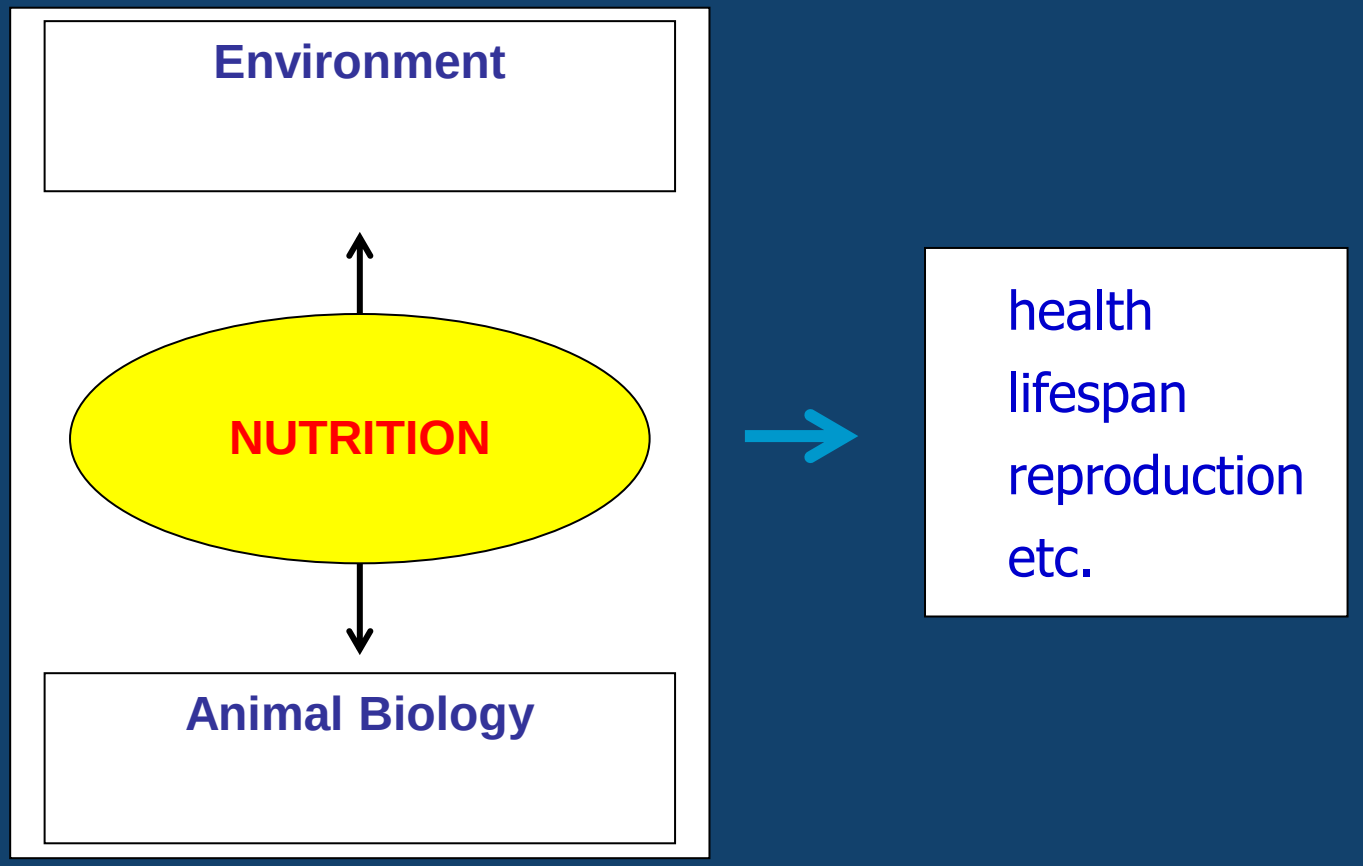
Evolution not Revolution: what can we learn about human health from nutritional ecology?

David Raubenheimer
Leonard P Ullman Chair of Nutritional Ecology
Faculty of Vet Science | School of Biological Science | Charles Perkins Centre

Nutritional Ecology is ….

- Ecological / evolutionary approach to nutrition

  - focus on how nutrition mediates the relationship between animal & environment

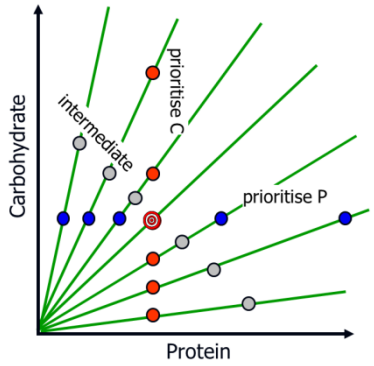


  - to determine health and wellbeing

Aims for the talk

- Introduce Nutritional Geometry: approach for studying these interactions
- Show how it has been used to understand:

NUTRITIONAL GEOMETRY



Environment

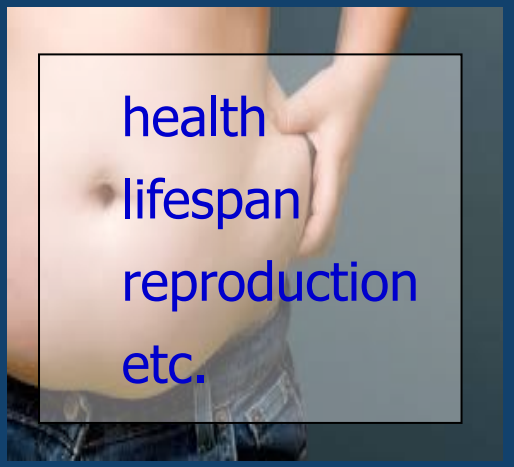
MODERN FOODS

NUTRITION

Animal Biology

HUMAN APPETITE

OBESITY



1) Obesity: a not so obvious question

2) Nutritional geometry

3) Stepping back in time: wild apes

4) Humans

5) Closer look at our environment

6) A closer look at human biology

1. Way back ....

- Luxuries
  - honey
  - tubers

- fruit

- Staples
  - lean meat
  - low GI vegetables

- Diet
  - high protein (25–30%)

(picture credits: Wikipedia)

2. Agriculture

- Grains
  - high starch

- Domesticated fruit
  - increased sugar

- Livestock
  - higher fat than game

- Diet
  - reduced % protein

3. Industrial revolution

- Bulk extraction
  - carbs
  - lipid

- Processed foods

- Diet
  - further reduction in % P

Overview

- Problem
  - fats + carbs limiting

- Solution
  - culture lifts limitation

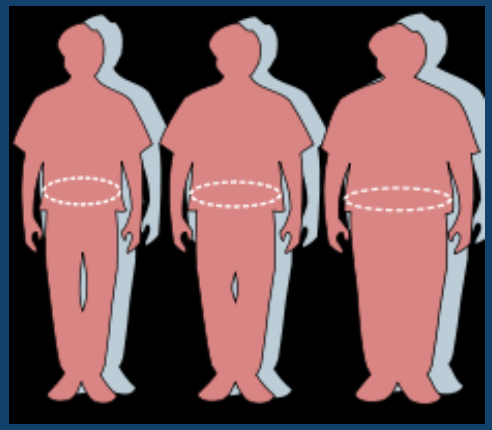
- satisfies appetite

- evolved strong appetite for F+C

- stone age physiology
- modern environment

- New problem

MALADAPTED



The not-so-obvious question

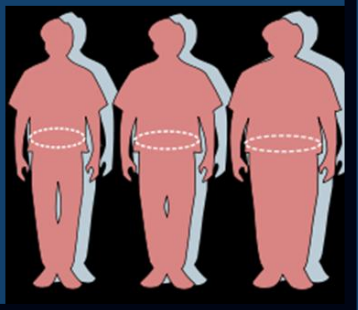
- Problem
  - fats + carbs limiting

  - strong appetite for F+C
  - stone age physiology
- New problem

- Solution
  - culture lifts limitation

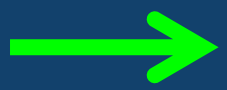
  - modern environment
  - satisfies appetite

MALADAPTED



WHY do we over-eat energy on diets high in fats + carbs?

1) Obesity: a not so obvious question



2) Nutritional geometry

3) Stepping back in time: wild apes

4) Humans

5) Closer look at our environment

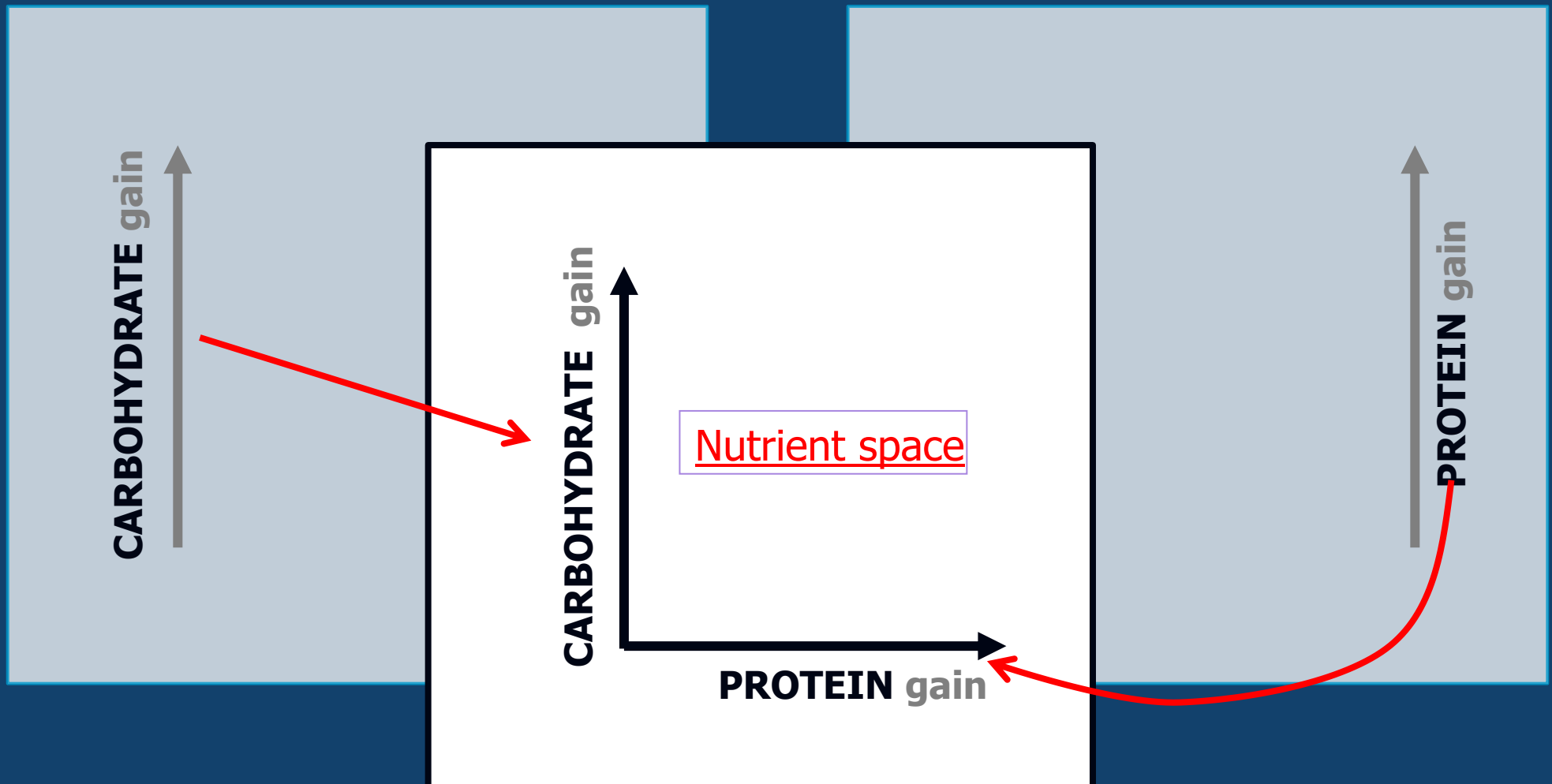
6) A closer look at human biology

What is nutritional geometry?

- models nutrition in terms of: (i) two or more NUTRIENTS

  (ii) their *interactive* effects on animals/humans

- by constructing a multi-dimensional nutrient space



Can then plot in this space:

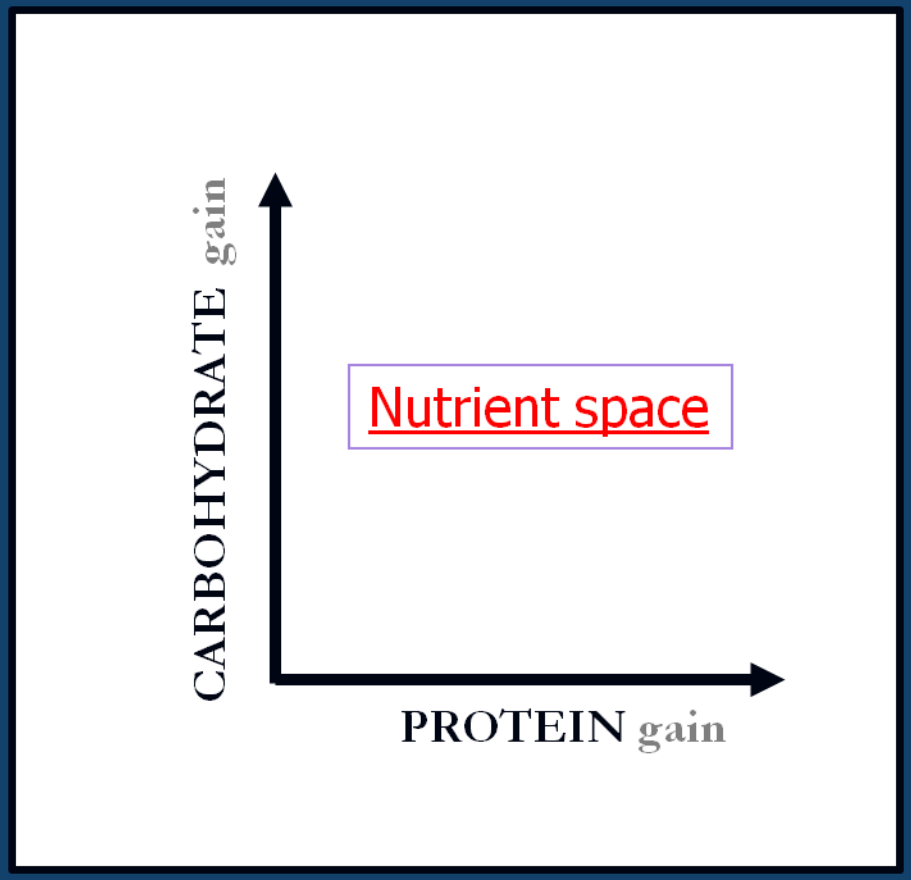
1. Nutrient requirements

2. Foods

3. Feeding

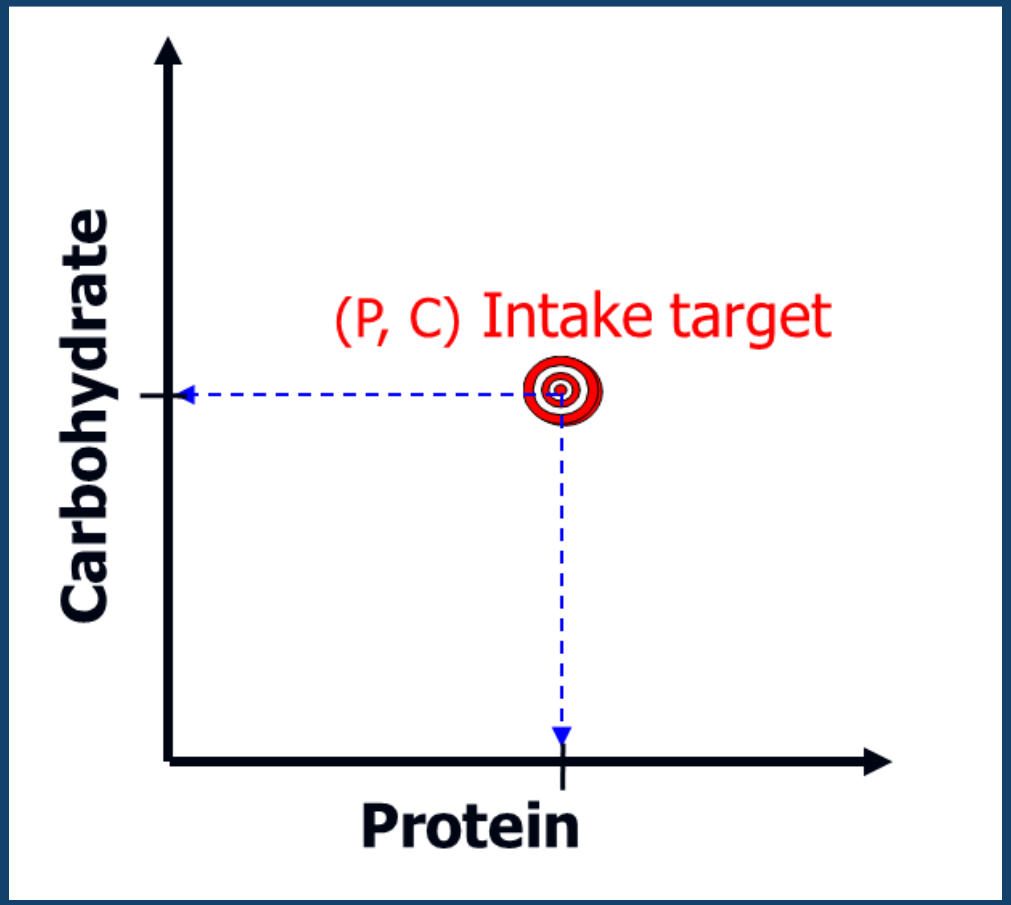
4. Consequences

etc..



