reproduction

- Fat soluble (e.g. provitamin A, vitamin E)
- Water soluble (e.g. B-vitamins)

Can not be synthesized
Enzyme cofactors

Ascorbic acid

Nucleic acids

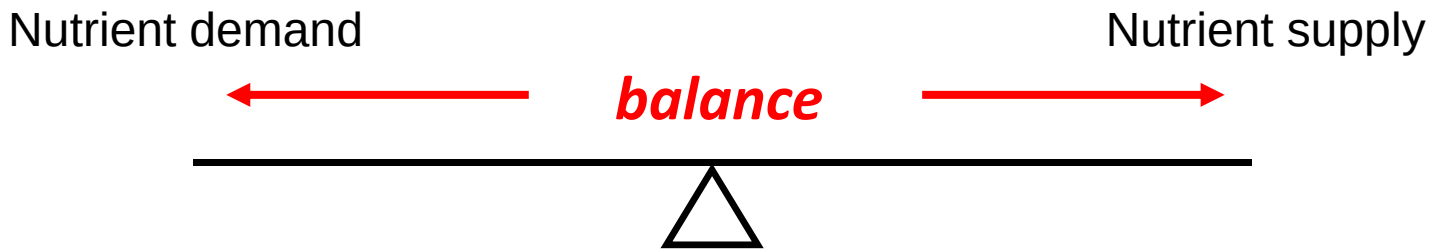
Inorganic compounds

- e.g. Sodium, potassium, calcium, magnesium, chloride and phosphate

Metals

- Iron, zinc, magnesium

Nutrient balance matters

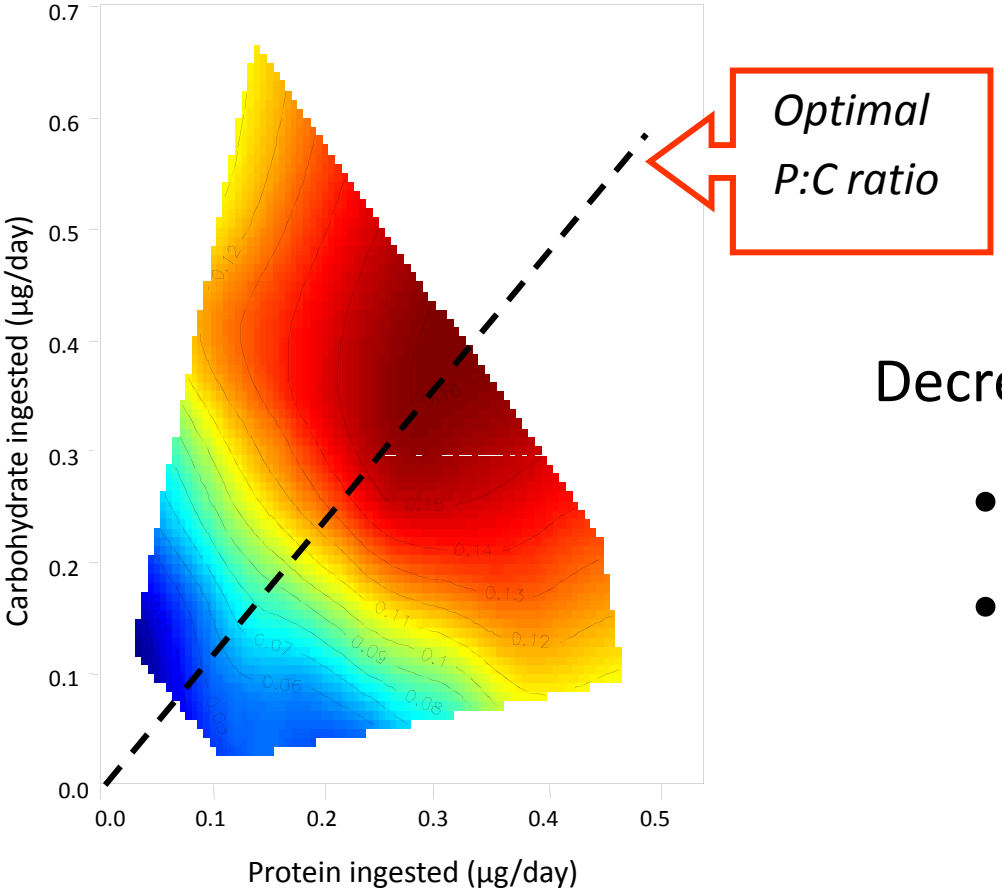


Evolutionary

Day to day

Nutrient balance matters

Example: Australian plague locust
5th instar



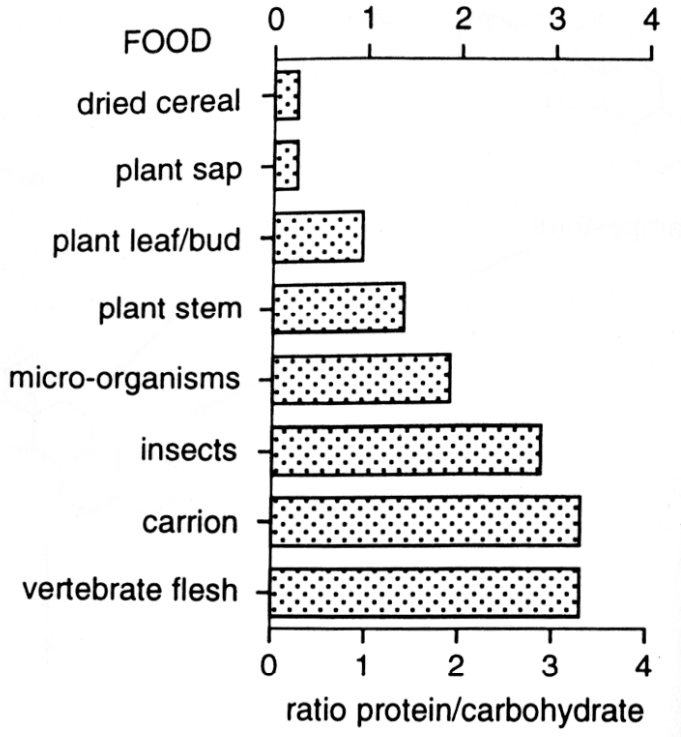
Decreased growth rate

- nutrients diluted
- suboptimal ratio P:C

Nutrient balance matters

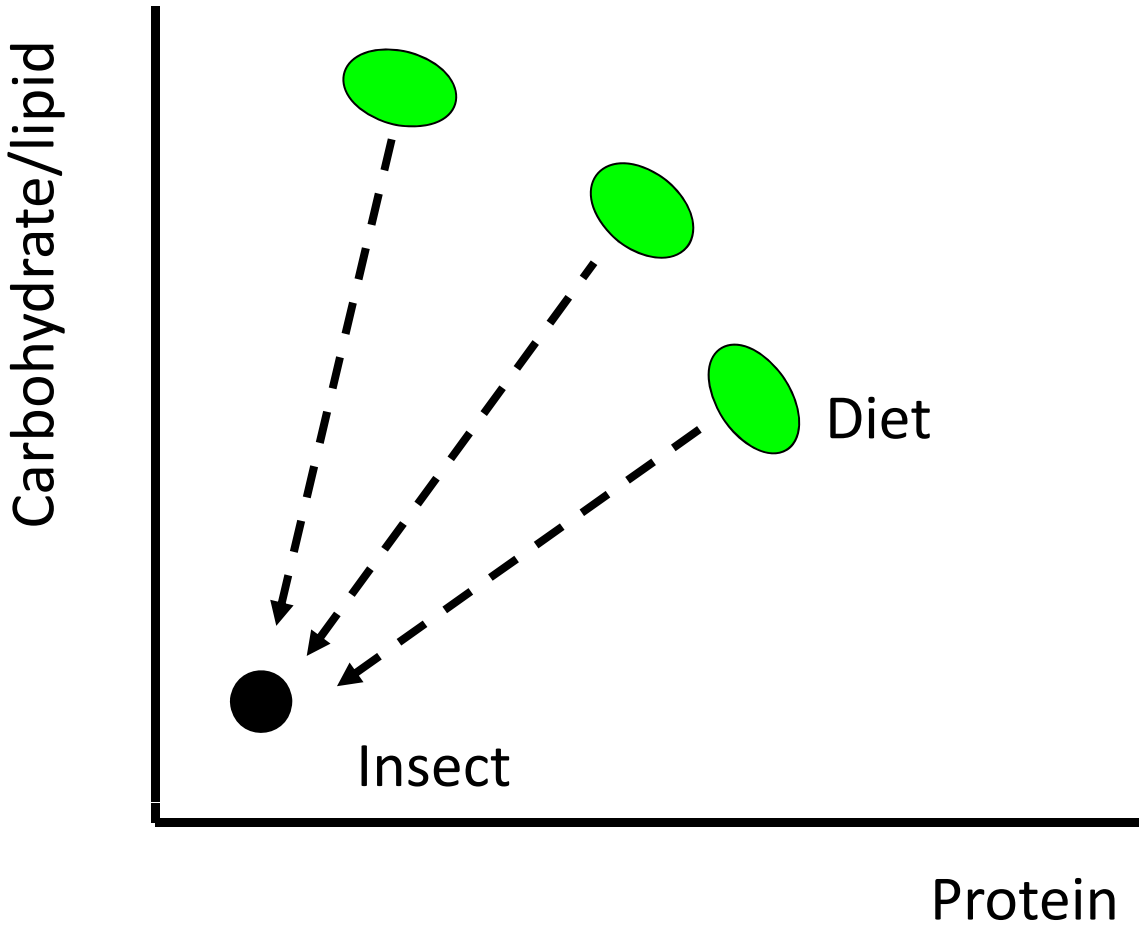
Between macronutrients

- protein versus carbohydrate

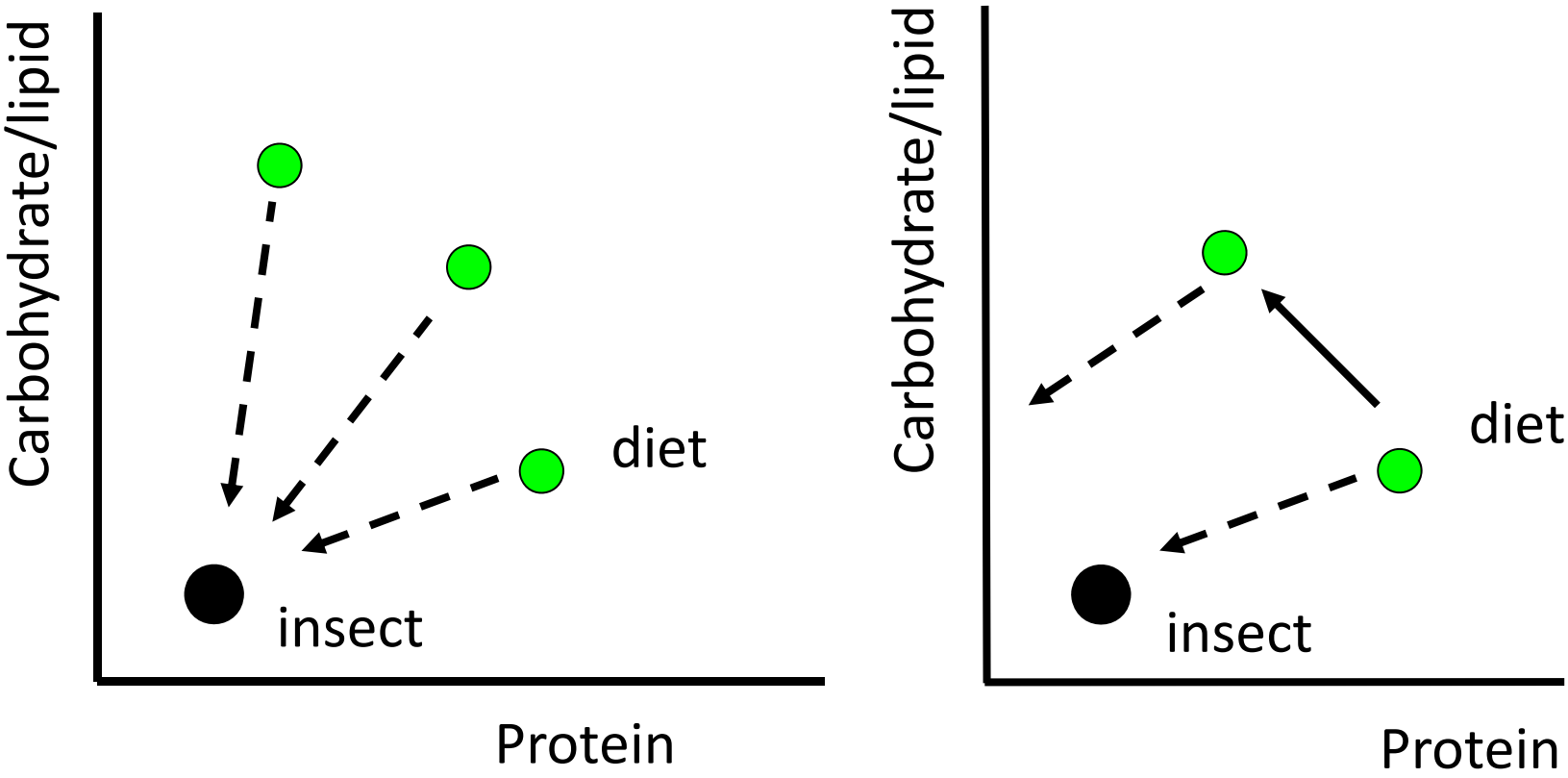


Chapman, 1998

Nutrient composition of diet