- and model the relationships among these

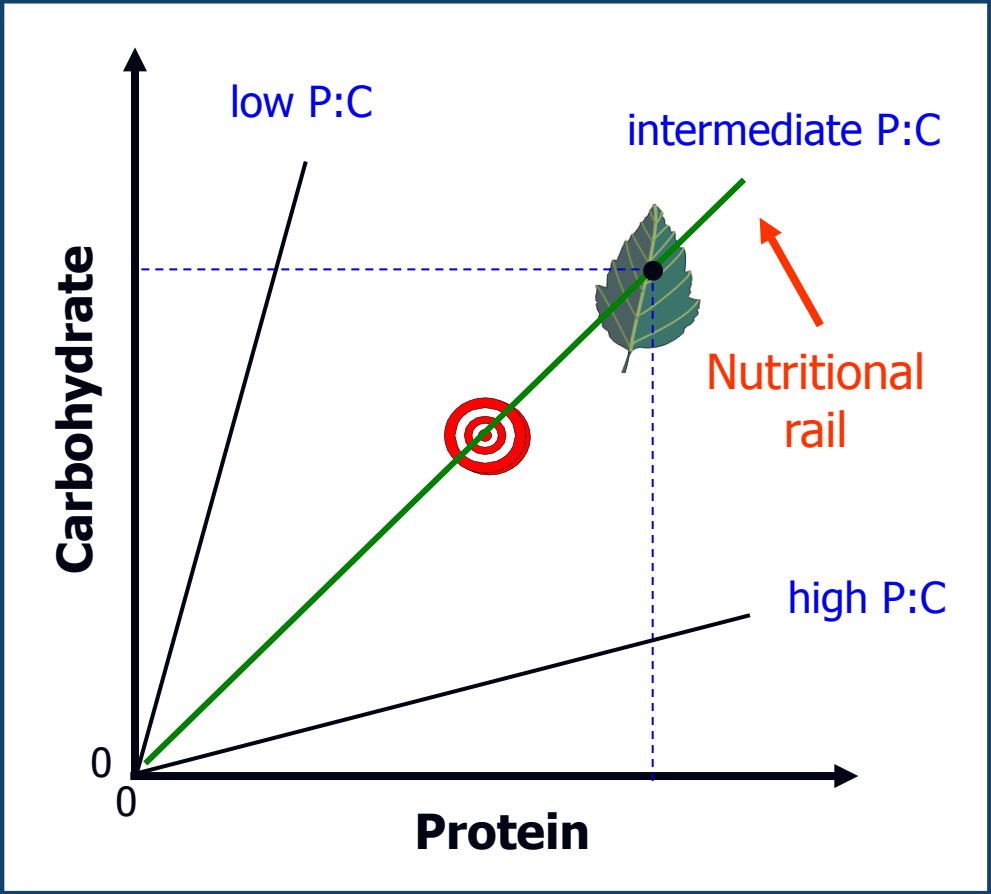
1. Nutrient requirements



2. Foods

i. amount of nutrients

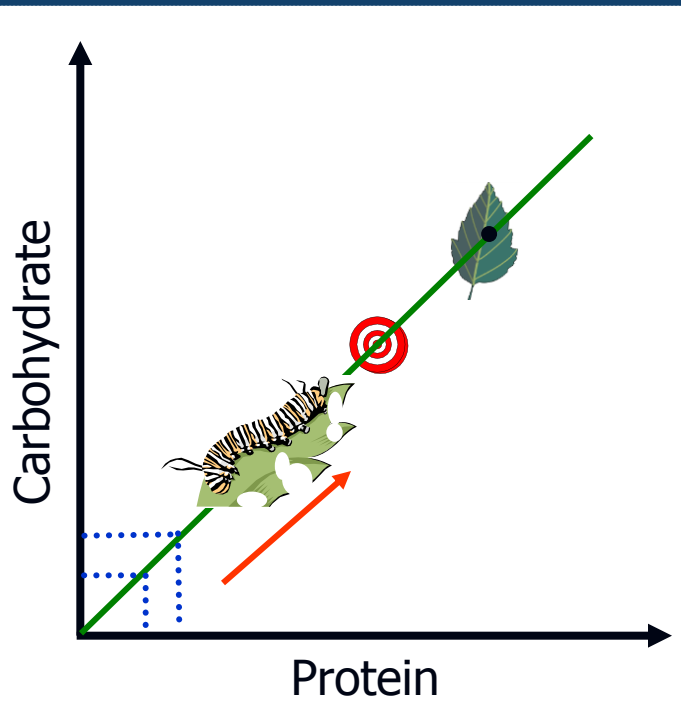
ii. balance of nutrients



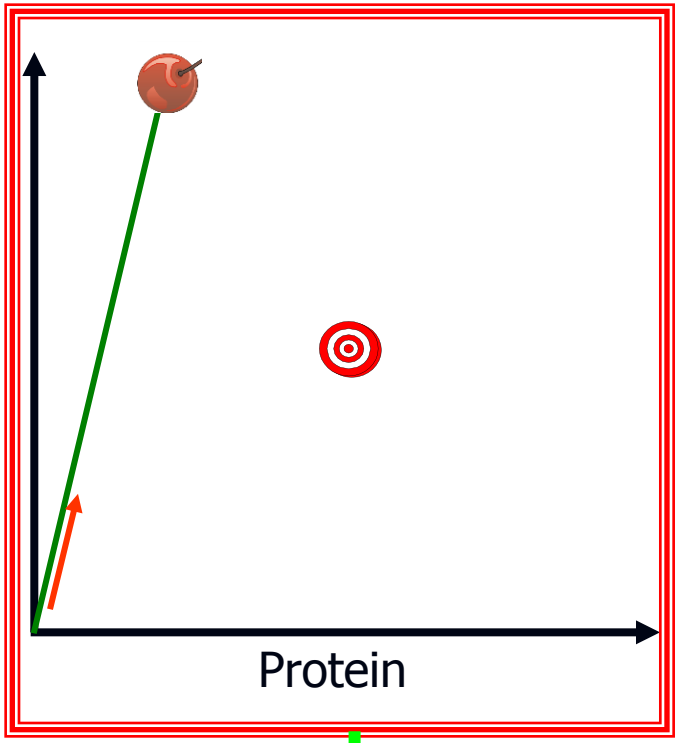
3. Feeding

- the animal gains nutrients in same balance as the food – as it eats, it "moves" along rail

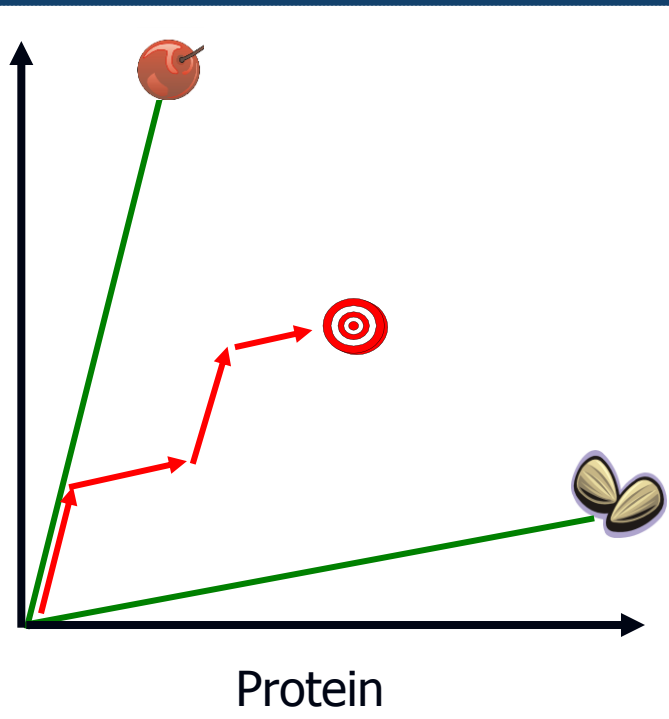
i. balanced



ii. imbalanced

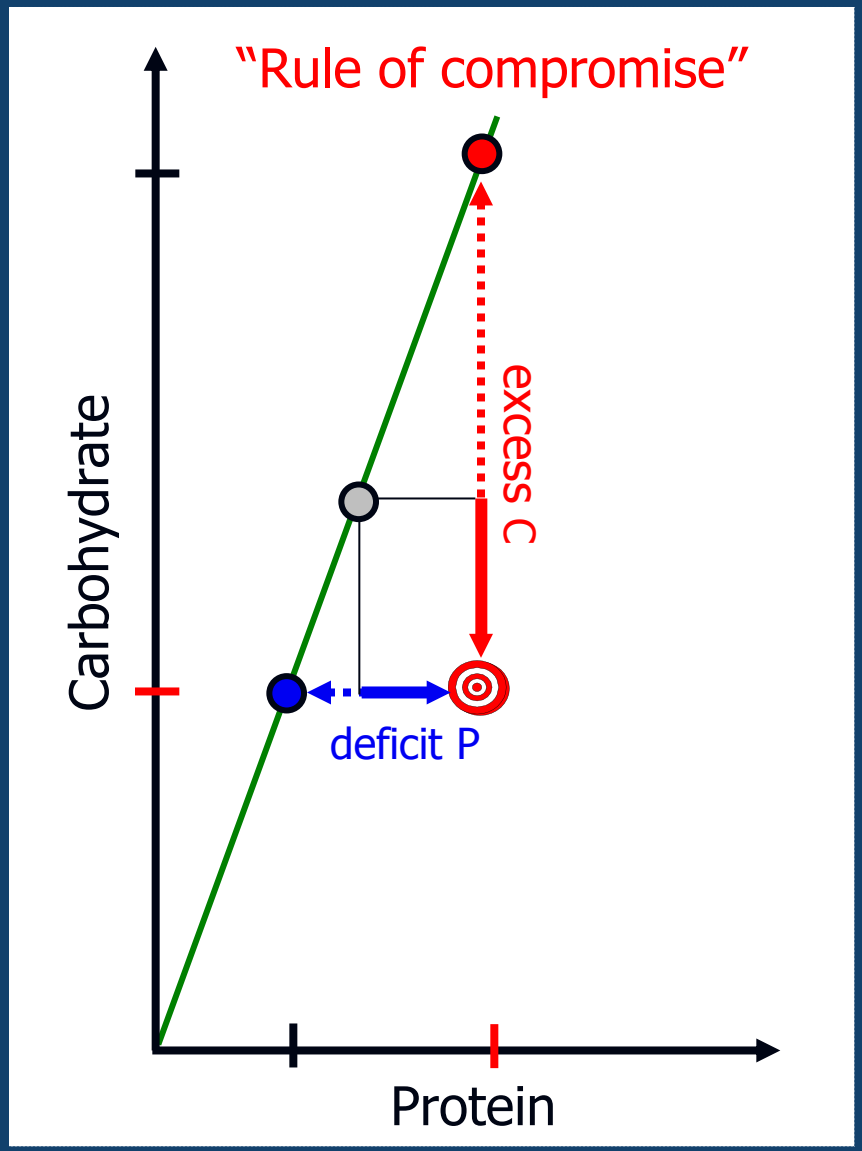


iii. complementary



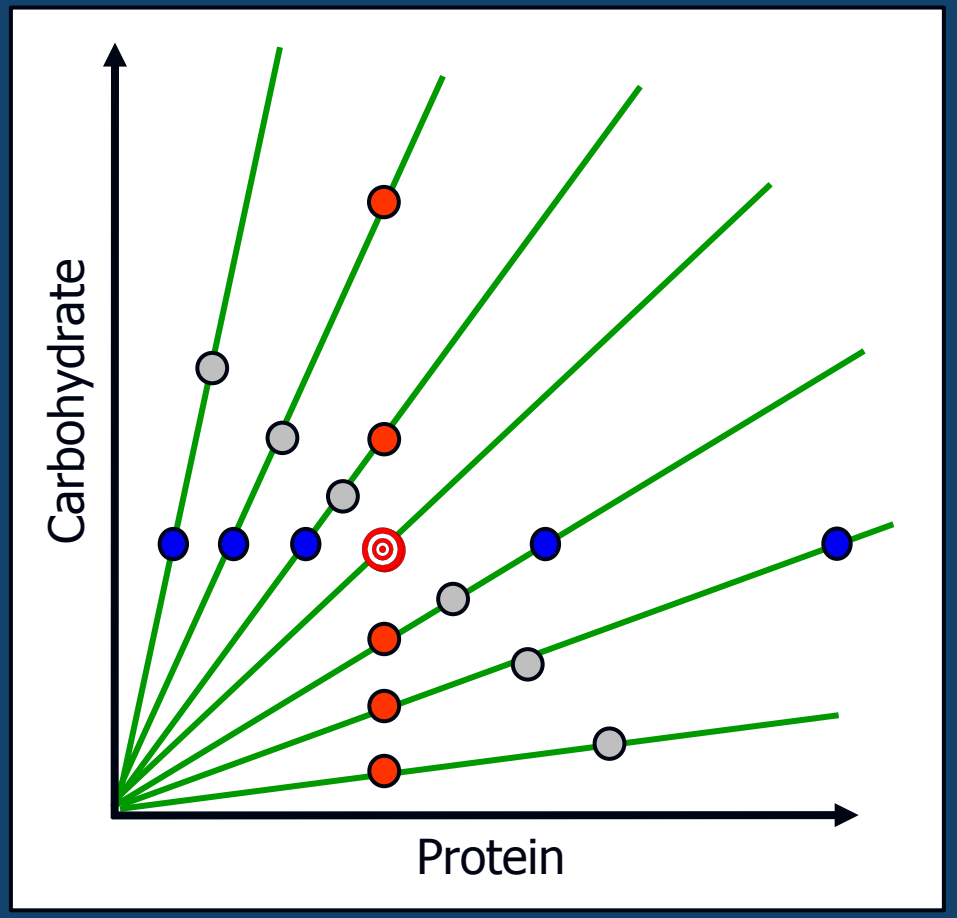
- what are the options?

- there are main 3 options:



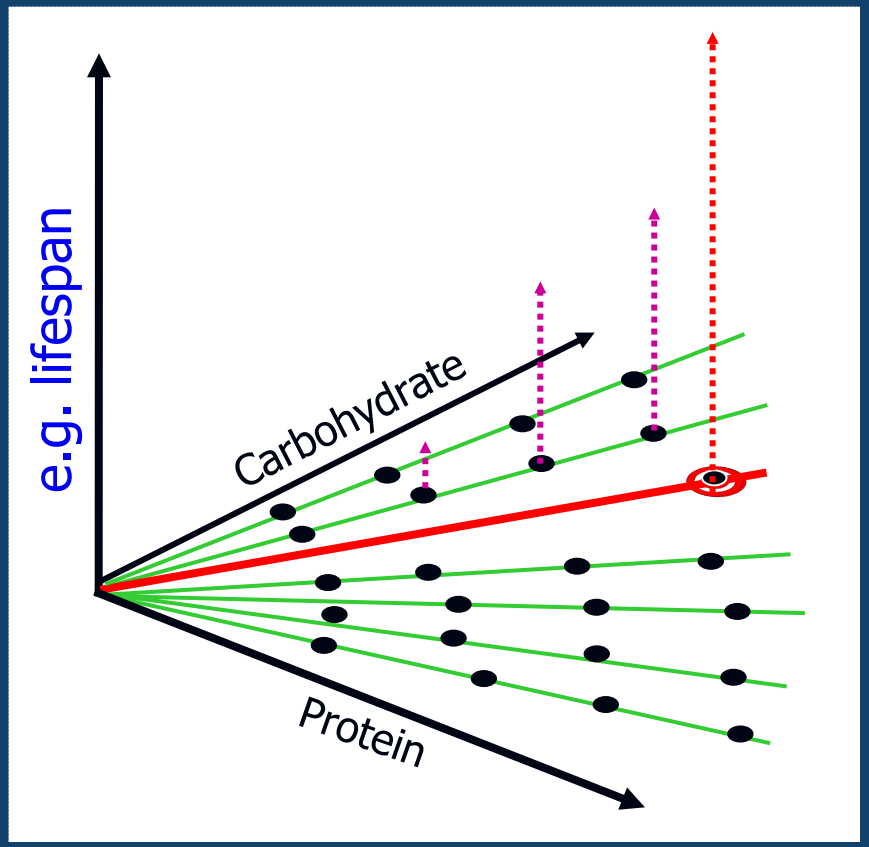
- how to measure the rule of compromise?

- prioritise carbohydrate
- prioritise protein
- some balance of excesses & deficits

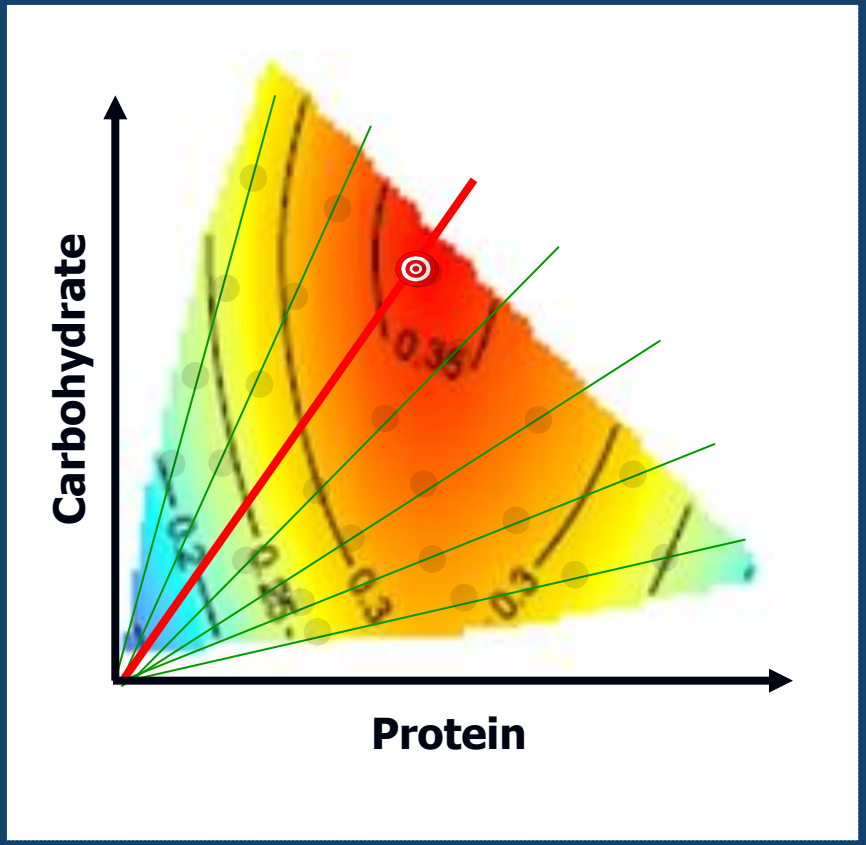


4. Consequences

- response surface



- or contour plot



1) Obesity: a not so obvious question

2) Nutritional geometry

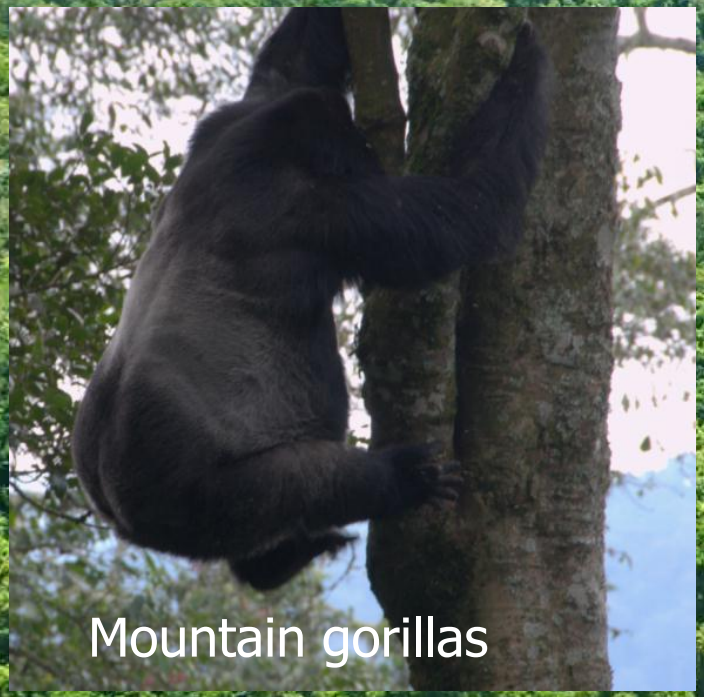
→ 3) Stepping back in time: wild apes

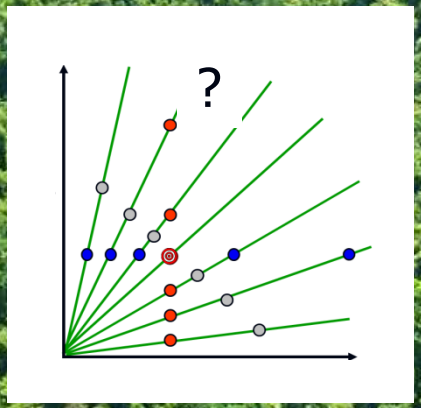
4) Humans

5) Closer look at our environment

6) A closer look at human biology

How do they prioritise macronutrient intake?





1. Mountain gorillas

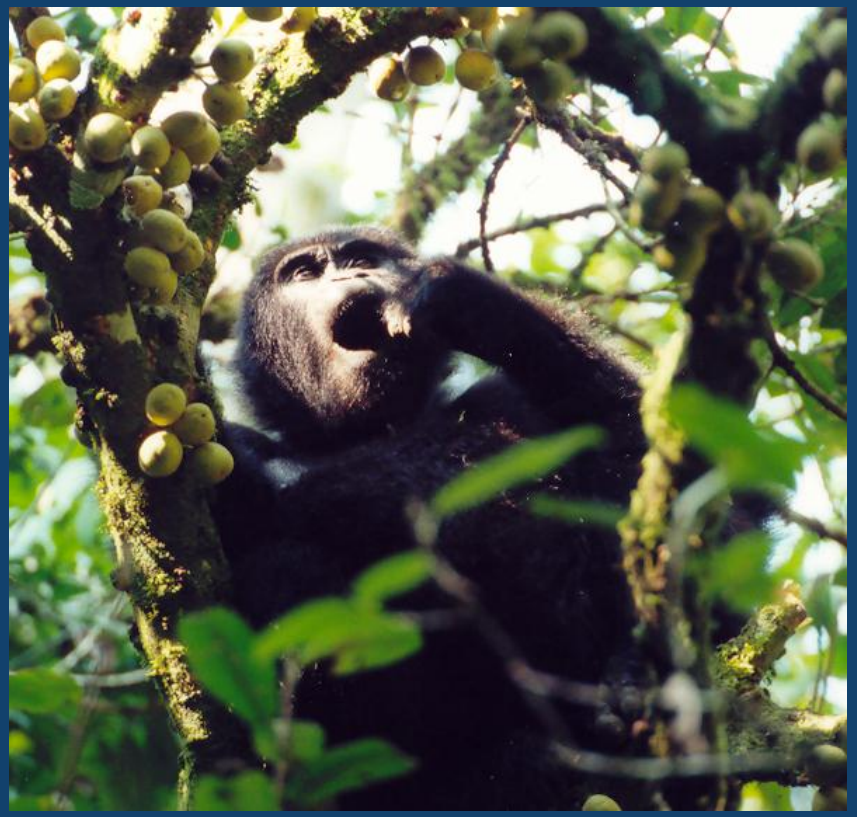
Method

- Direct observations
- Record:
    - i. what is eaten
    - ii. how much
    - iii. nutrient content

- Analyse data using nutritional geometry

Diet

- mainly fruits: 4 months



- low % protein

- mainly leaves: 8 months

- high % protein

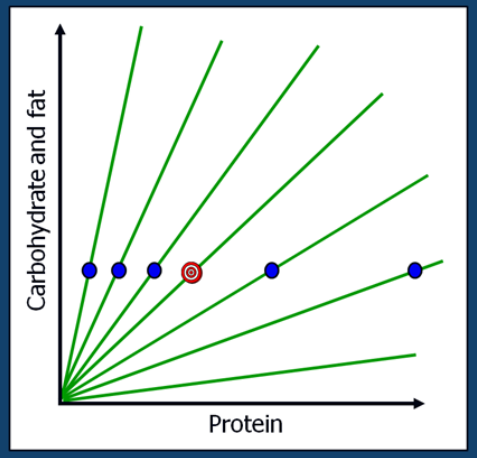
Results

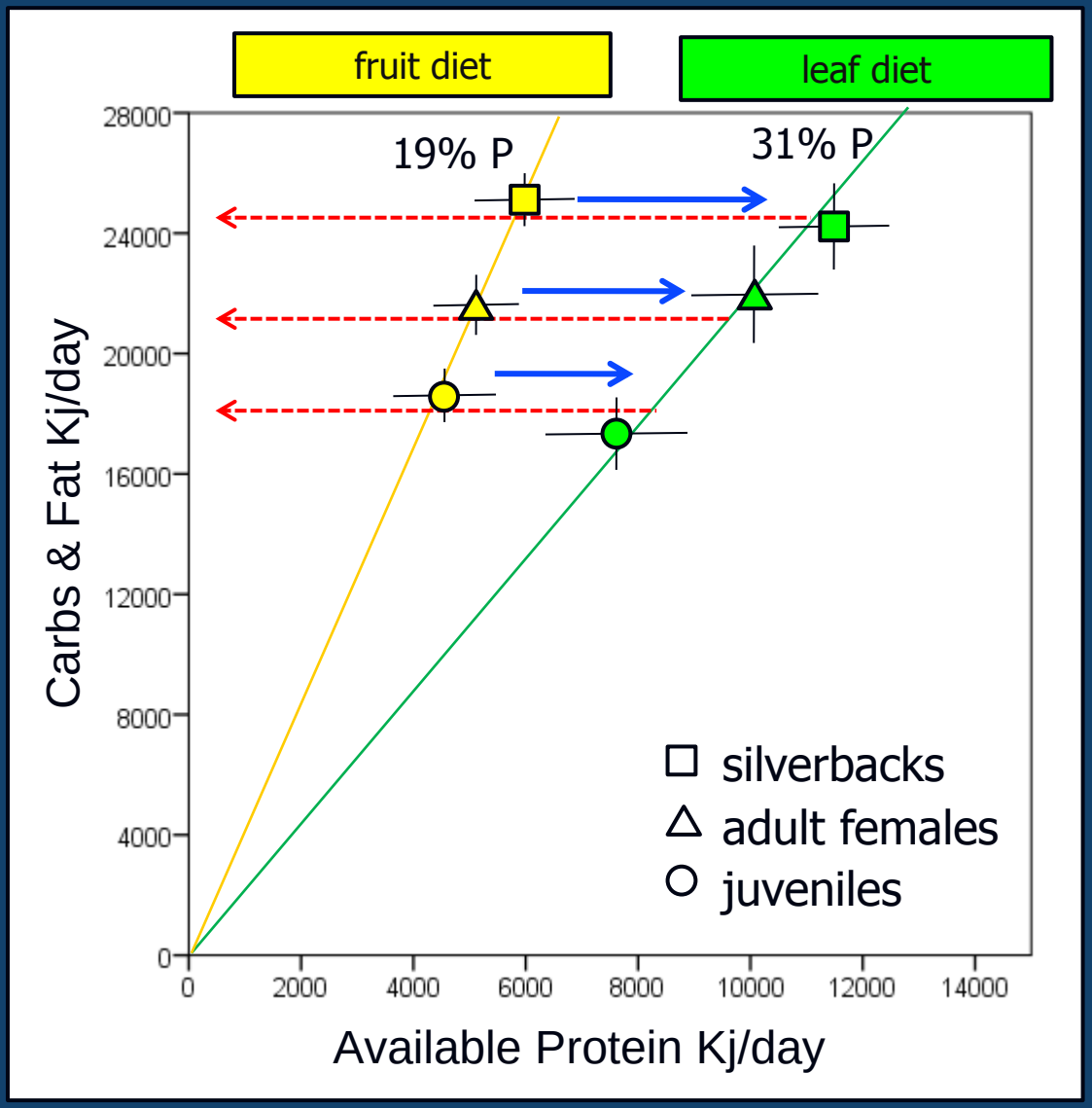
- Fruit diet: 19% P
- Leaf diet: 31% P
- Rule of compromise

  i. regulated to target Carb + Fat intake

  ii. to do so, over-ate P

- i.e. prioritise non-P energy

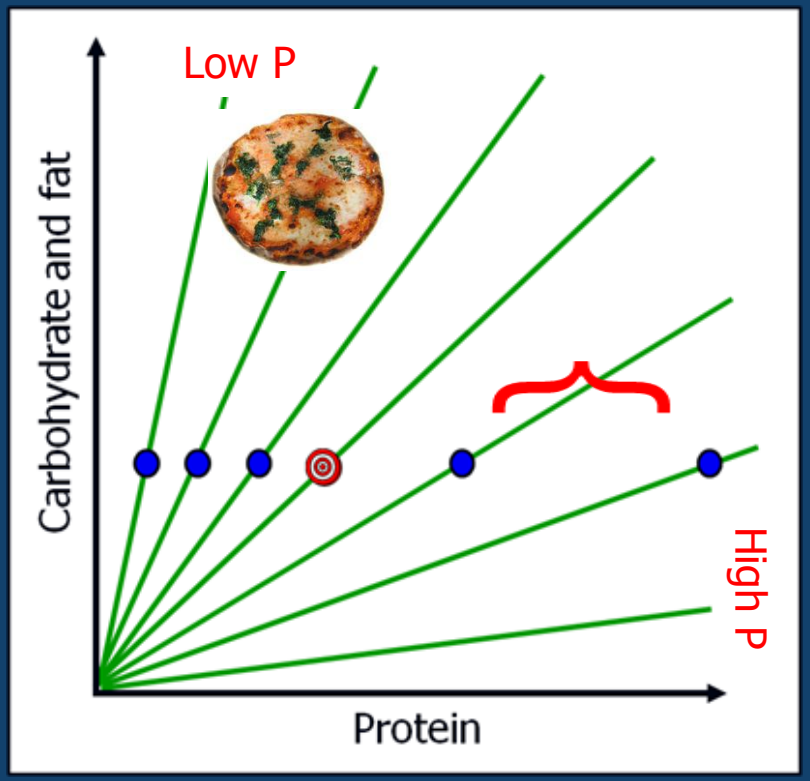




Biology Letters 2011 7:847-849.

Closer look at what it means

- Similar carb + fat intake on all diets
- AND higher P intake on high-P diets
- i.e. Mountain gorillas eat MORE energy on high P diets
- Unlikely to get fat in modern human environments

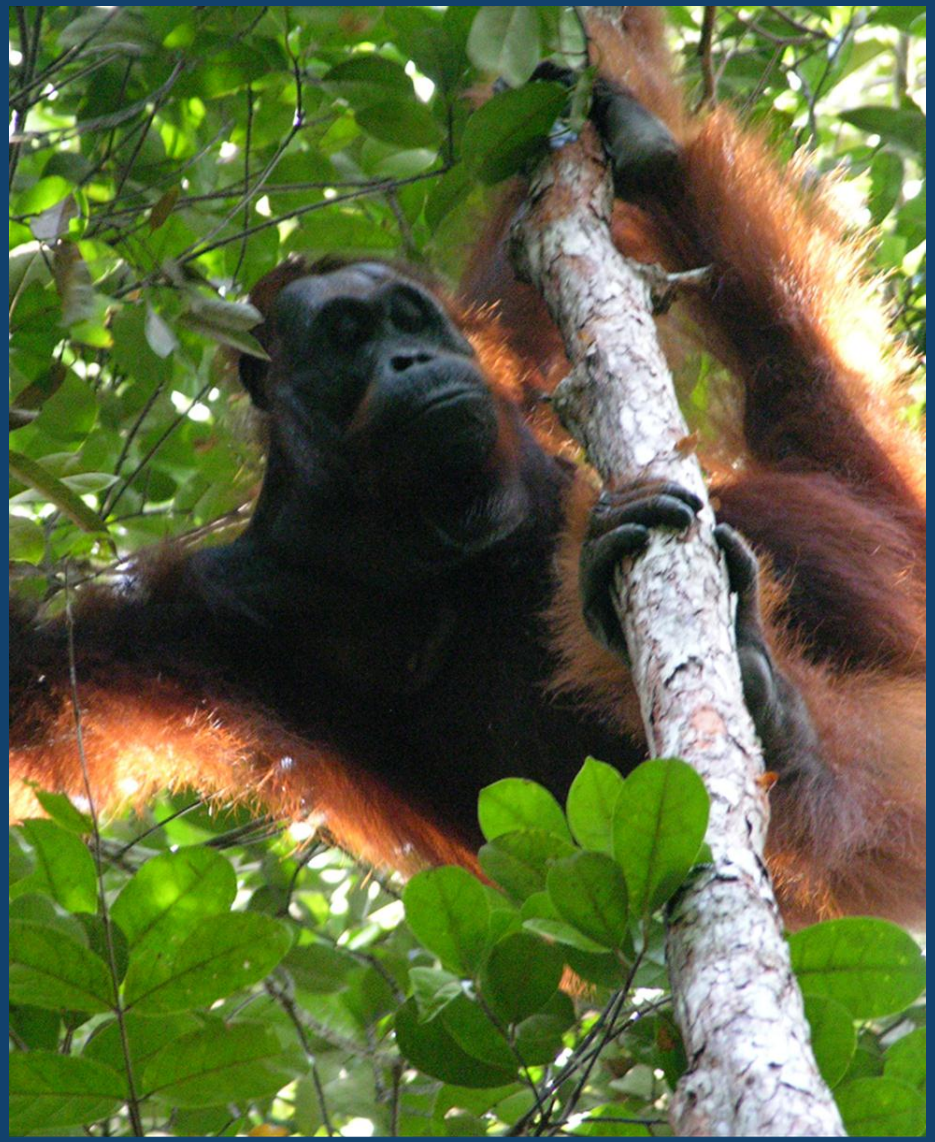


High protein

High fats + carbs

WHY DO WE OVER-EAT ENERGY ON DIETS HIGH IN FATS + CARBS?

2. Orangutans



Method

- Observations over a 7 year period
- 49 orangs
- 2,233 full day observations
- 49000 hours
- also physiology