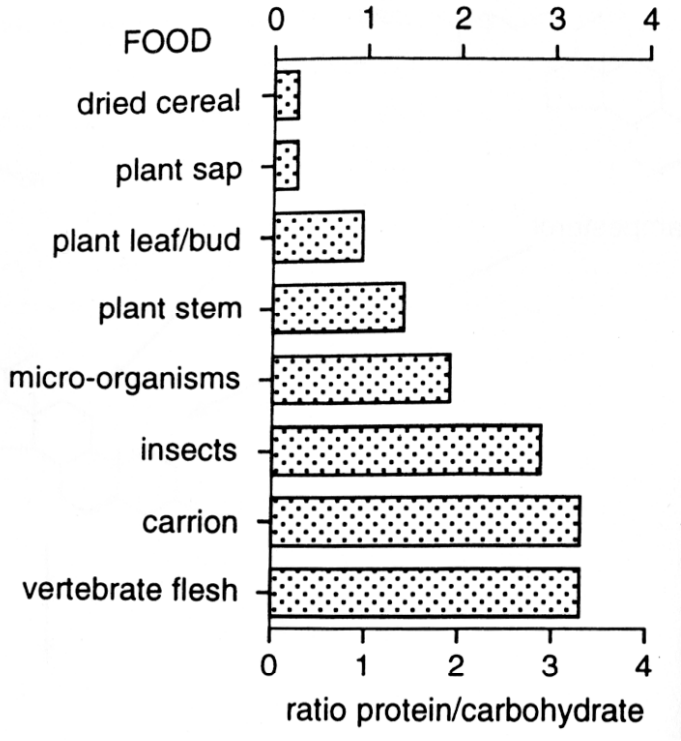
Nutrient composition of diet



Nutrient balance matters

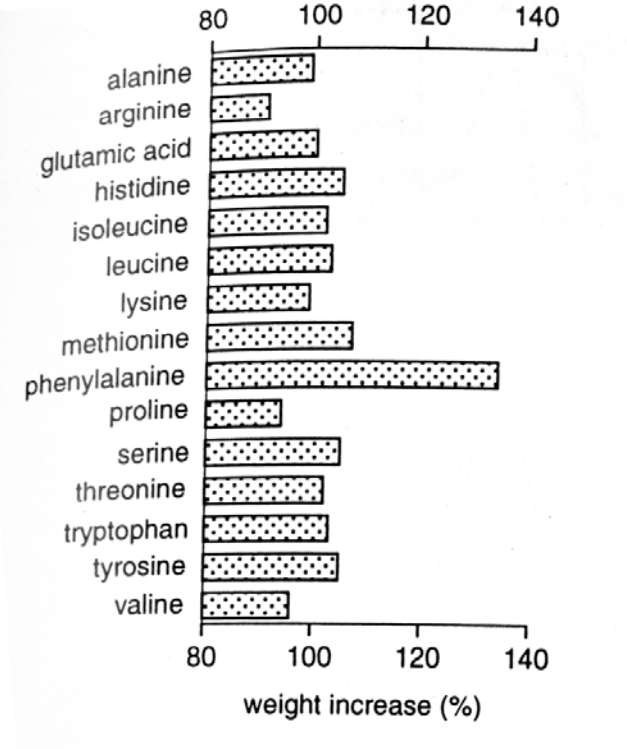
Between macronutrients

- protein versus carbohydrate



Within macro nutrients

– amino acid balance



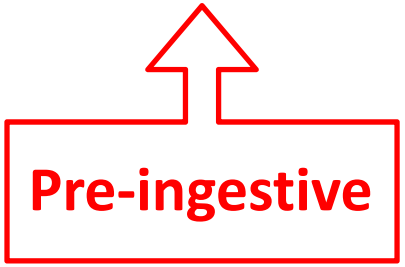
Chapman, 1998

Nutrient balance matters

Nutrition = chemicals required for growth, tissue maintenance, reproduction and all other life activities

Is the outcome of **ingestion, digestion, absorption, metabolism** and **excretion**

NUTRITION = IN – OUT



Pre – ingestive balancing

Choose

- What to eat
- Amount – meal size
- Frequency – meal frequency

Foods contain all the necessary chemicals but not in the correct balance

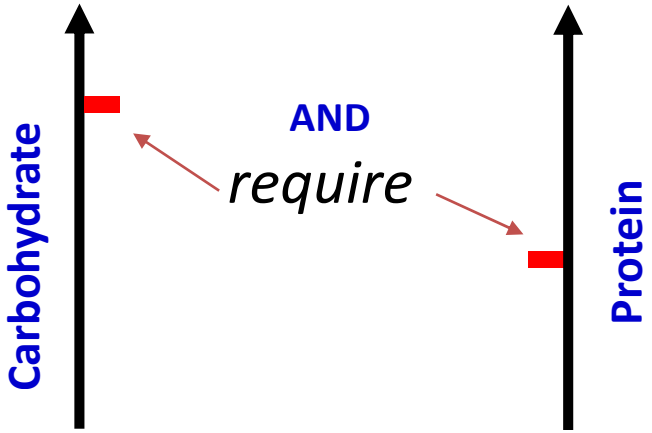
Which nutrients to regulate?