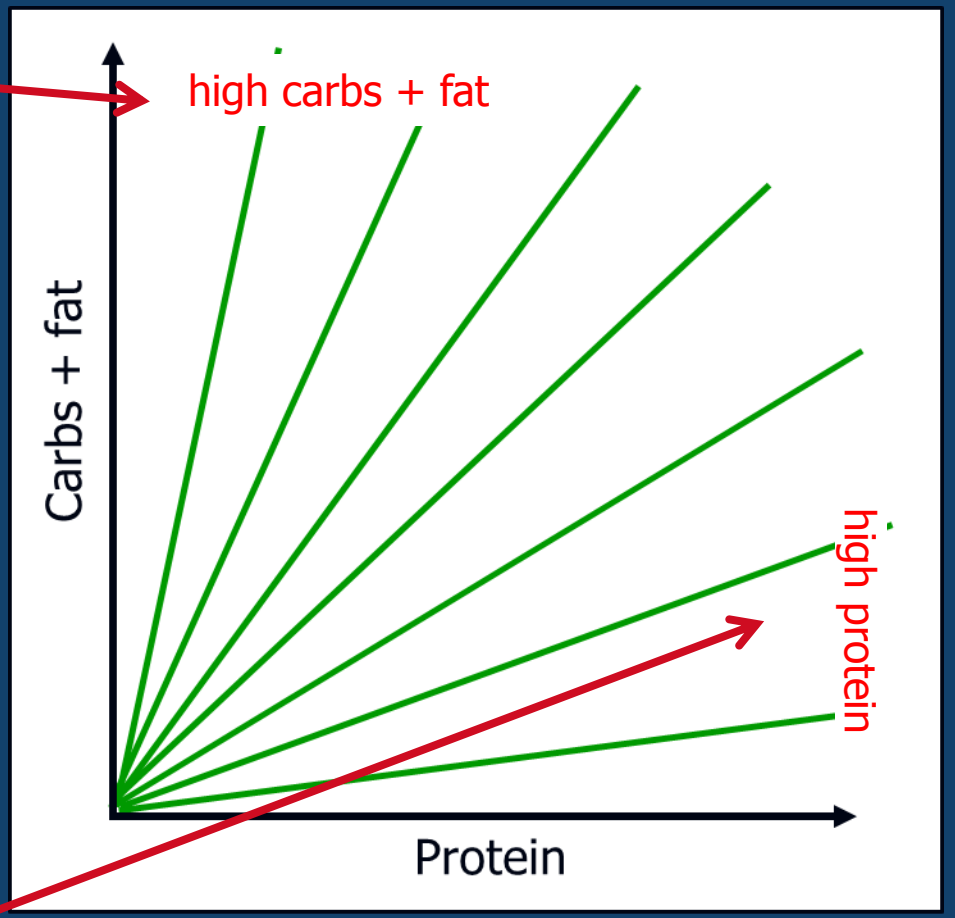
Diet

- Preference
  - fruits: high carbs + fat

  - but availability unpredictable

- So also eat
  - leaves + cambium

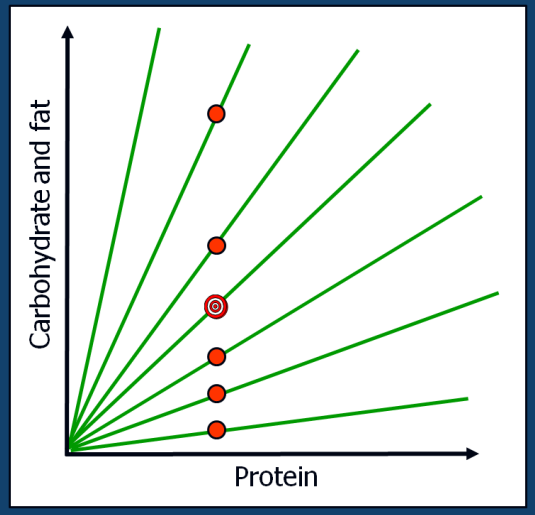
  - high protein

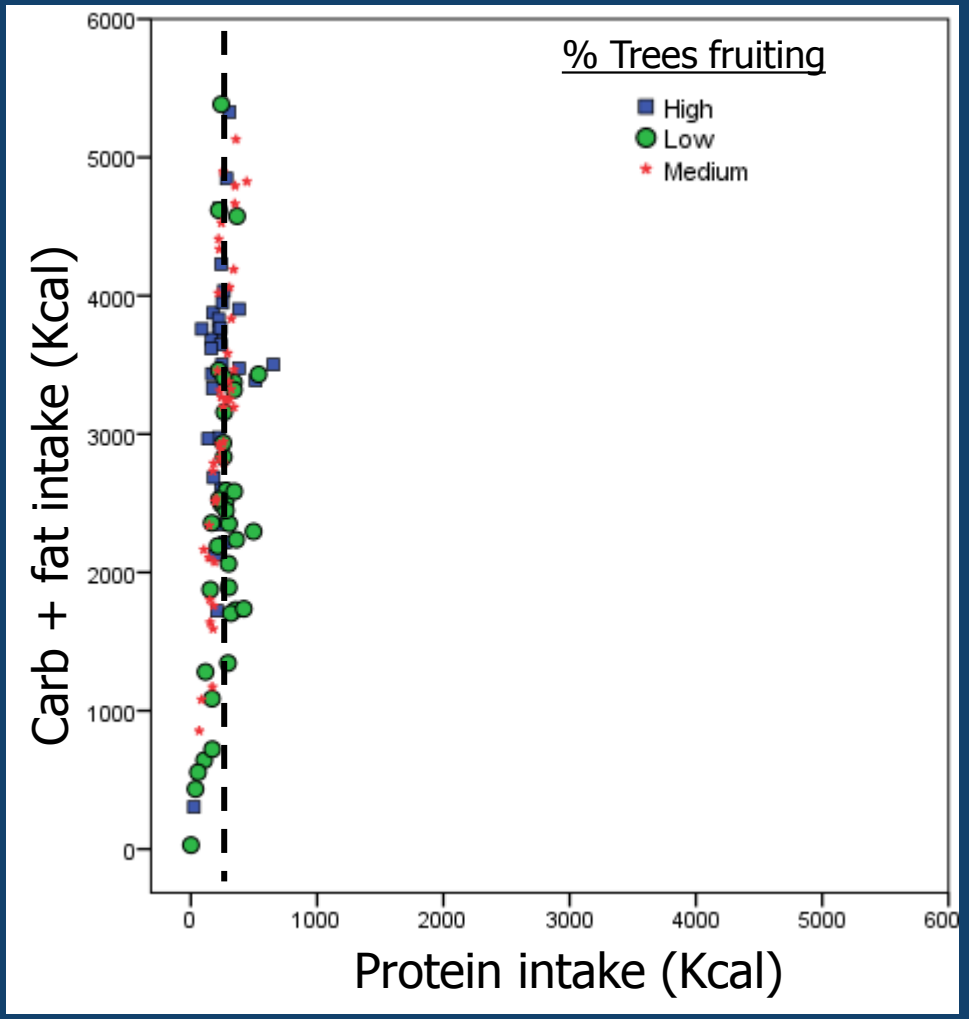


Result

- Wide variation in carb + fat intake
- Tight regulation of protein

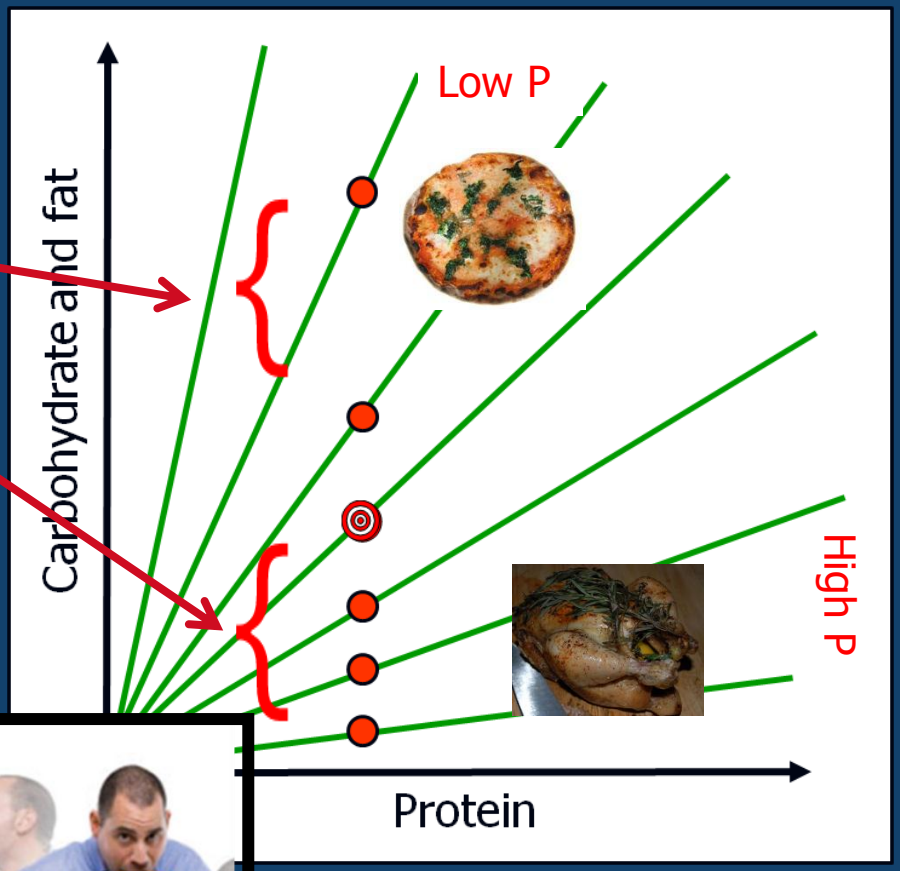
  - i.e. prioritise non-P energy



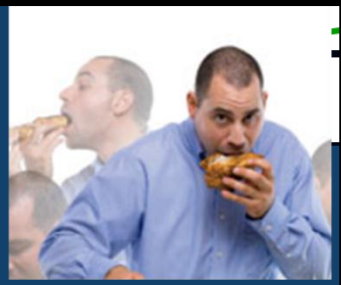


Implications

- Will over-eat fats + carbs on low-P diets
- Or under-eat fats + carbs on high-P diets
- Could the same pattern explain why humans get fat in modern environments?



High protein



High fats + carbs

WHY DO WE OVER-EAT ENERGY ON DIETS HIGH IN FATS + CARBS?

And .....

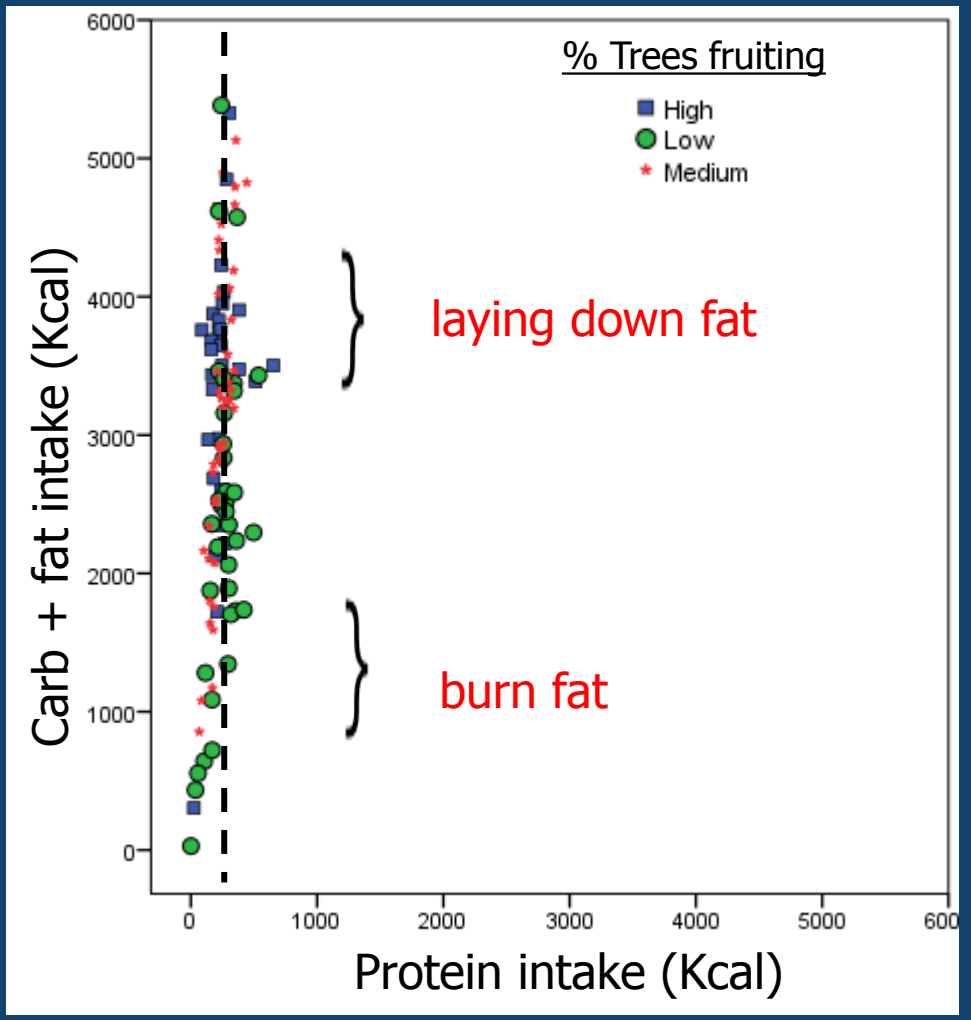
- Physiology tells us

  - lay down fat when energy (fruit) is abundant

  - draw on it when energy is scarce

- i.e. Adapted to "boom and bust" ecology

- As are humans!



1) Obesity: a not so obvious question

2) Nutritional geometry

3) Stepping back in time: wild apes

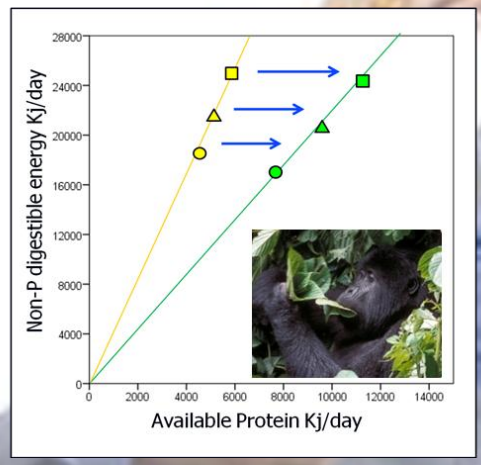
→ 4) Humans

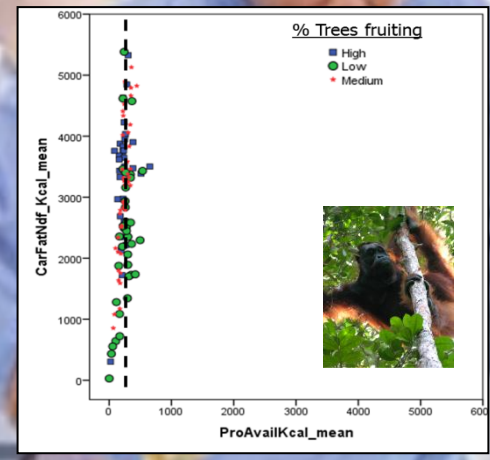
5) Closer look at our environment

6) A closer look at human biology

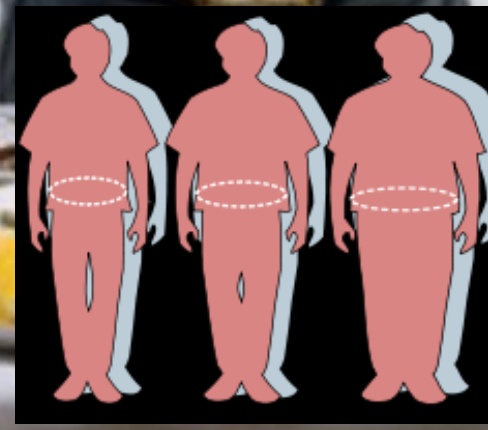
Two Questions:

i. How do we compare with other primates?



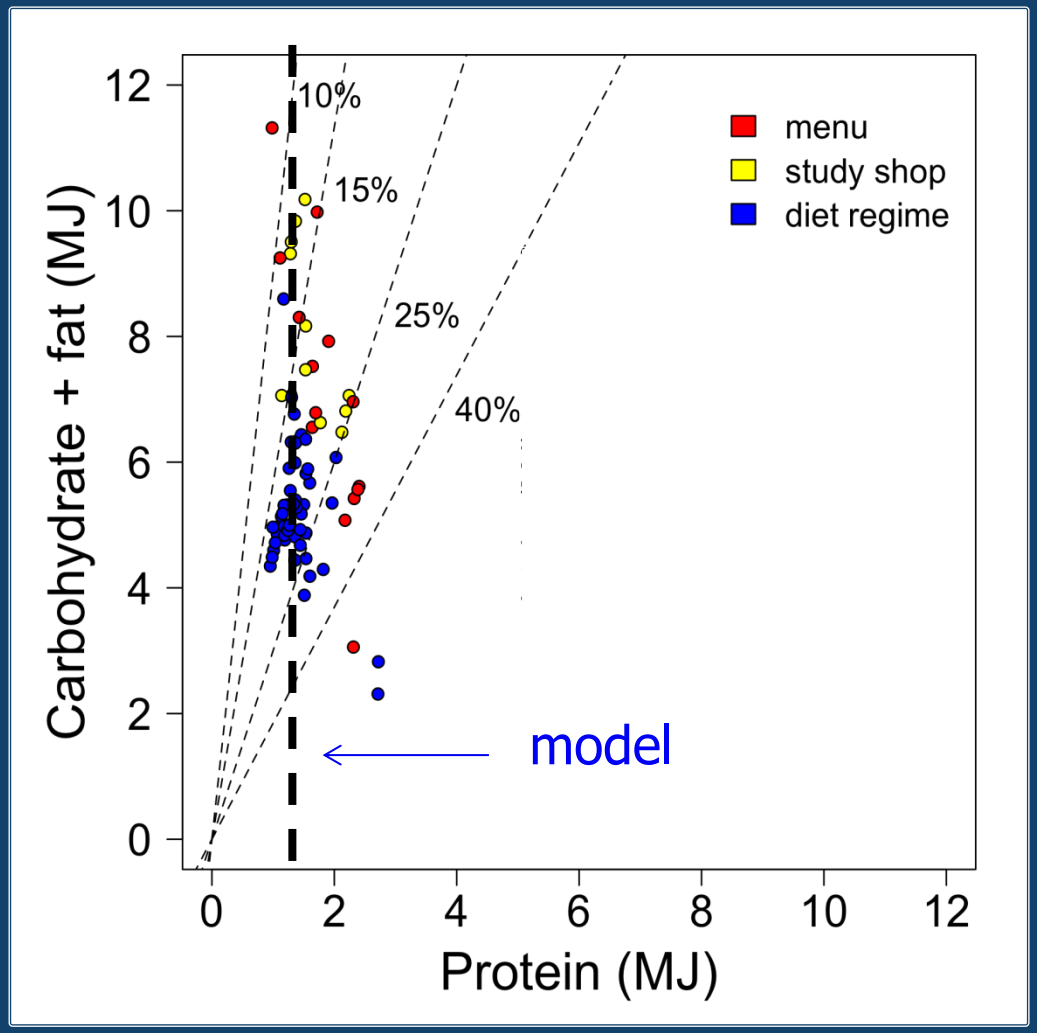


ii. What are the implications for obesity?