Nutrient requirements

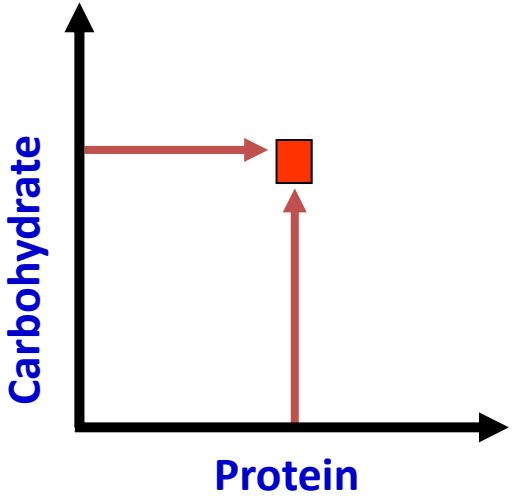
- multiple nutrients

Protein

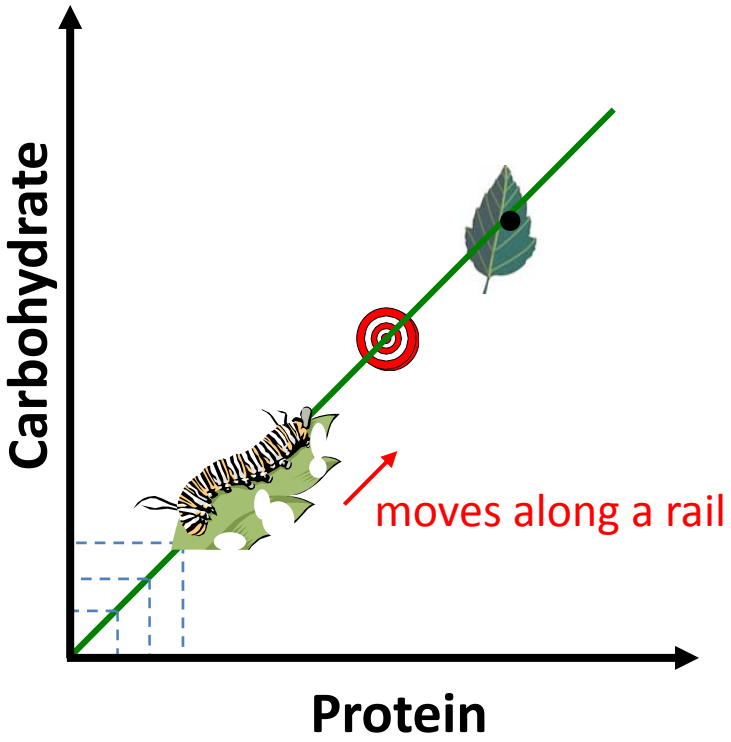
Carbohydrate



- nutrient *interactions*



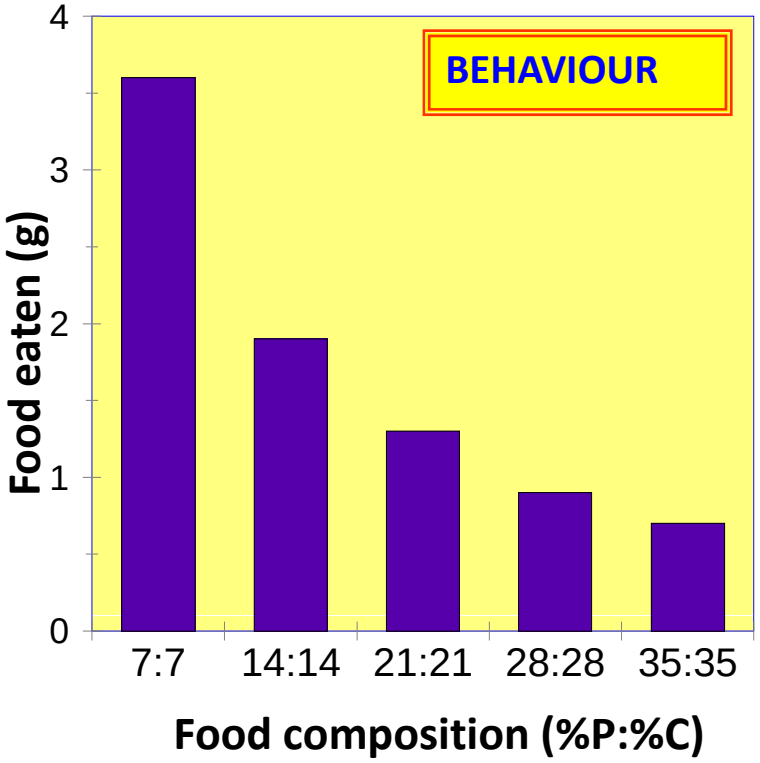
a) Balanced food

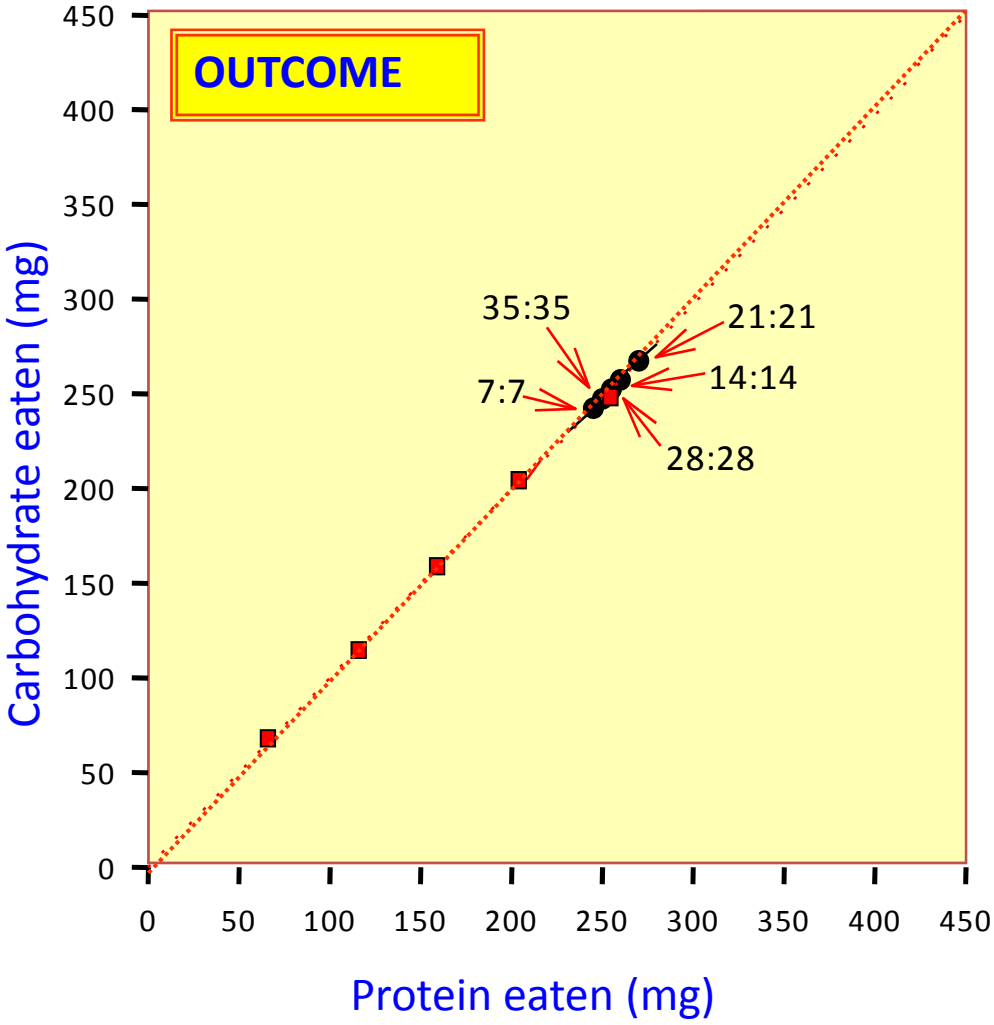


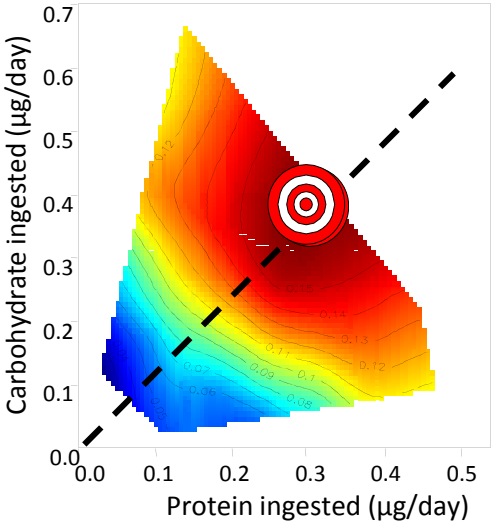
Nutrient dilution

Manipulation:

- **Diluted**, 5-fold range

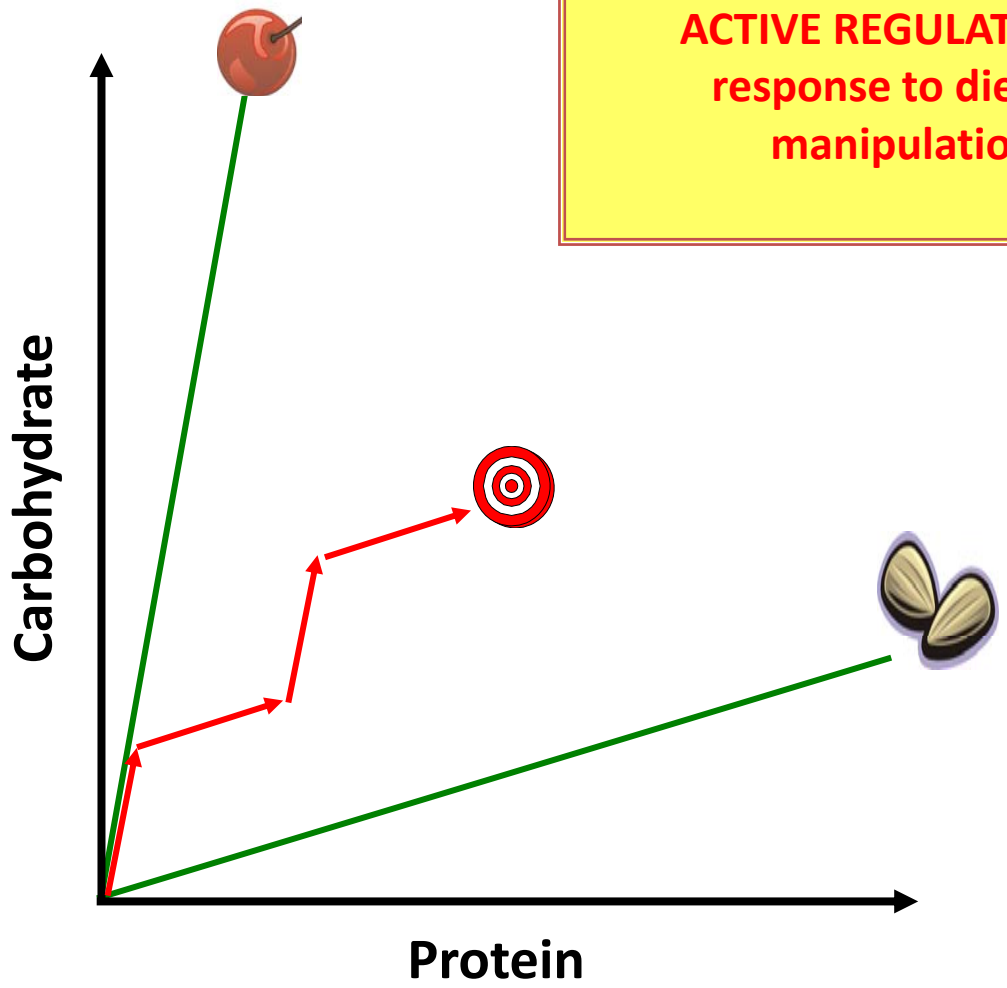






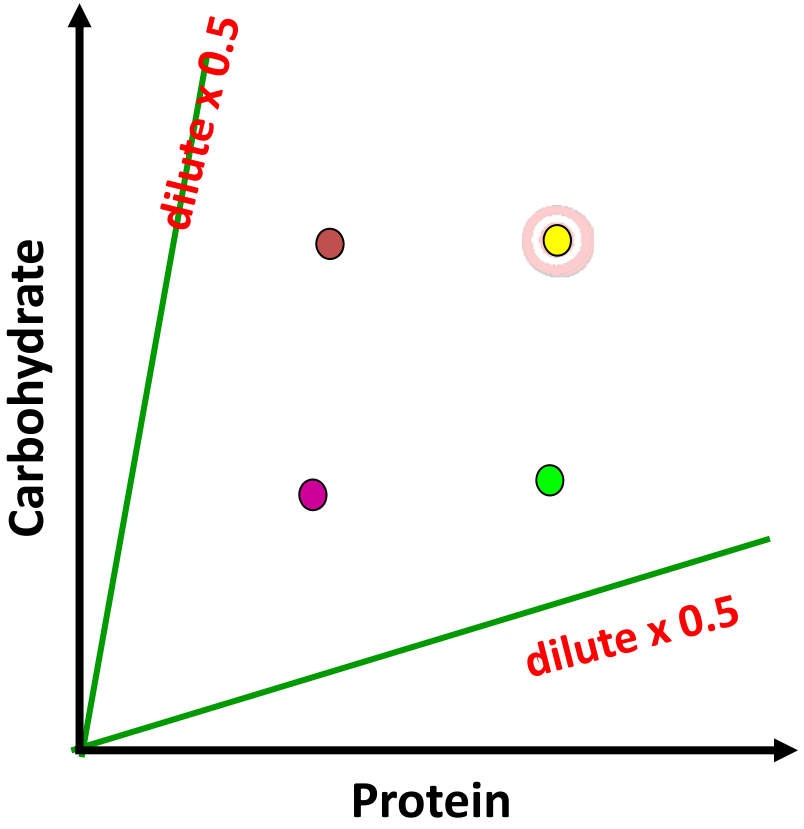
b) Multiple foods

ACTIVE REGULATION in response to dietary manipulation

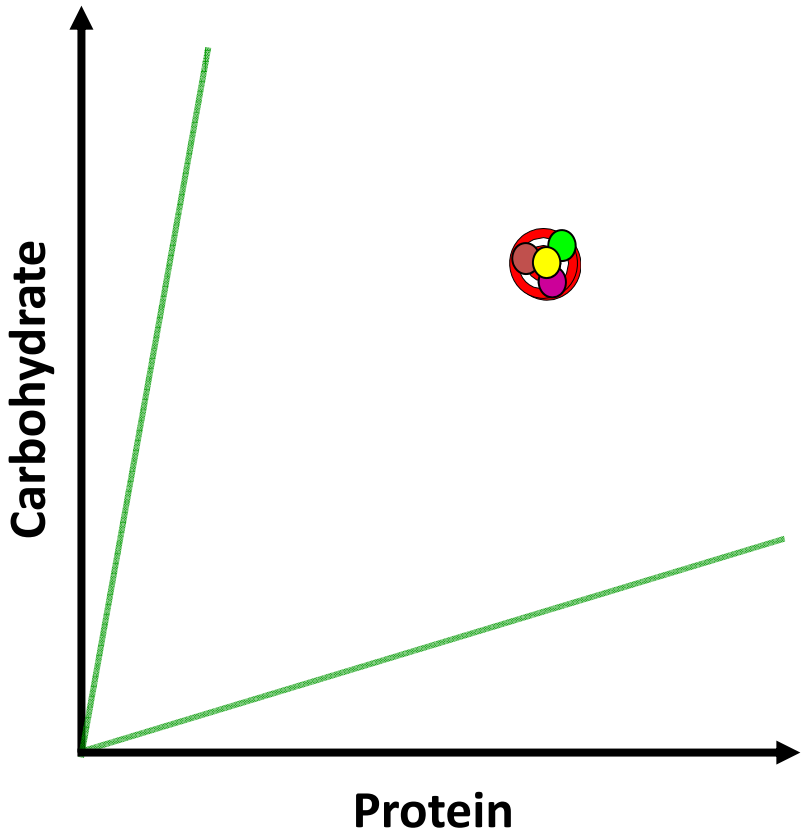


Powerful test of target defence

- Undefended



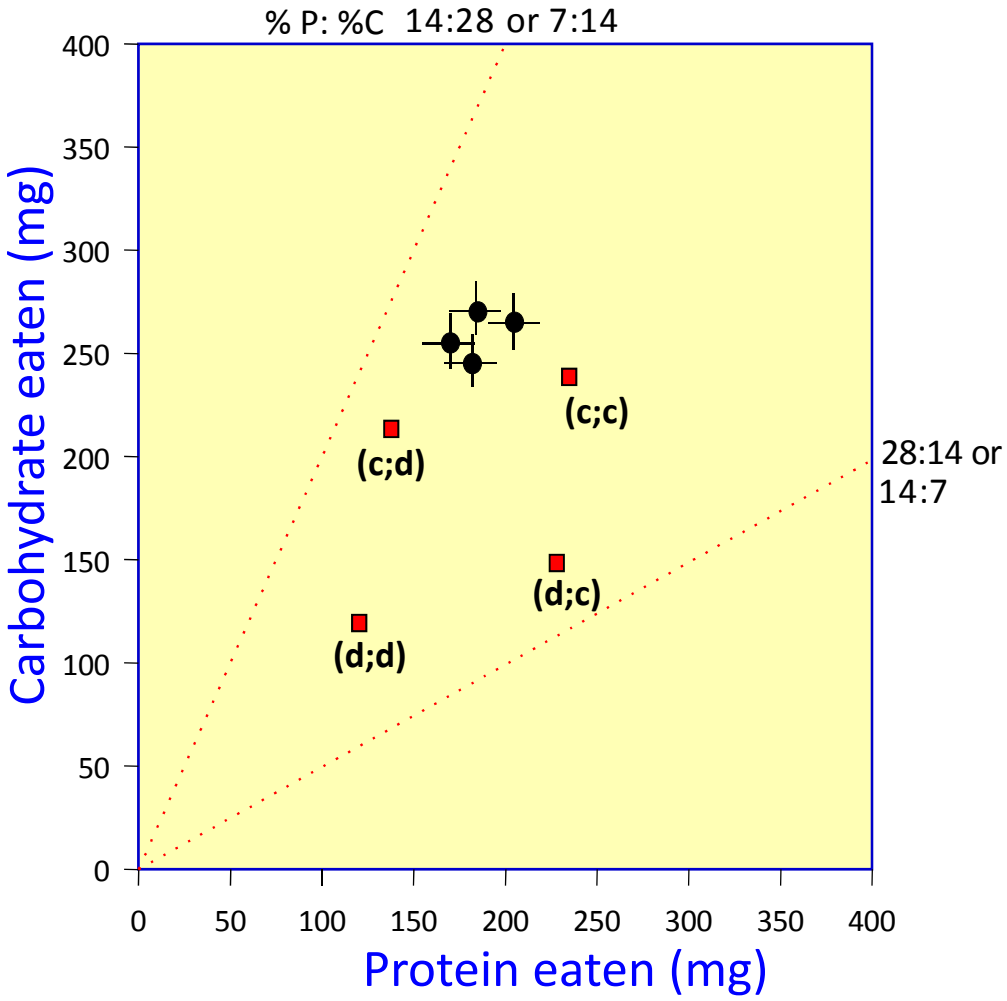
- Defended – *active regulation*



African migratory locust - *Locusta*

Manipulation:

Two synthetic foods each,
% P, **C** and **bulk** different



Nutrient requirements

Can meet nutritional requirements

Pre-ingestive

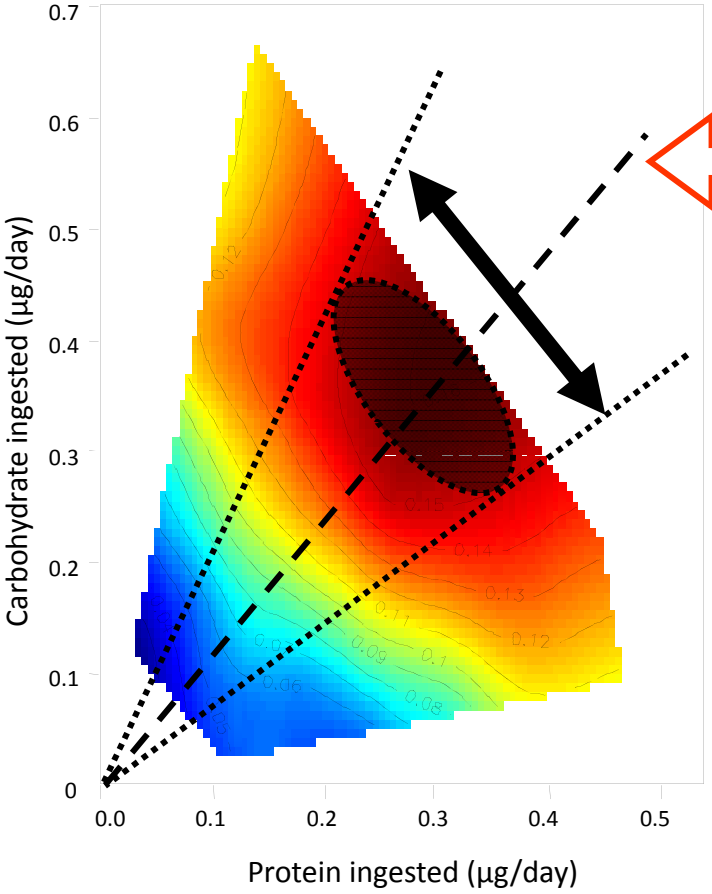
- What is eaten
- Meal size
- Meal frequently

But life not that easy

Host range for many insects restricted

Nutrient requirements

Growth and Rate of Development



Optimal P:C ratio

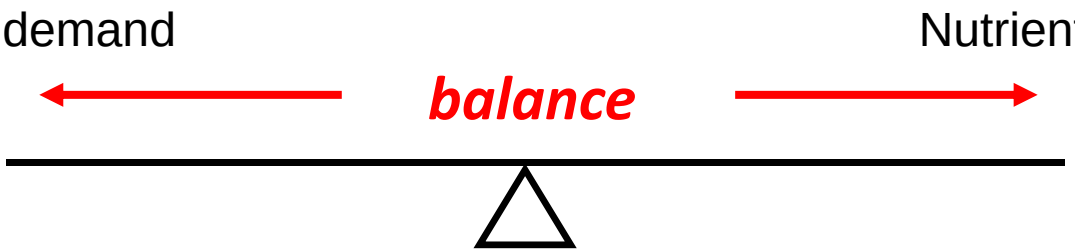
Decreased growth rate

- nutrients diluted
- suboptimal ratio P:C

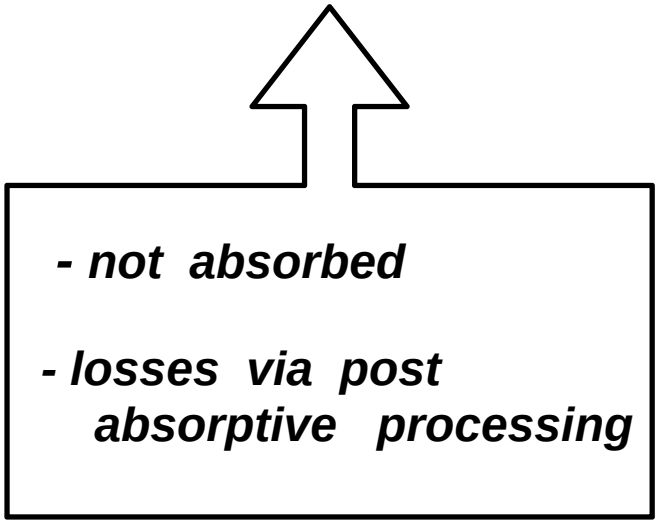
- Performance unaffected over a range of P:C ratios
- Similar body compositions