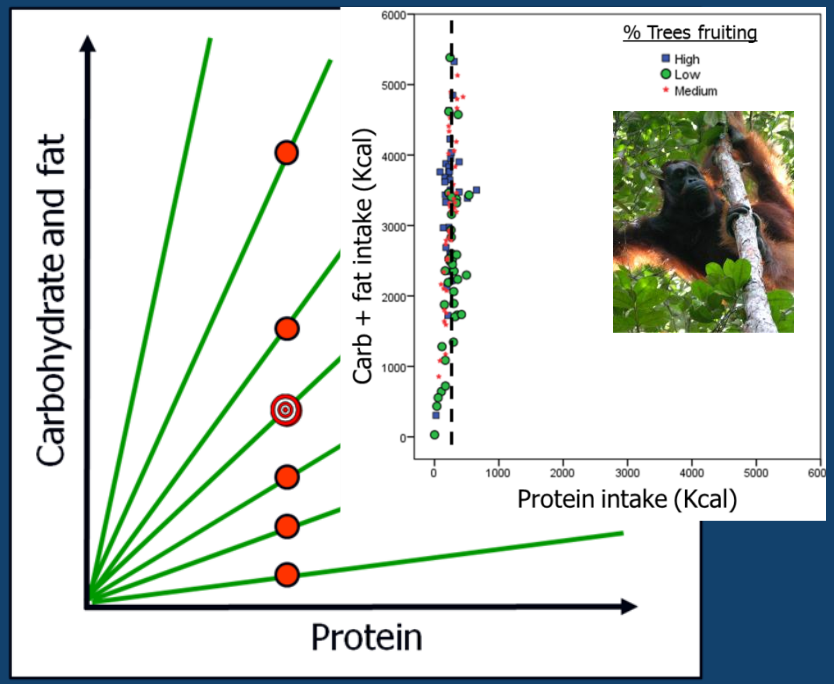


Human macronutrient regulation

- 3 experimental studies: Oxford, Sydney, Jamaica
- Meta analysis: 26 published trials



Alison Gosby



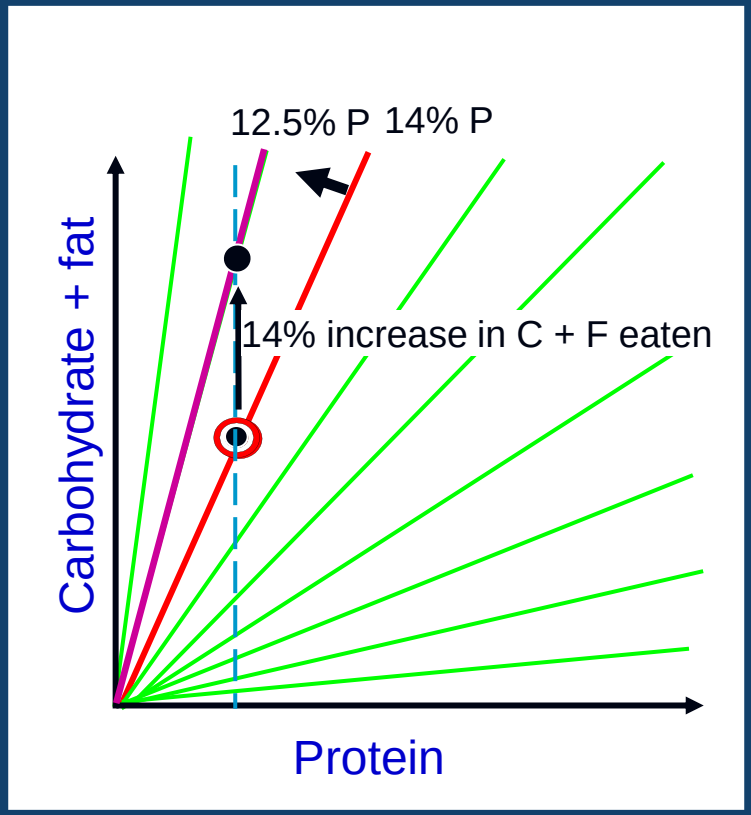
- Prioritise P, like orangs

Gosby et al., Obesity Reviews 2014

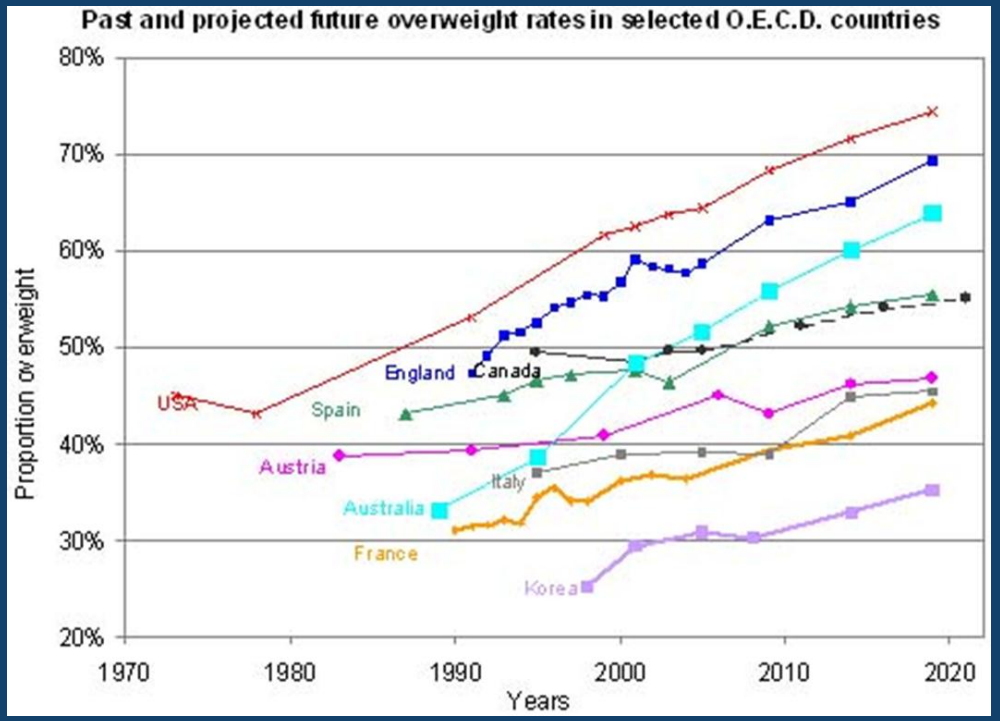
Implications of protein prioritisation for obesity

- A small change in % P in foods will result in a disproportionately large change in the amount Carbs + Fat eaten

- For example, a 1.5% decrease in % P



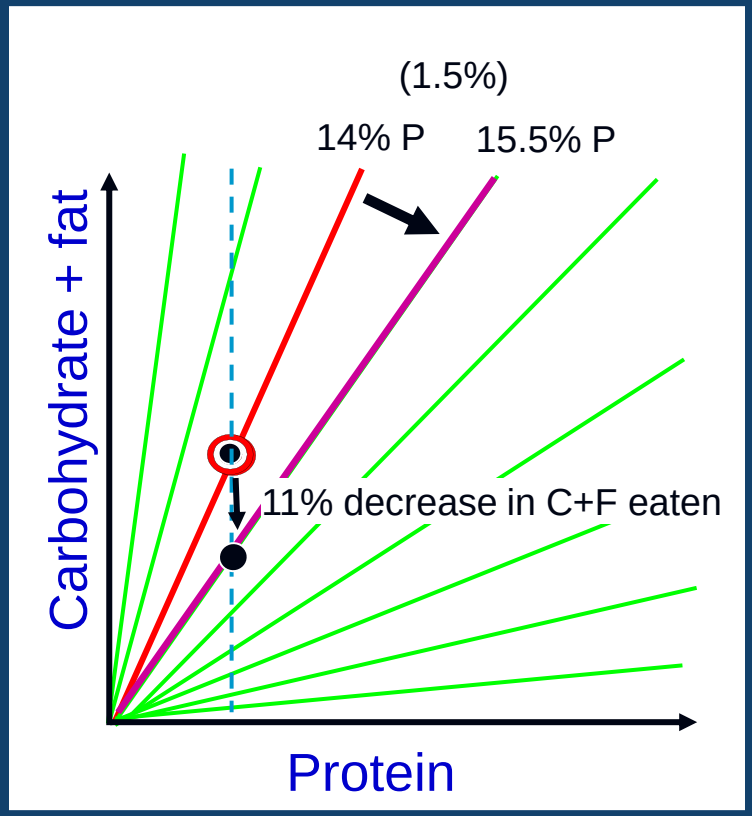
- could this explain the obesity epidemic?

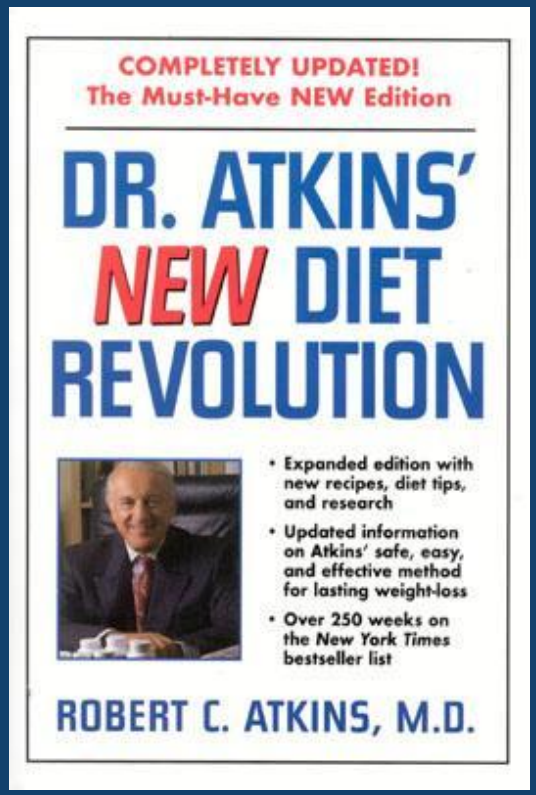


And weight loss …

- a small increase in % protein will result in a large decrease in carbohydrate and fat eaten

- could this explain why high protein weight loss diets work?

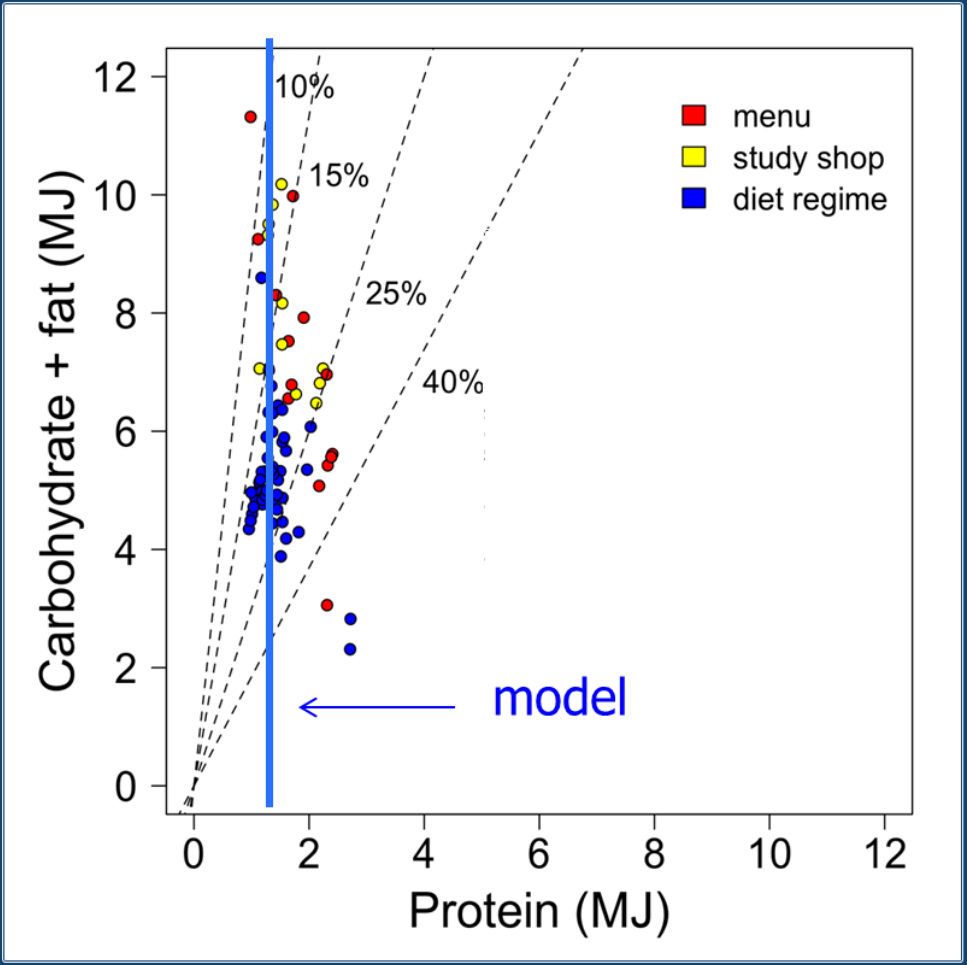


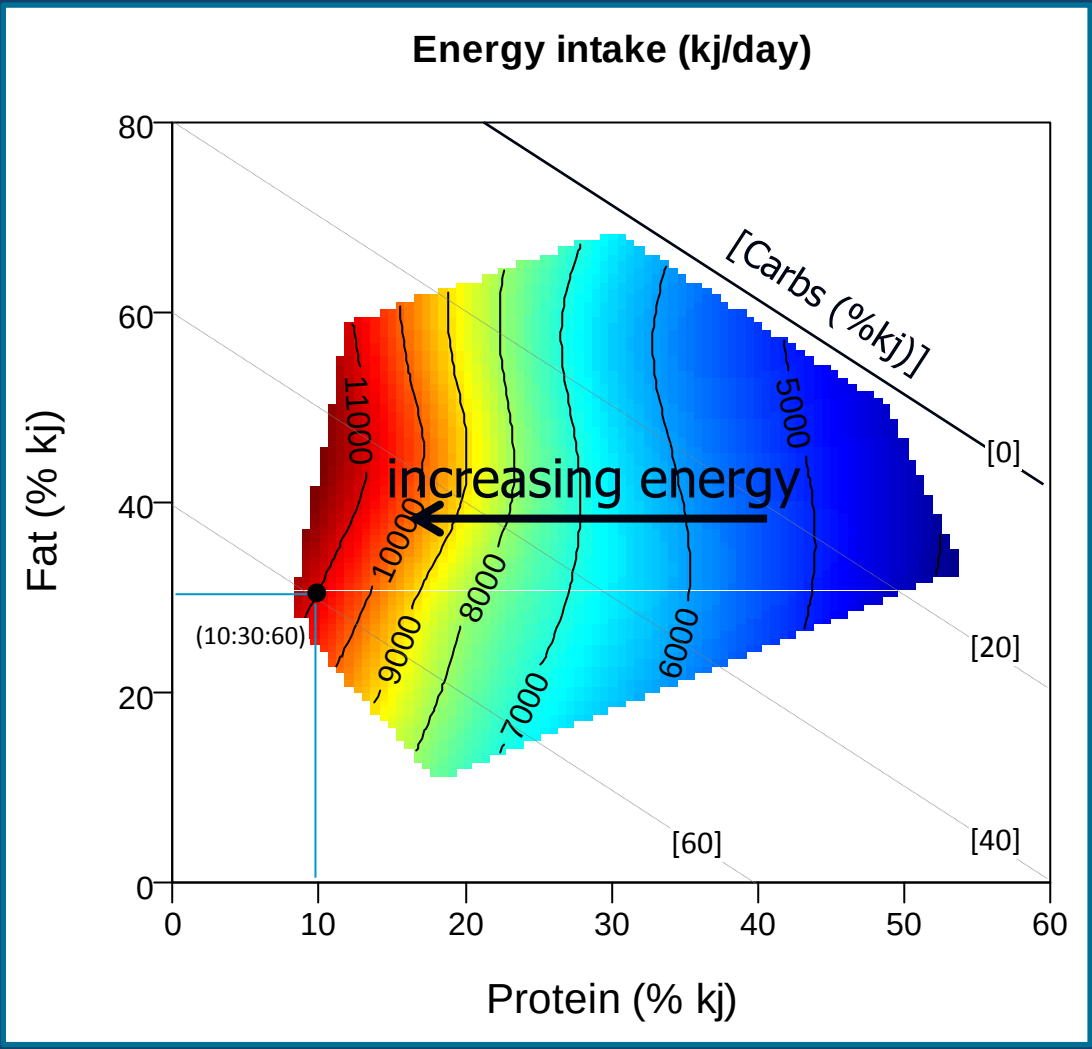


-> Called the "Protein Leverage Hypothesis" (PLH)

Two predictions of PLH

1) Energy intake increases with decreasing %P

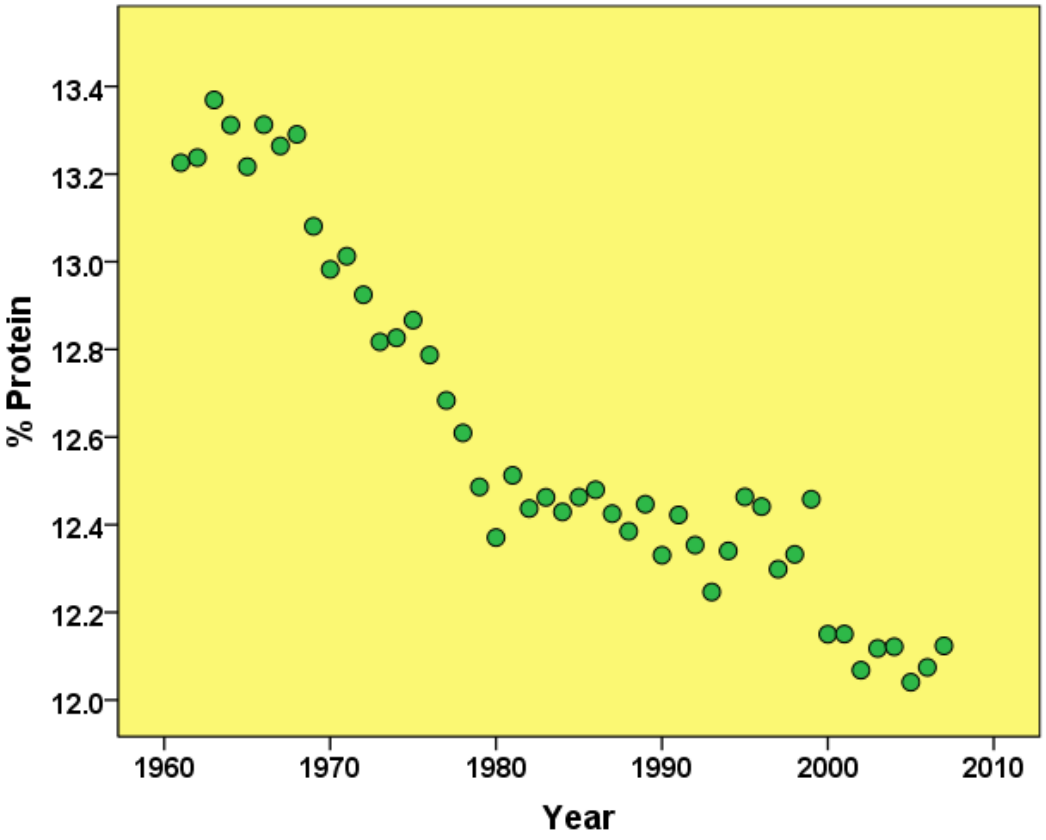


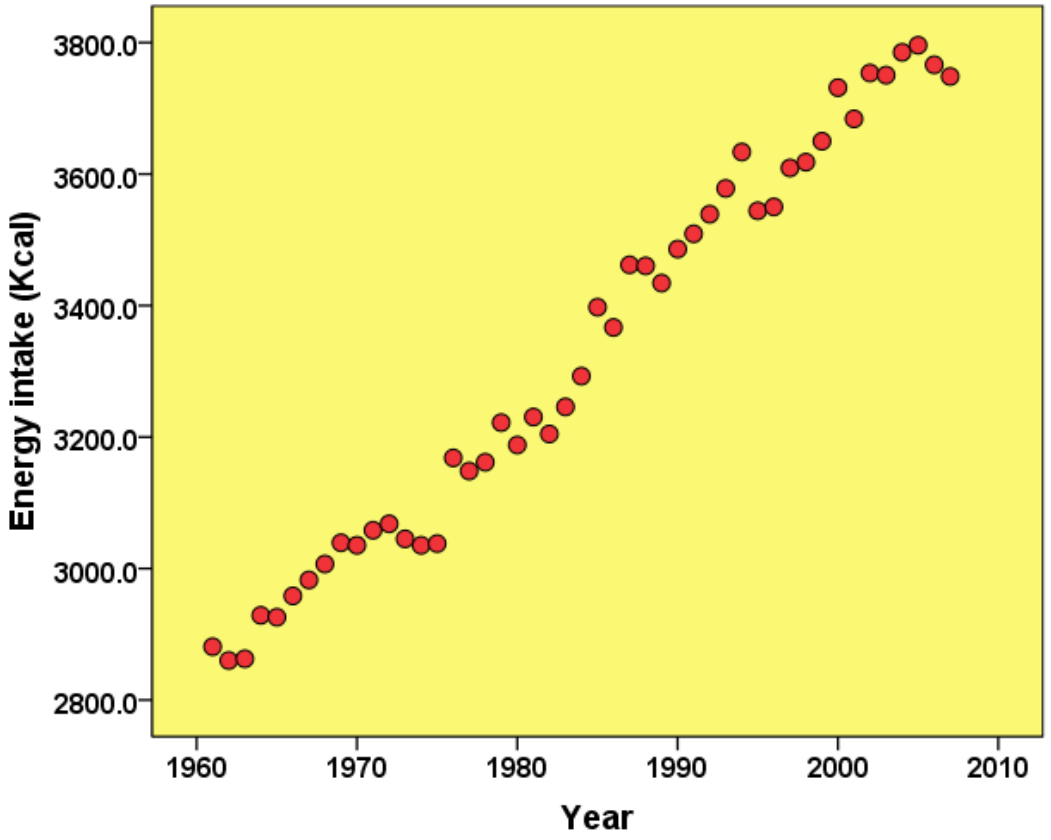


- Yes!