Foraging

Acquiring the correct blend of nutrients



NUTRITION = IN – OUT



Examples

- **morphological**
- **physiological**

Example: *morphological*

NUTRITION = IN – OUT ***- not absorbed***

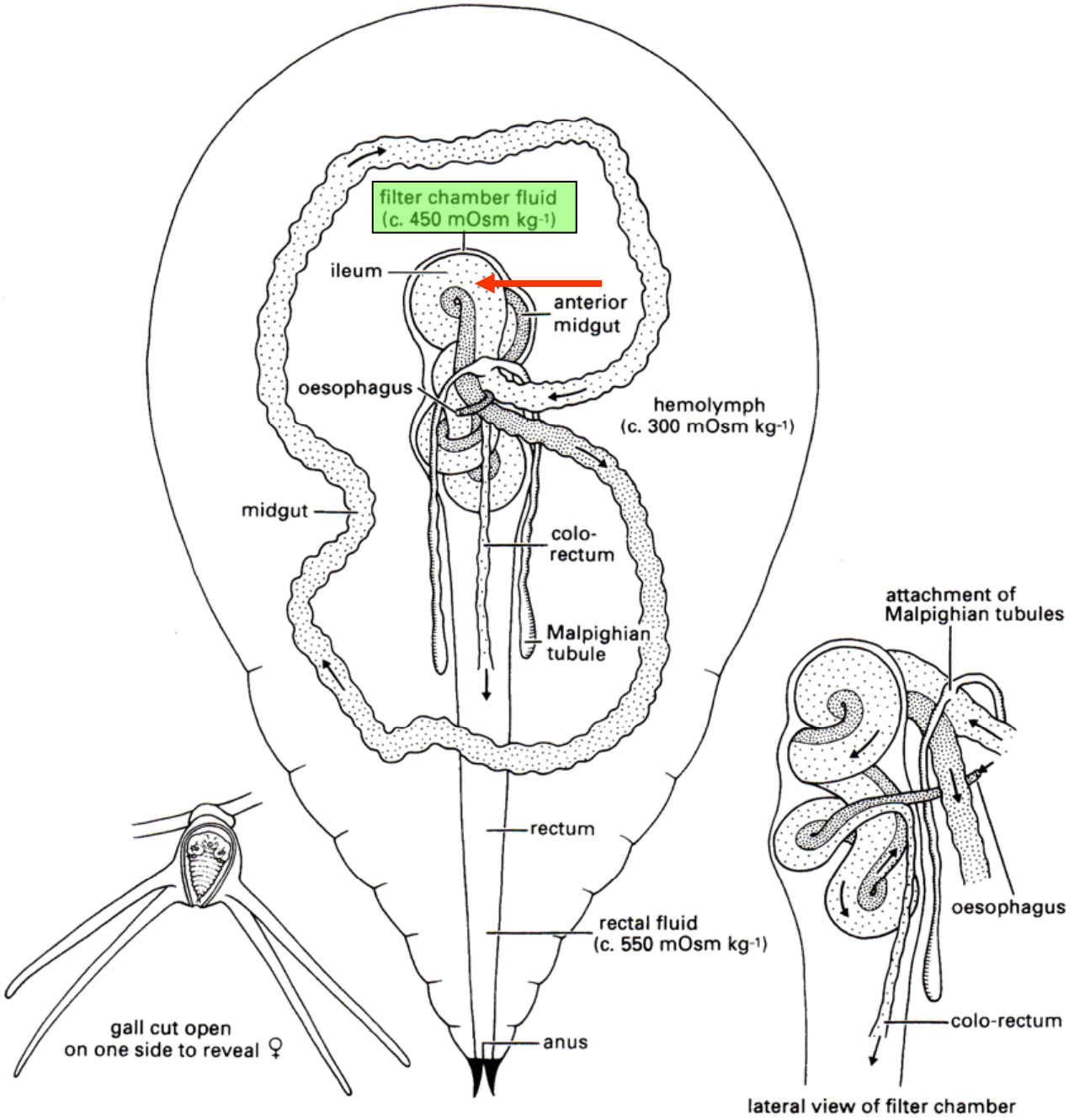
Modification of gut

Phloem feeders:

e.g. aphids, psyllids, scale insects

phloem = sugar & water > nitrogen

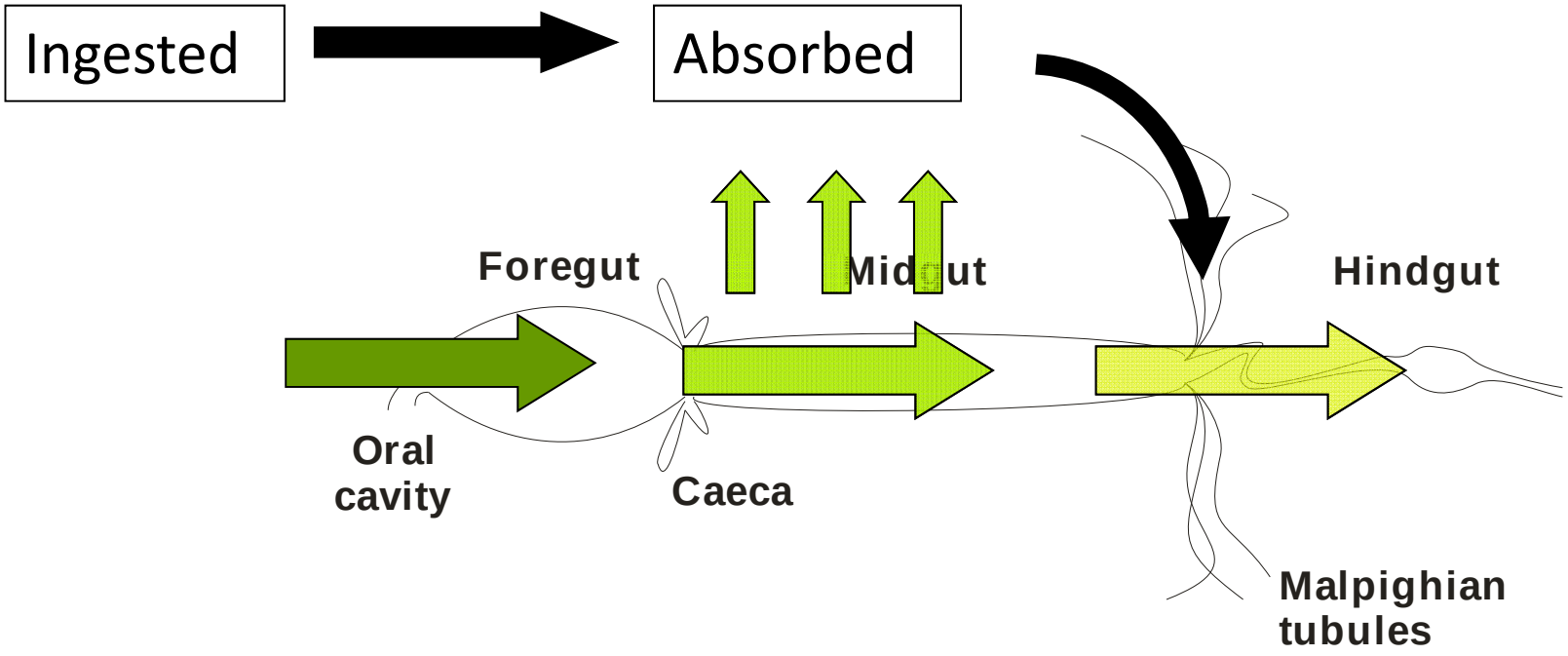
Filter chamber: modified gut to allow water and simple sugars to bypass midgut



Gullan and Cranston, 2005

NUTRITION = IN – OUT

Nutrition = ingestion – not absorbed – losses via post absorptive processing



Post – ingestive balancing

- Pre-absorptive
  - Differential release of digestive enzymes

    (Clissold et al. 2010)
  - Change in alimentary canal morphology

    (Raubenheimer and Bassil 2007)
  - Altered transporters?
- Post-absorptive
  - Metabolism/Excretion

    Deamination of amino acids (change N-compounds to C-compounds), excrete excess N

    Dietary induced thermogenesis (removal of excess C-energy)

    Excretion of inorganic ions

Example: *physiological*

NUTRITION = IN – OUT - not absorbed

Differential release of enzymes

Herbivores (& Carnivores)

e.g. *Locusta migratoria*

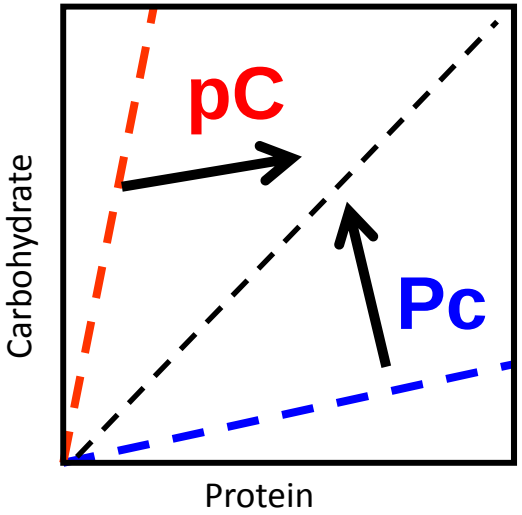
extraoral digesters??