Prediction 2). Dietary % P has decreased with the rise in obesity

- e.g. USA





- yes!

Data: FAOSTAT 2010

1) Obesity: a not so obvious question

2) Nutritional geometry

3) Stepping back in time: wild apes

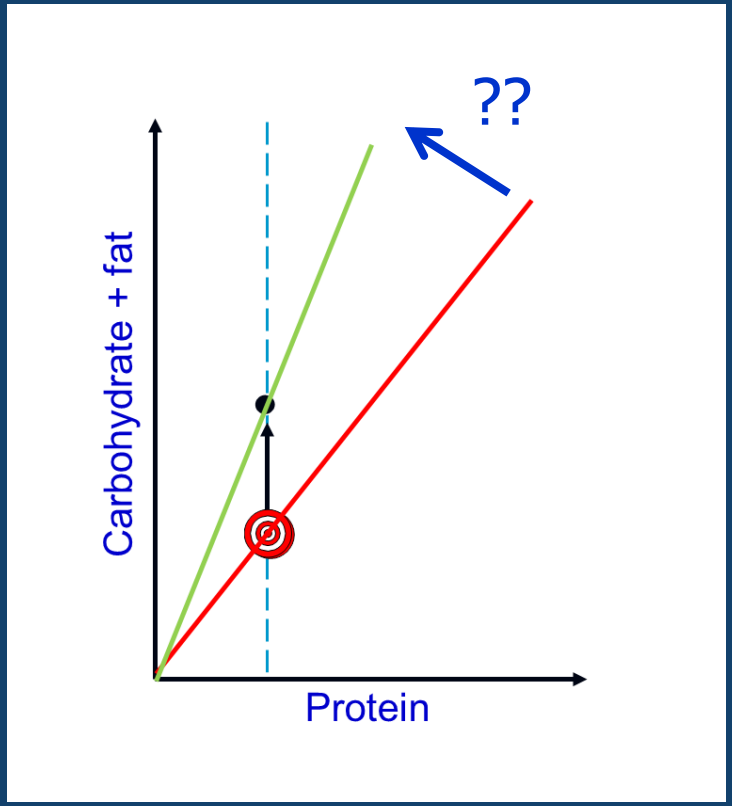
4) Humans

→ 5) Closer look at our environment

6) A closer look at human biology

The general question

- PLH suggests that because humans prioritise P, energy intake will be higher on low-P diets

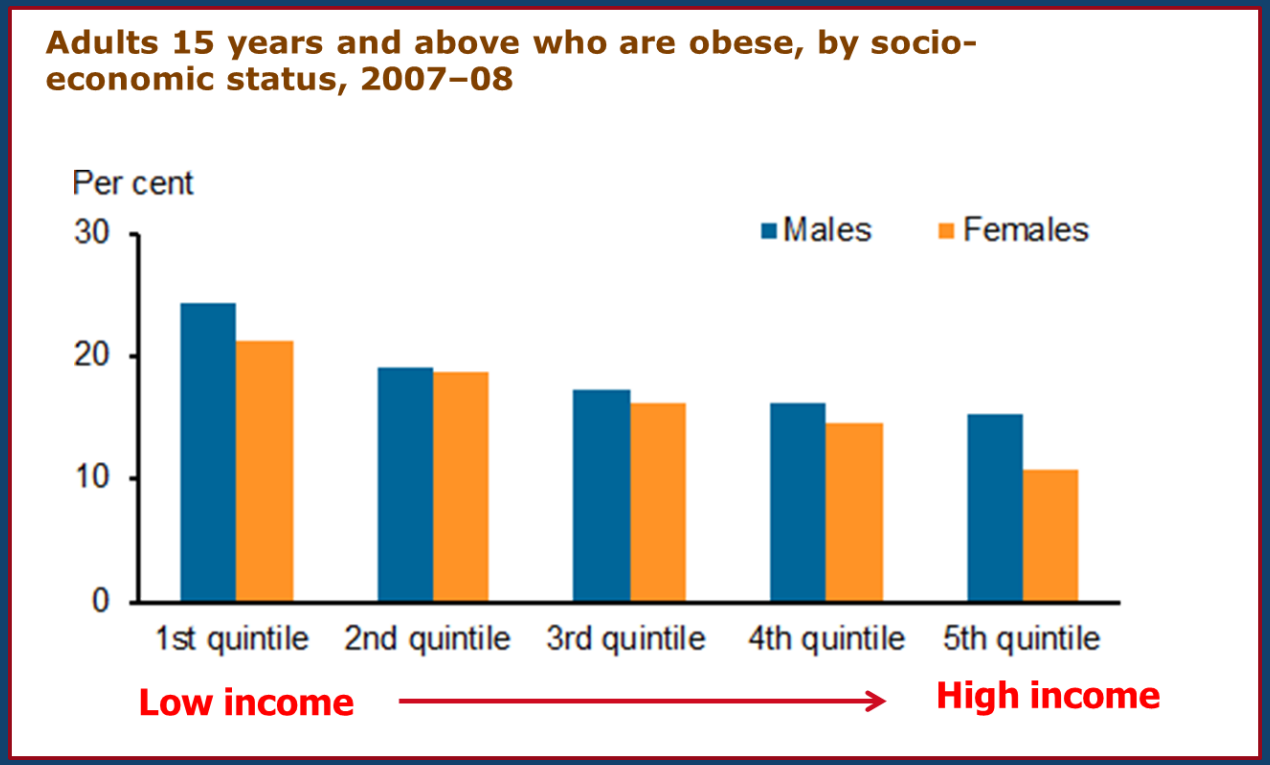


- *What changes in the environment cause the shift to low-P diets?*

A Role for Economic$

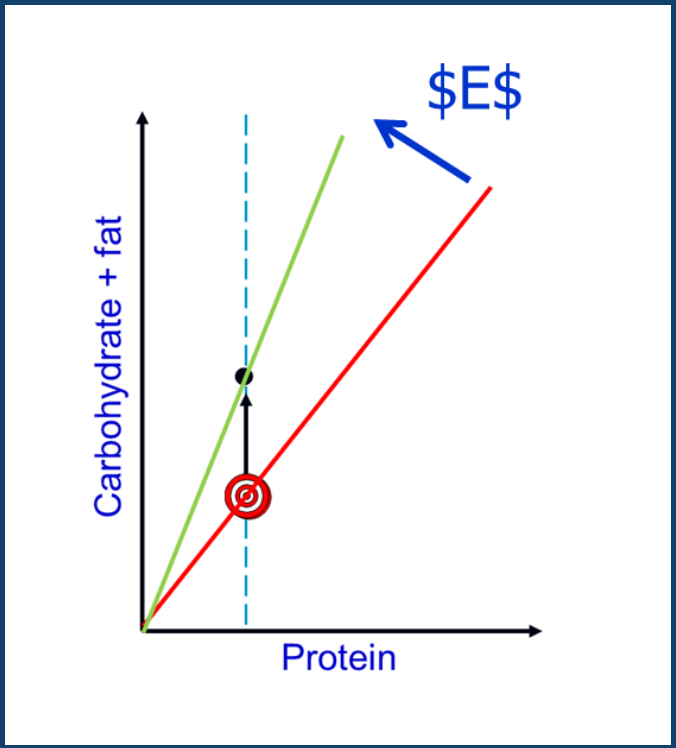
- A clue that economics is involved:

  - obesity is more common among low SES groups



Source: Australian Institute of Health and Welfare

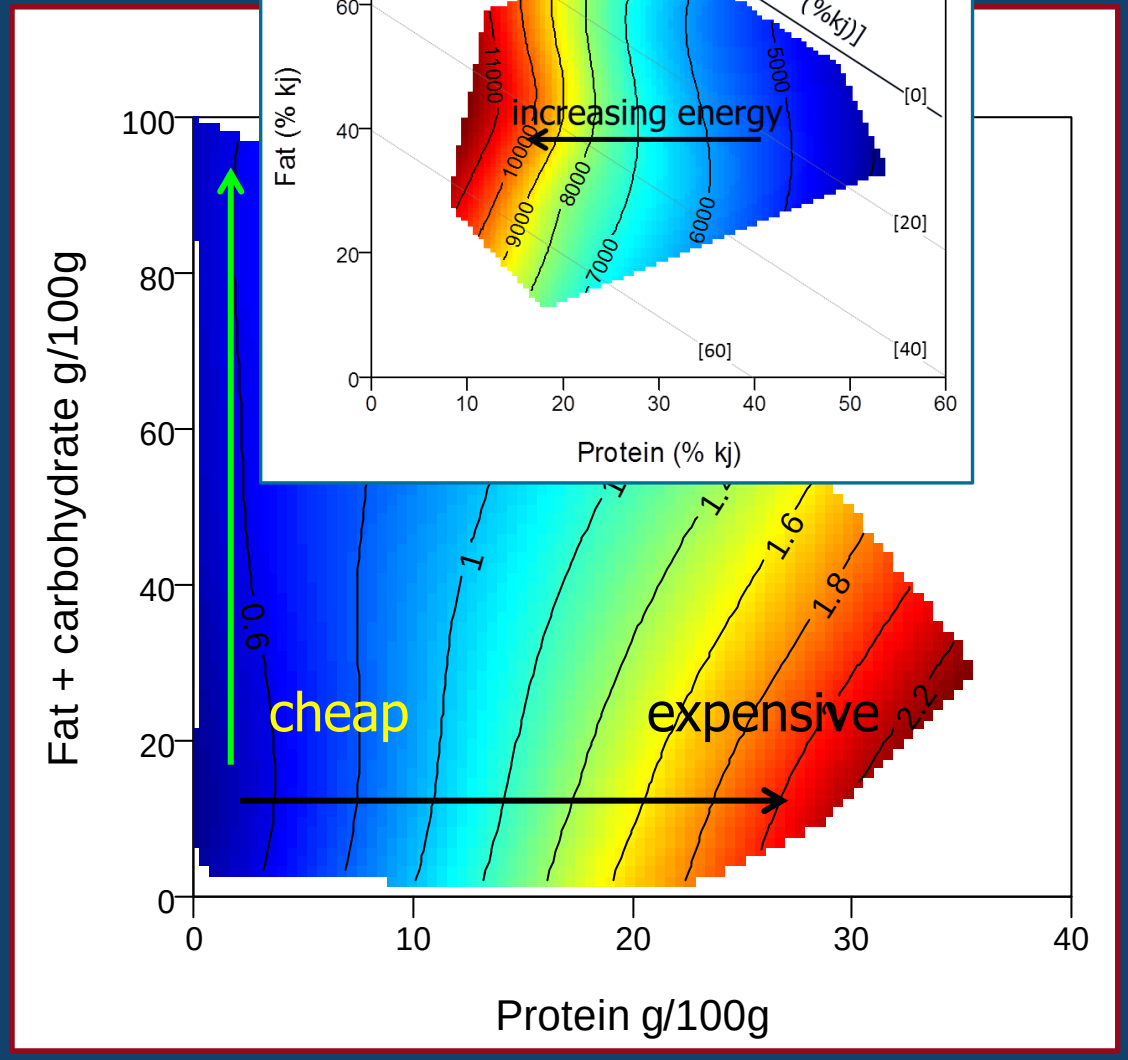
- *Is this related to variation in dietary % protein?*



Three predictions

1) Protein is more expensive than fats and carbs

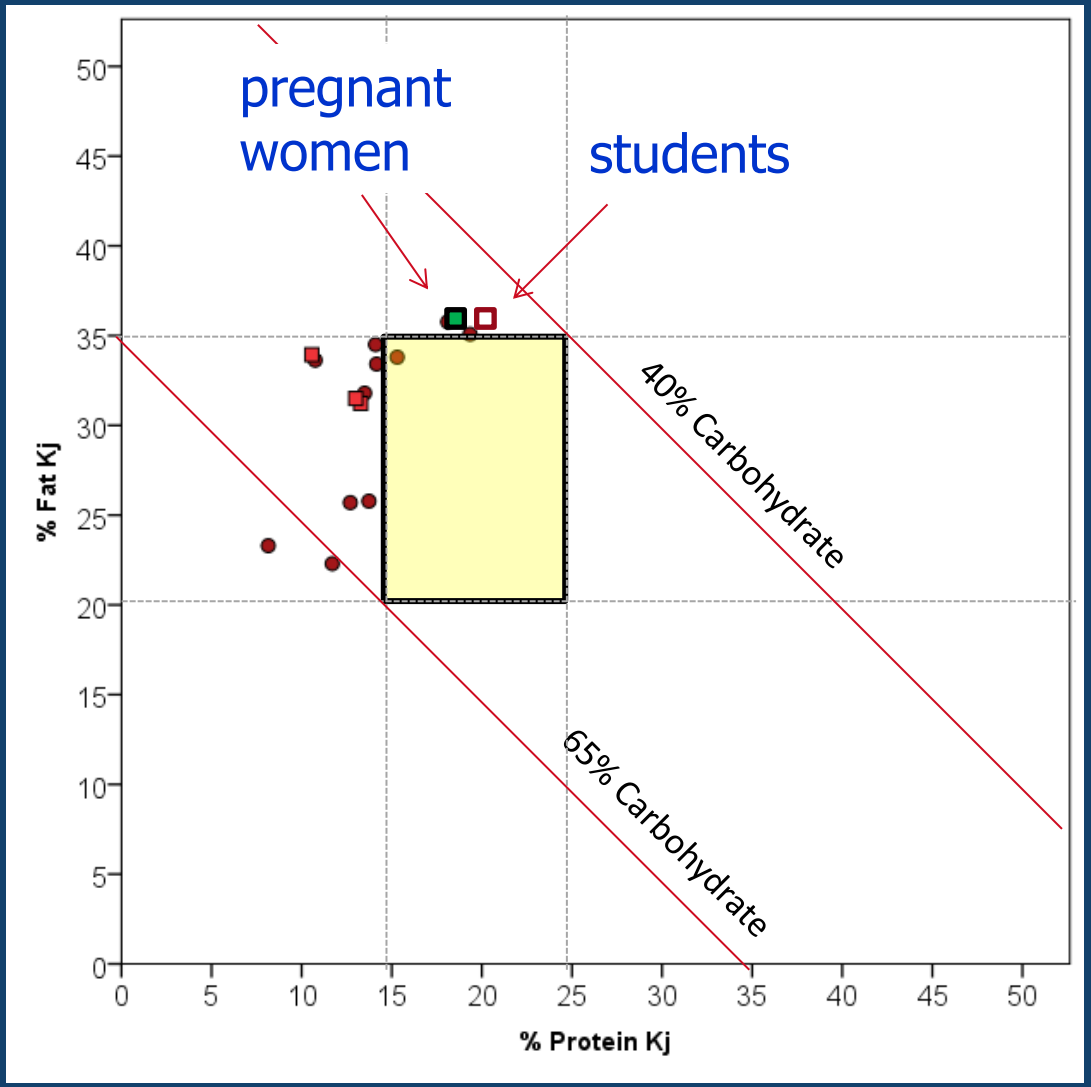
- Test
  - 106 supermarket foods
  - compared the separate contributions of each g of Pro, Fat and Car to the cost food
- Result
  - price increases with P
  - not with fats & carbs
- Conclude
  - *suggests an economic incentive to eat low P foods*
  - *= high energy intake*



Brooks *et al.* (2009) *Obesity reviews.*

Prediction 2). Low SES groups eat low-protein diets

- Aboriginal study
  - 14 diet surveys of low SES indigenous Australian communities
- Low relative to:
  1. Australian recommendations (AMDR)
     - most have low % P relative to recommended range
  2. Higher SES groups

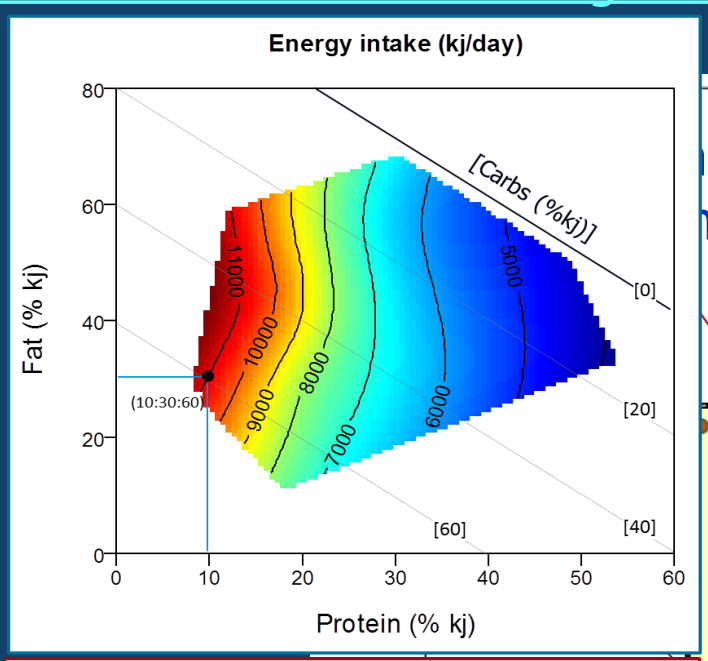


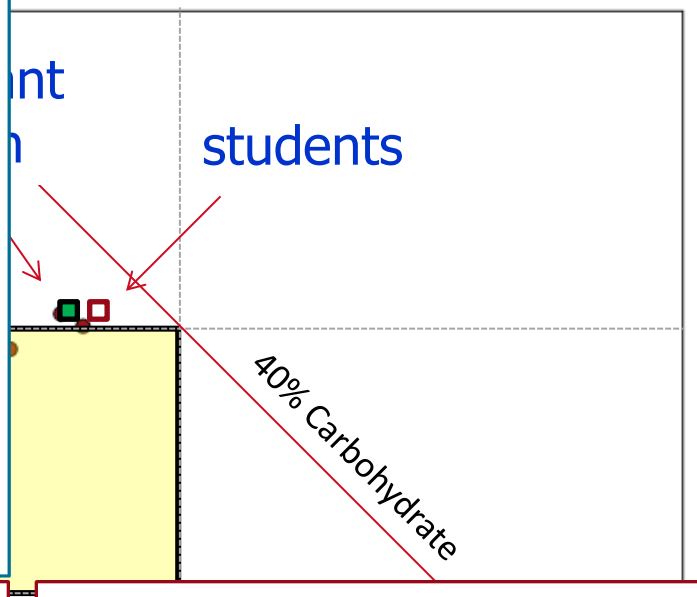
[With Aboriginal Nutrition Project Node]

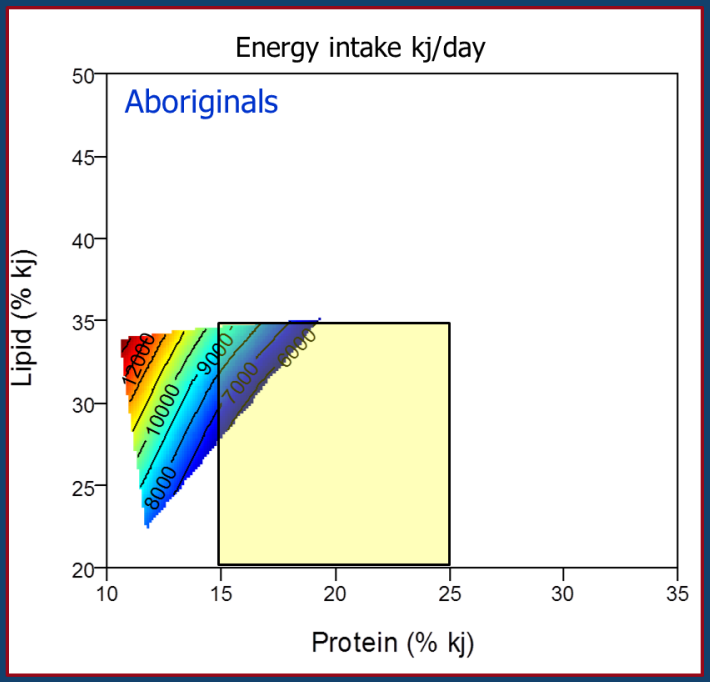
Prediction 3). Low protein diets are associated with high energy intake

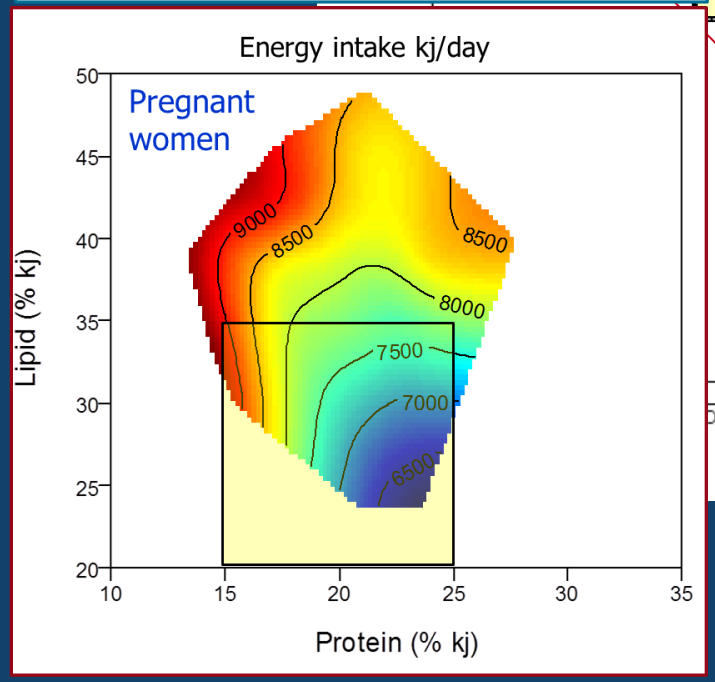
- yes!

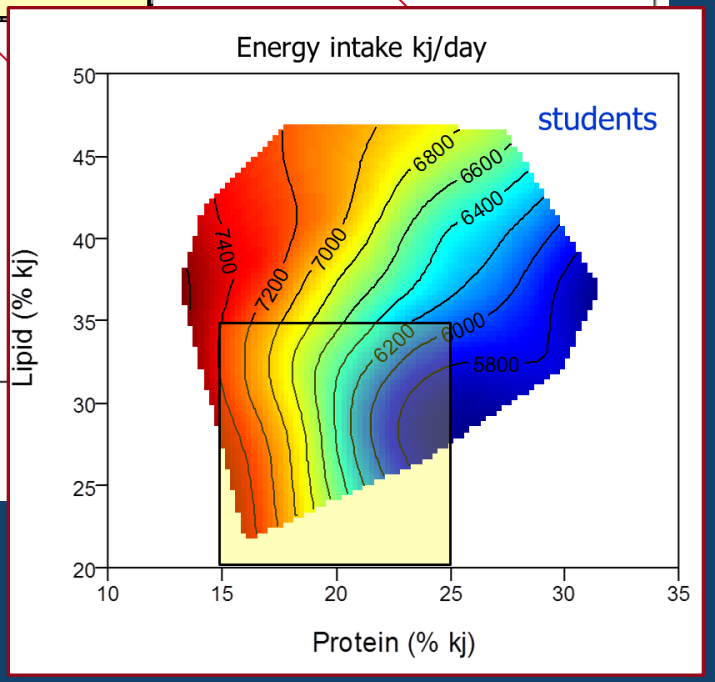
- as we found in experimental studies



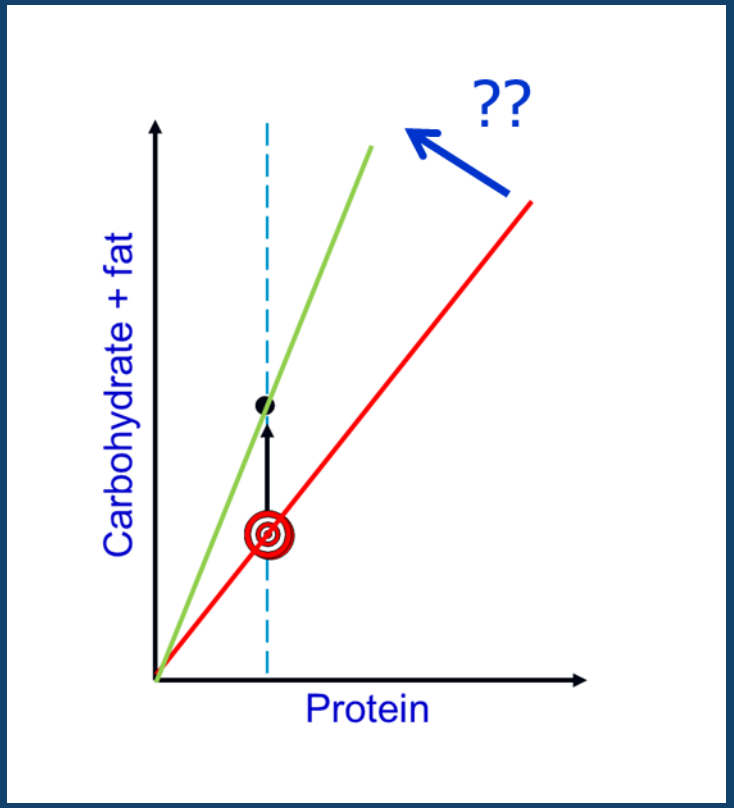


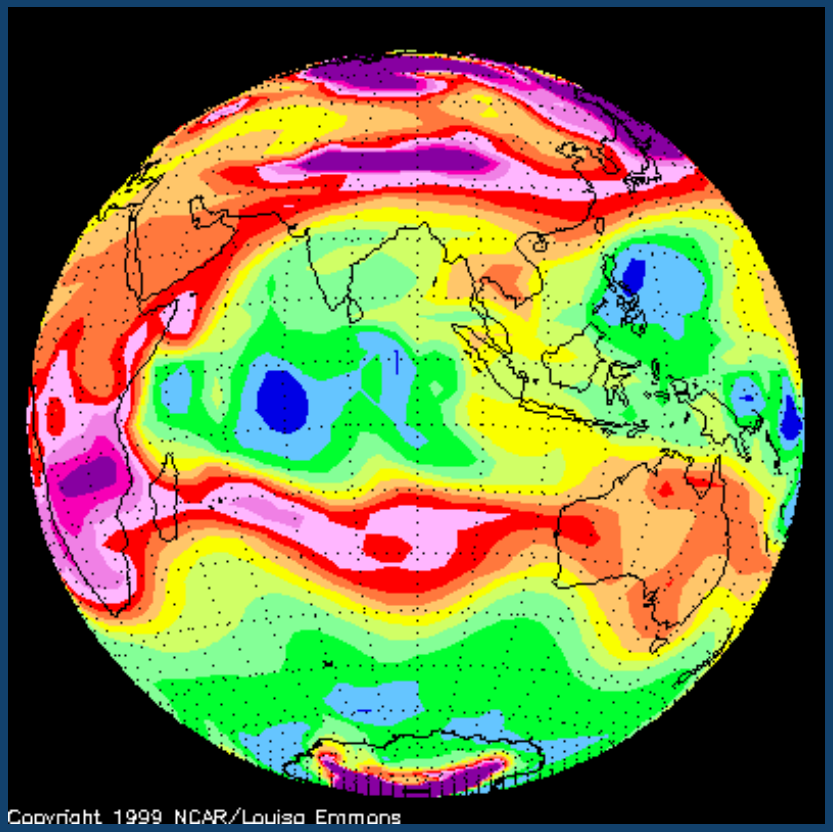






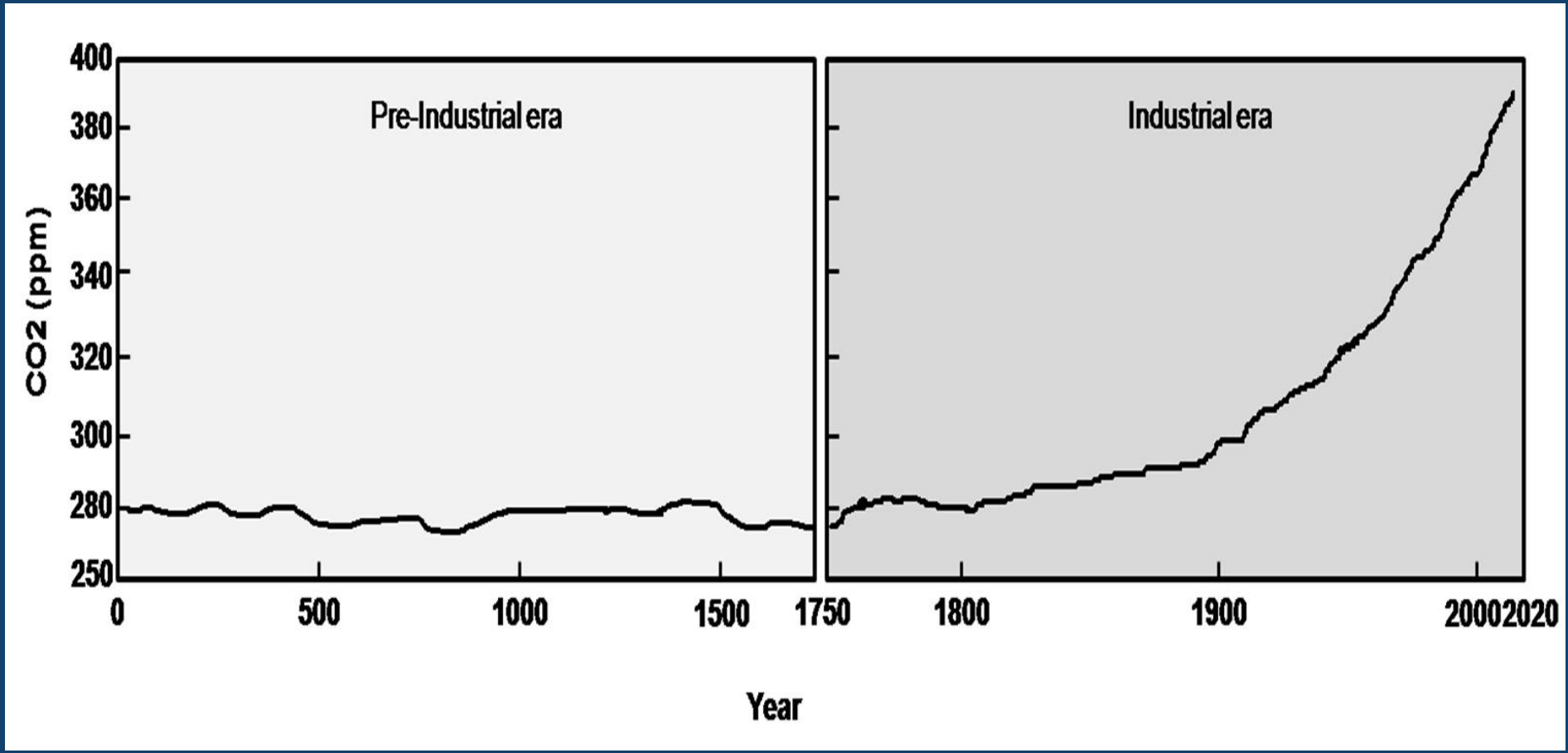
A role for global change





[With Human Food Chain Project Node]

Rapid increase in atmospheric CO2

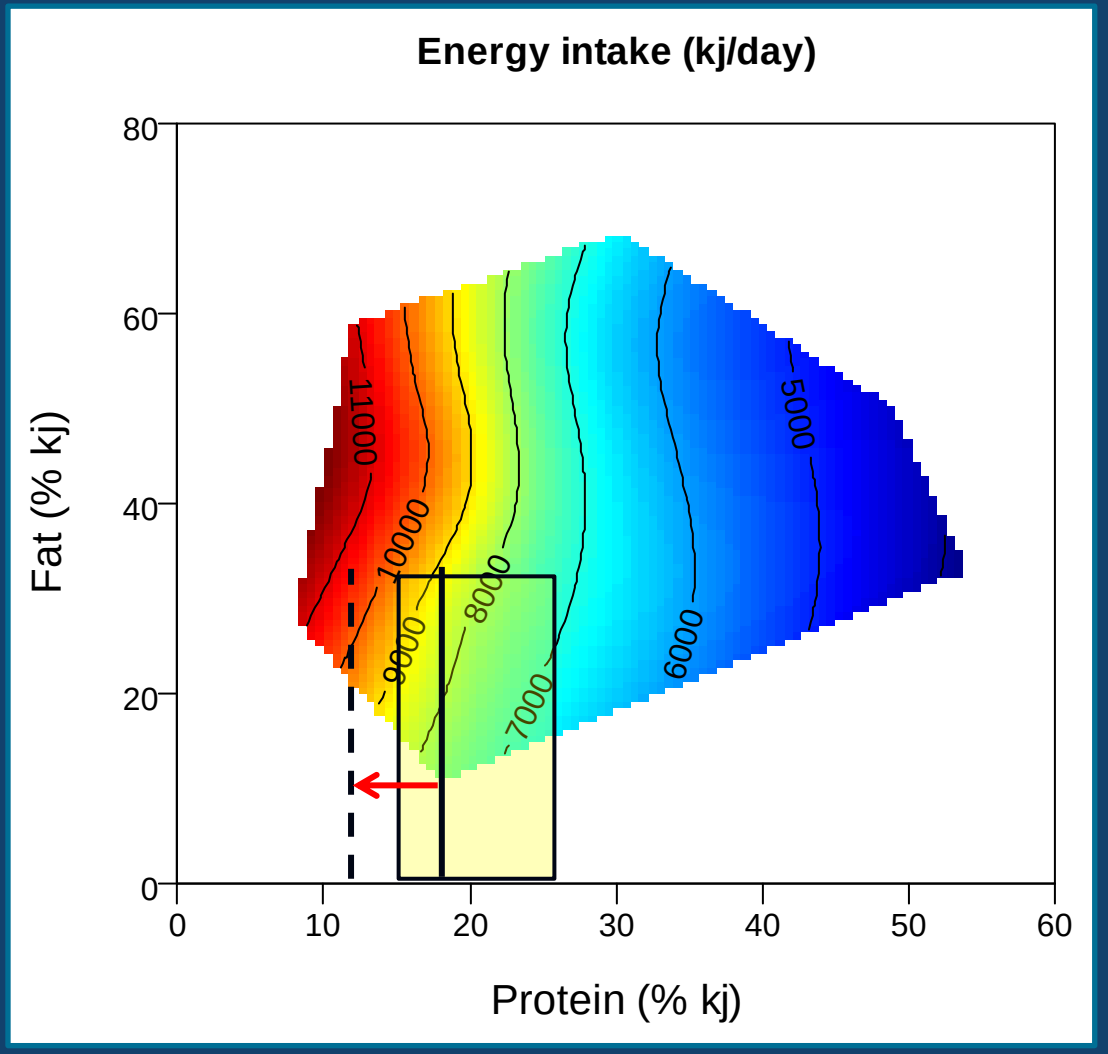


Raubenheimer *et al.* (2013), in review

Alters plant composition

- Robinson et al. 2012*

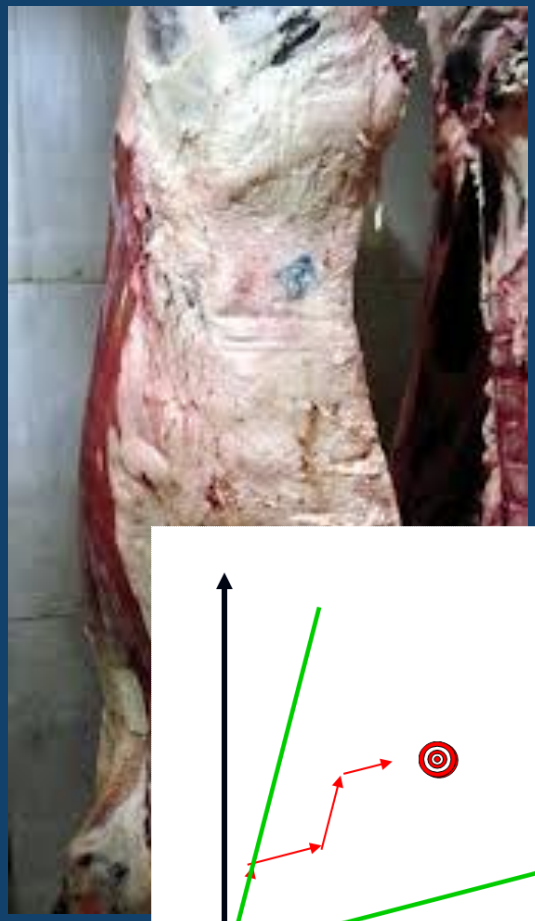
  - CO_2 enrichment results in an average 54% increase in the carbohydrate:protein ratio