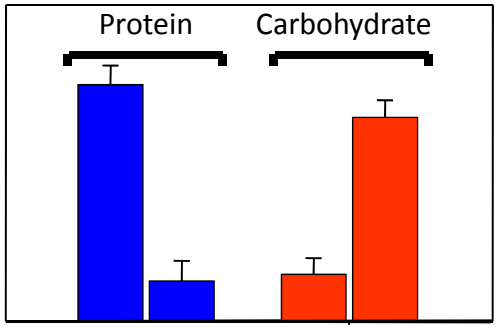
Example: *physiological*

NUTRITION = IN – OUT ***- not absorbed***

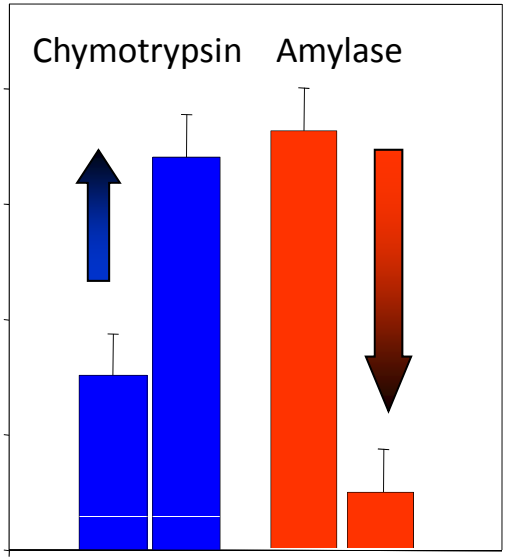
Locusta migratoria

Ingested





Pc pC Pc pC

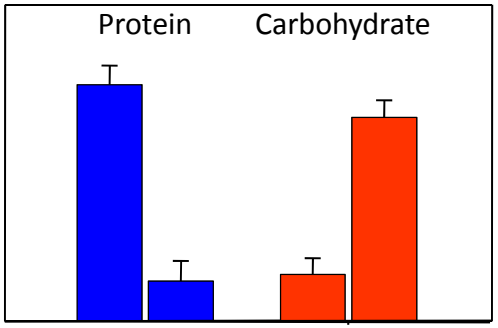


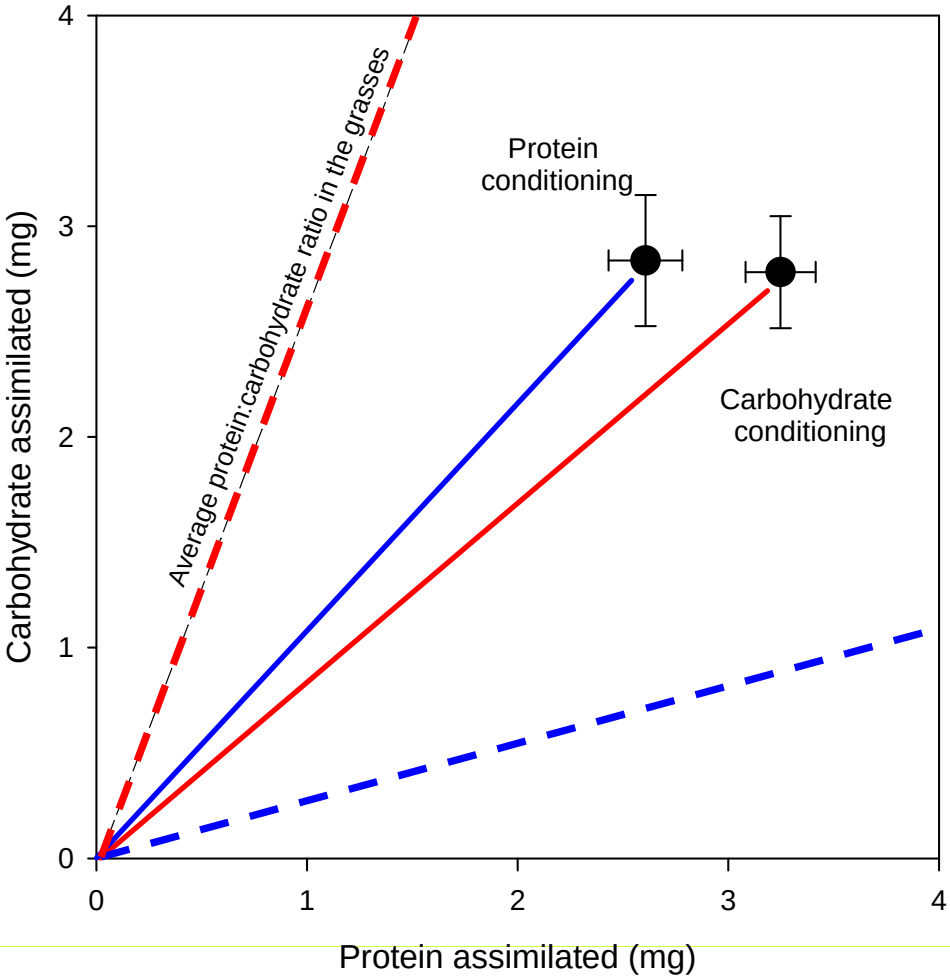
Pc pC Pc pC

Clissold et al. 2010

Example: *physiological*

Locusta migratoria





Clissold et al. 2010

Example: *physiological / behavioural*

NUTRITION = IN – OUT ***post absorptively removed***

Protein - demainate and excrete N,

use the CHO backbone as energy

C-based (carbohydrate and lipid)

- increase metabolic rate

Example: *morphological / physiological*

NUTRITION = IN – OUT

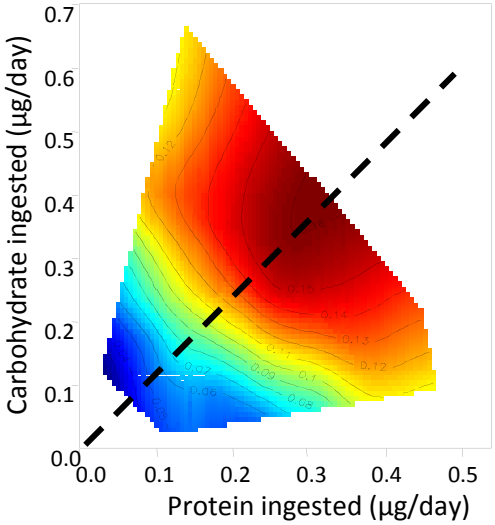
Symbionts

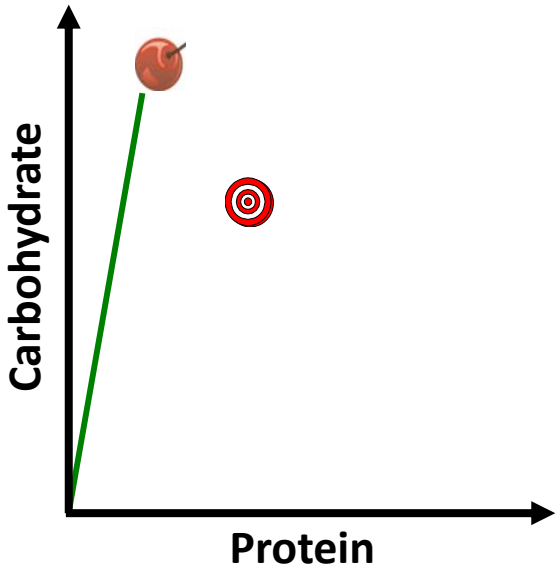
- extra- or intracellular microorganisms (bacteria, yeast, protists, fungi).
- Contribute to the insects nitrogen (a.a. synthesis), vitamin, sterol and/or carbohydrate economy