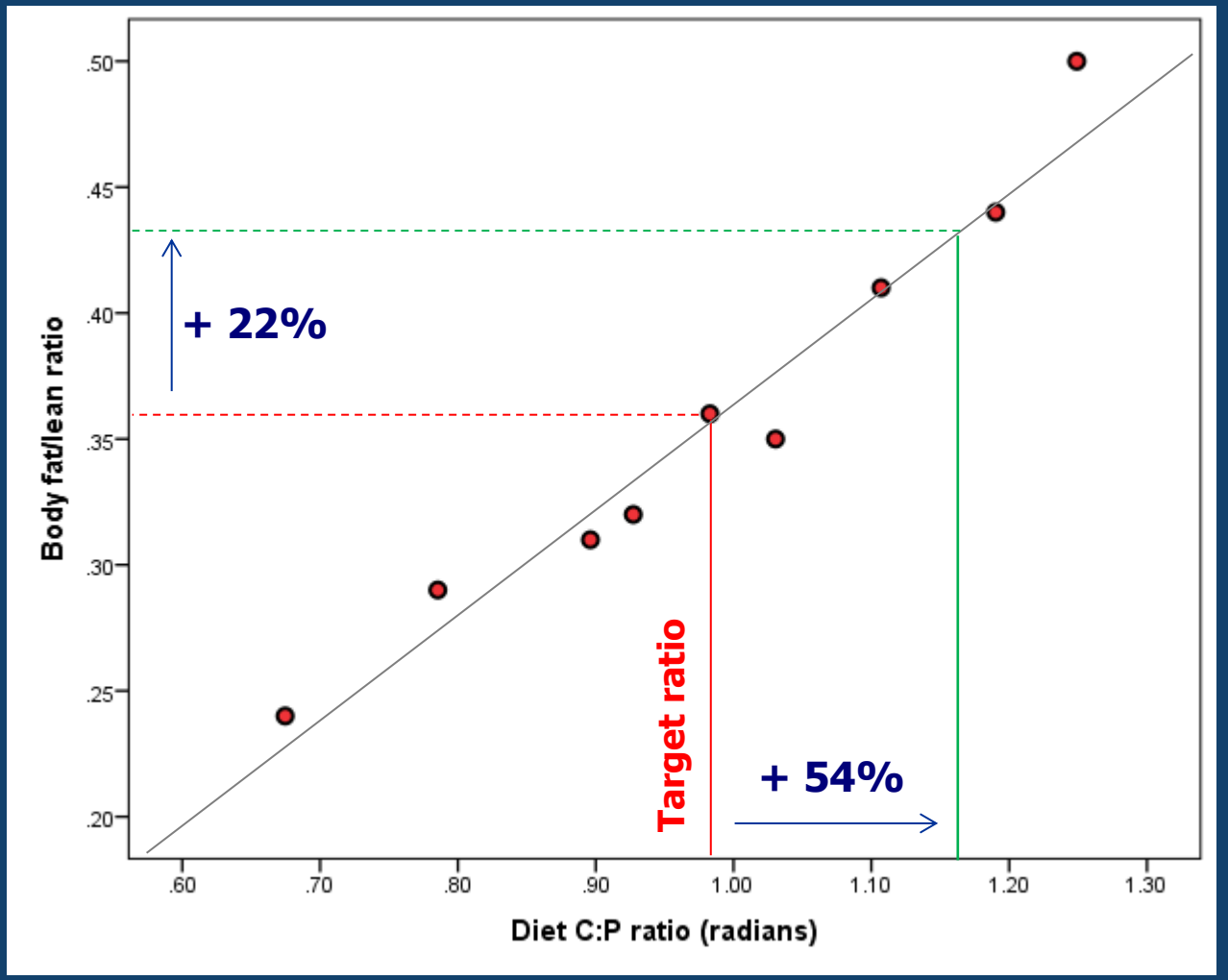


*New Phytologist 194:321-336

Raubenheimer *et al.* (2014), in review

Likely to impact not only on plant foods





1) Obesity: a not so obvious question

2) Nutritional geometry

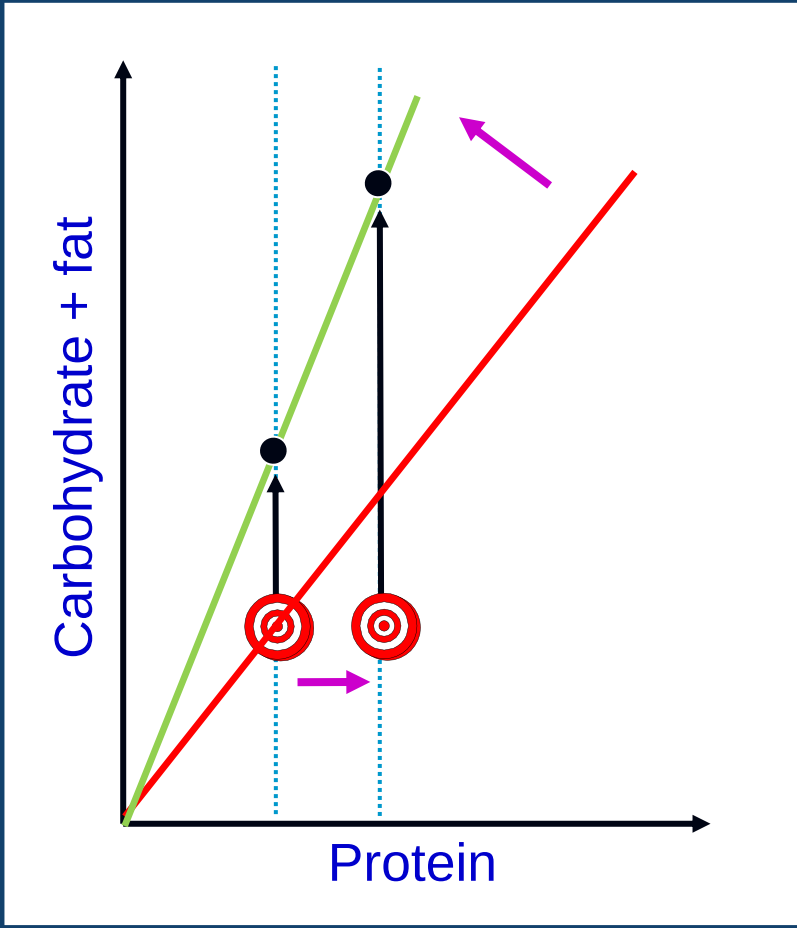
3) Stepping back in time: wild apes

4) Humans

5) Closer look at our environment

→ 6) A closer look at human biology

A Role for Protein Requirements



- protein leverage is expected to be proportional to protein requirements

- can variation in P requirements help explain variation in obesity?

1. Obesity as a cause of increased P requirements

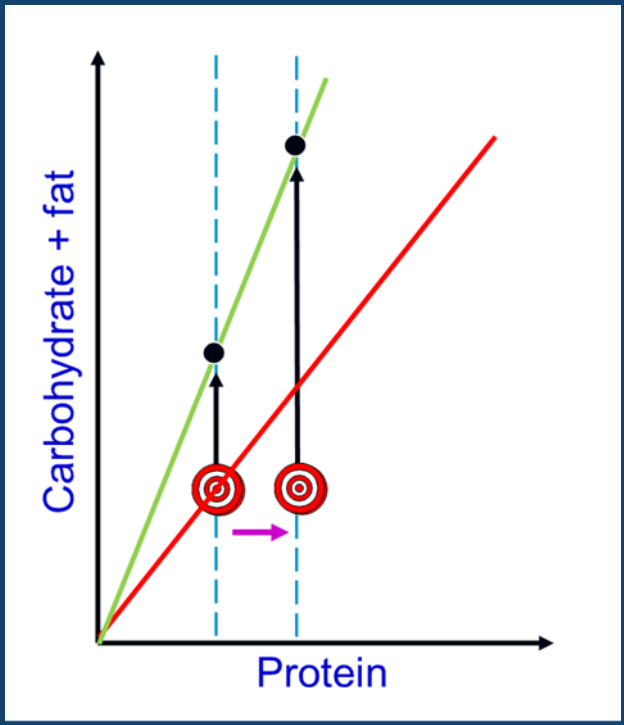
http://www.theguardian

- Physiological effect of obesity: Protein efficiency is reduced

- So more protein needs to be eaten to meet needs

  - and P leverage is enhanced

- *Suggests a positive feedback: obesity drives further excess energy intake and obesity*



2. Dietary history (evolutionary or developmental?)

- Populations with high protein traditional diets are particularly susceptible to obesity when transferring to westernised diets

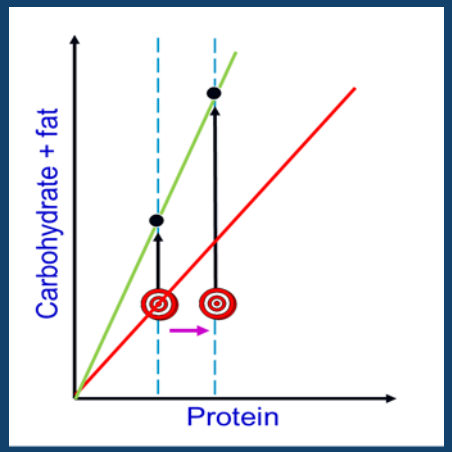
- For example, Alaskan Inuit

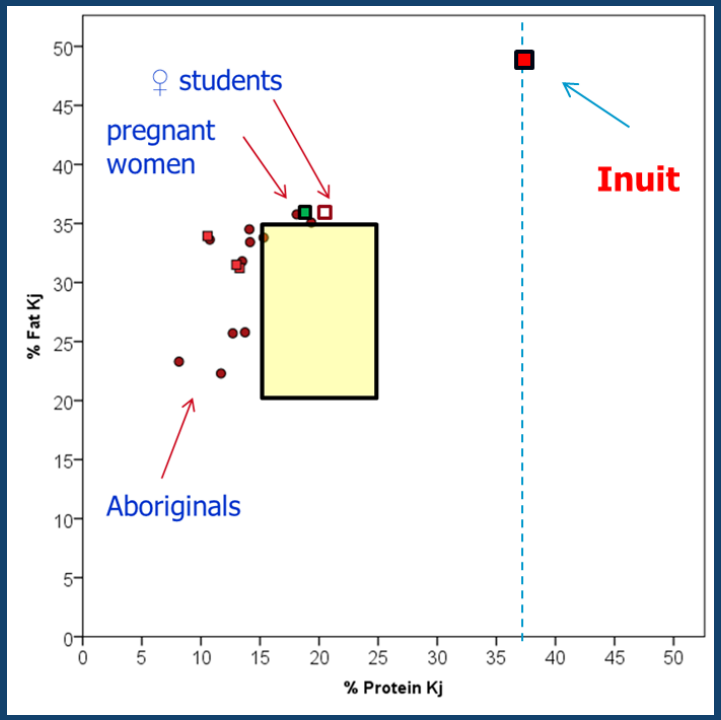
  - among the highest rates of obesity globally

  - traditional diet = 30-35% P

  - have developed low P efficiency

  - so higher P intake need



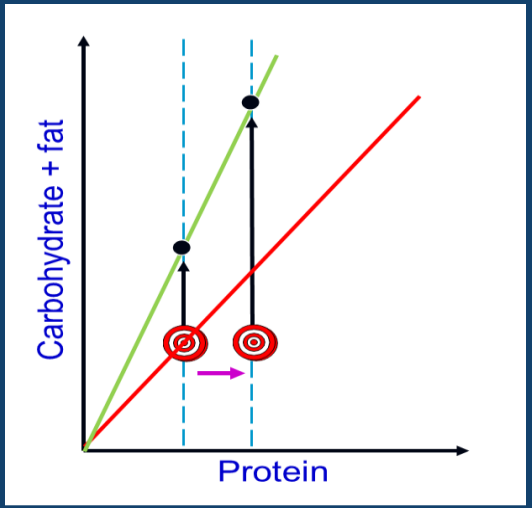


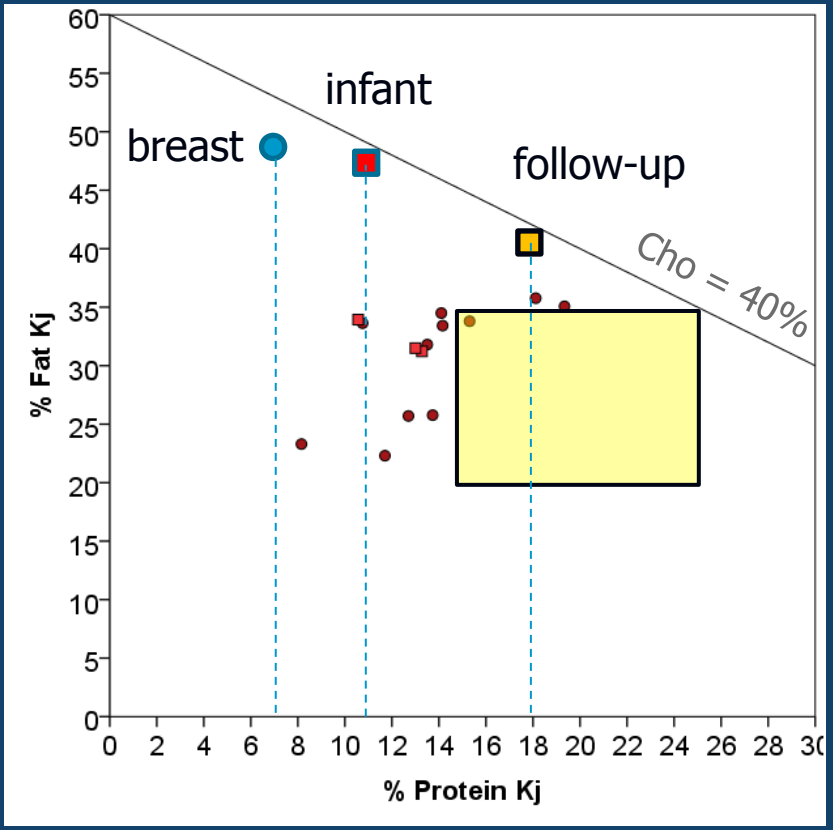
- *Could this explain their susceptibility to obesity?*

Data from Kang-Jey et al. (1972), AJCN 25:737-745.

3. Effects of early nutrition ("developmental programming")

- Formula-fed infants are more susceptible to obesity later in life than if breast-fed
- Milk formula is much higher in protein than human breast milk
- *Could high-P early in development lead to reduced P efficiency hence increased P target and energy intake?*

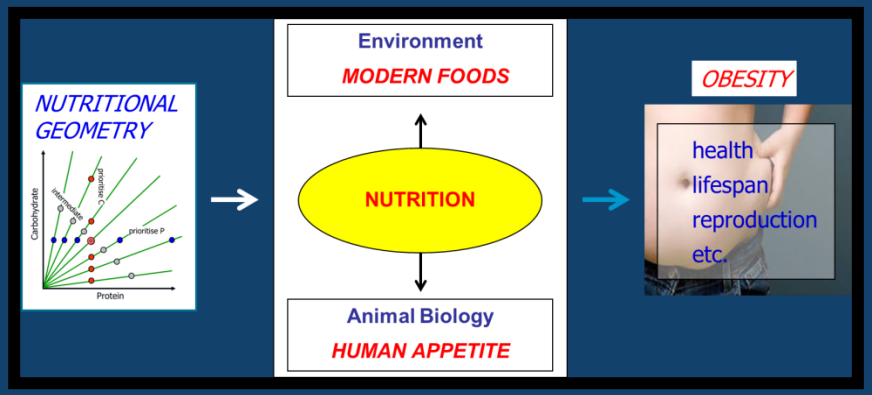




Data from Koletzko et al. (2009), AJCN 89:1836-49.

CONCLUSIONS

- Nutritional geometry can help to measure interactions among appetites for different nutrients



- Helps to understand the mismatch between humans and modern food environments

- And identify new areas for research and intervention

  - factors that reduce % protein in the human diet
  - factors that decrease human protein efficiency


Thank you for your attention!