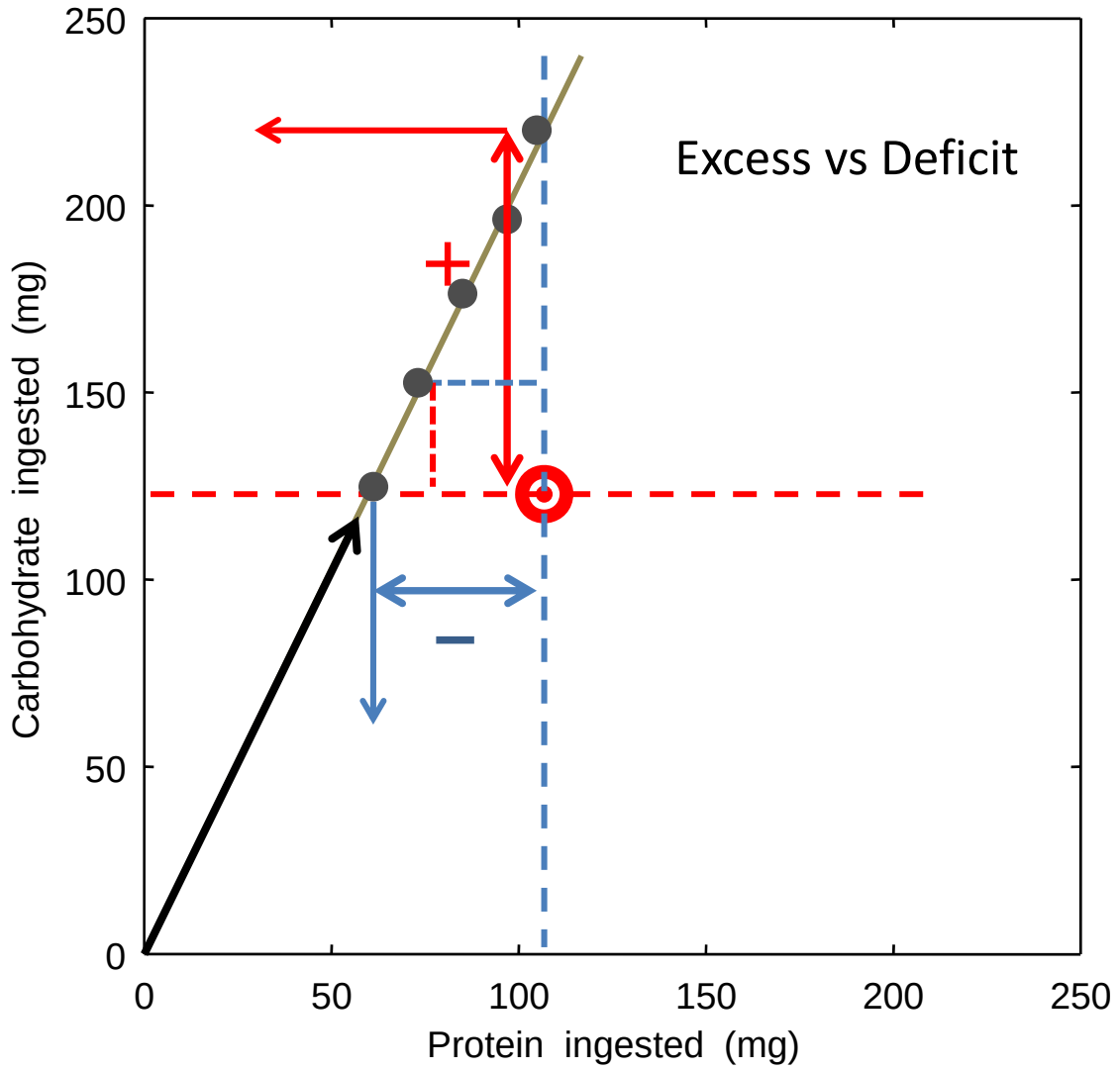
Post-ingestive balancing

can only do so much

What happens when insects are forced to eat a suboptimal diet?







Rules

Excess > Deficit

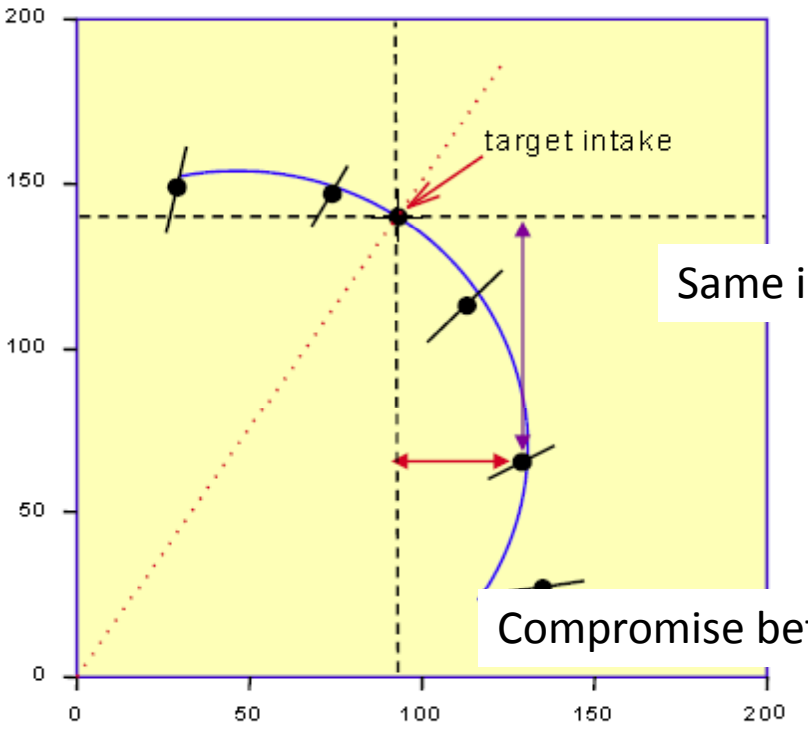
Excess = Deficit

Excess < Deficit

Specialist feeder

e.g. *Locusta migratoria*,

grass feeding specialist



Excess < Deficit

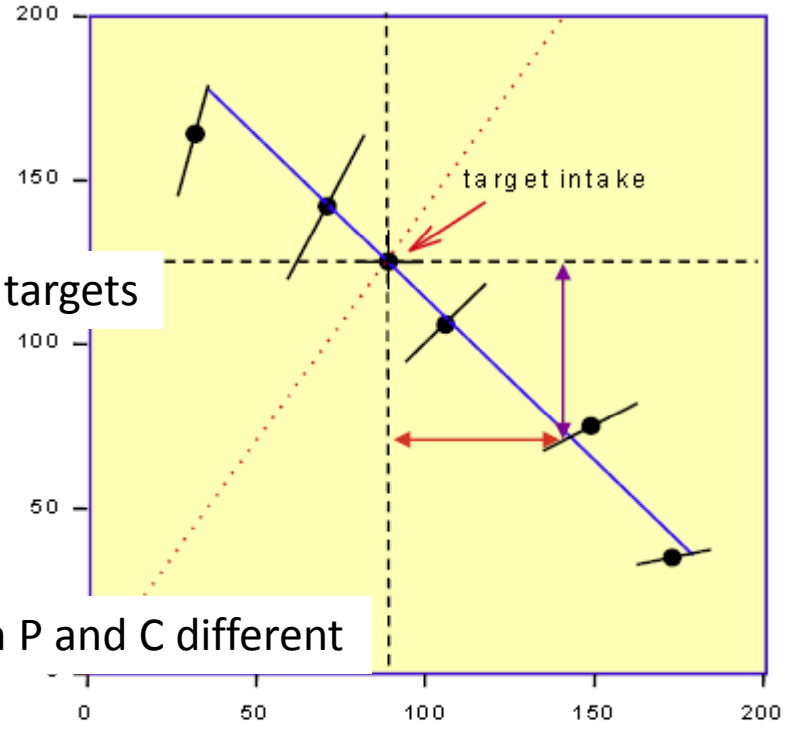
Same intake targets

Compromise between P and C different

Generalist feeder

e.g. *Schistocerca gregaria,*

feeds on grasses and forbs



Excess = Deficit

Regulation of nutrient intake requires

1) Assessment or knowledge of the nutrient composition of foods
    - directly by tasting
    - learning

2) Knowledge of the nutritional status of the insect
    - haemolymph composition
    - status of nutrient reserves e.g. fat stores

3) A method of comparing food and state
    - Controlled by the sensitivity of *peripheral taste receptors* which are regulated by metabolic and physiological feedbacks
    - learning from previous experience

Summary

Diet choice

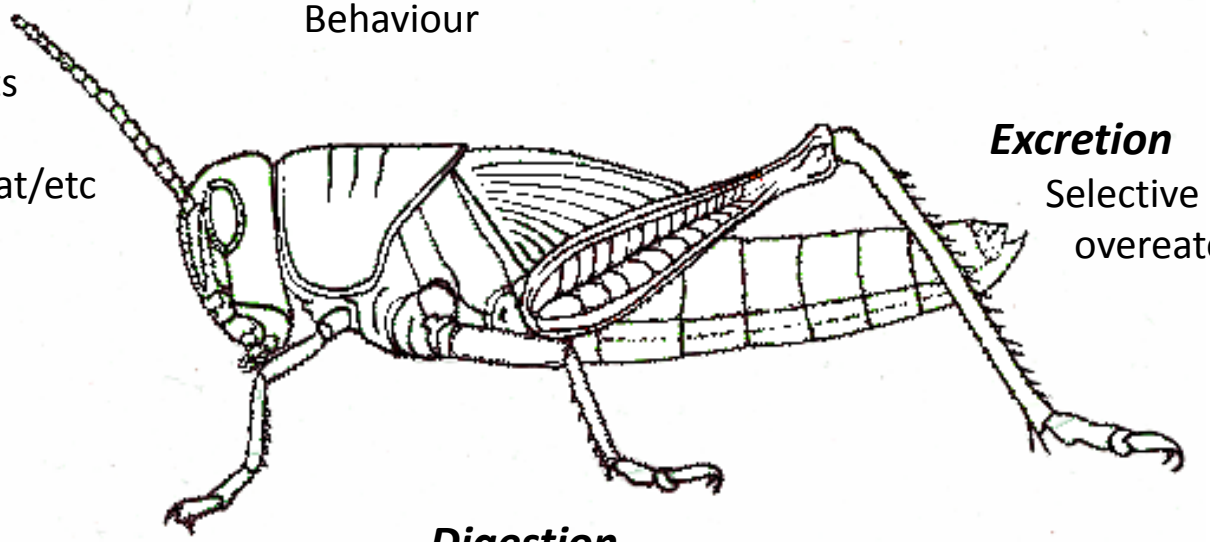
Nutrient requirements
- Age
- Previous history

Environment
- phagostimulants
- deterrents

Predators/microhabitat/etc

Assimilation allocated to growth

Costs of
- Metabolic requirements
- Diet processing and digestion
- Behaviour



Excretion

Selective egestion of overeaten compounds

Ingestion

Meal size

Digestion

Food retention time

Selective uptake – differential release of nutrients

Processing

Ease of extraction

Mandible sharpness

Summary

Nutrition

what insects need

how do insects balance demand and supply

Further reading

Chapman, 1998; Ch 4

Chapman & de Boer 1995, Ch 9

Chown & Nicolson, 2004 Ch 2

Nation, 2008; Ch 3

References

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Additional reading -

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