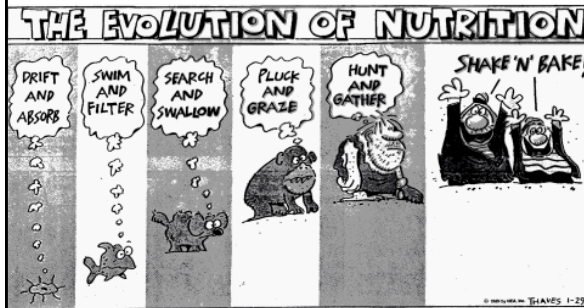
Evolution and Diet



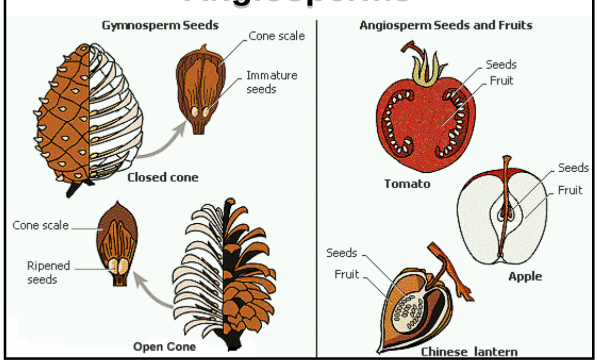
Cretaceous Period (135 - 65 m.y.a.)

- Extremely active geological period
  - Pangaea split into two segments by 125 m.y.a.
    - Northern land mass: Laurasia
      - Included North America, Europe, Most of Asia
      - Rise of the Rocky Mountains
    - Southern land mass: Gondwana
      - Included South America, Africa, Australia, Antarctica, Indian subcontinent
  - Worldwide climate much warmer than today so tropical and sub-tropical fossils are found far from the equator

Cretaceous Period 2

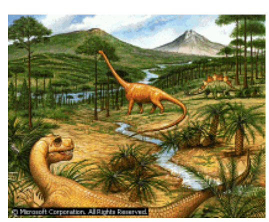
- Floral Shift from gymnosperms to angiosperms as dominant land plants
  - Gymnosperms are the vascular plants with seeds that are not enclosed in an ovary (naked seeds), mainly the cone-bearing trees (ferns, ginkos, cycads, and conifers)
  - Predominate from the Carboniferous period (about 350 m.y.a.) when they began to displace the earliest spore-bearing land plants to the Cretaceous (about 125 m.y.a.)

Gymnosperms vs. Angiosperms



Gymnosperms and Angiosperms

- Jurassic Scene with tall conifers and dinosaurs
- Bee collecting pollen and pollinating plant



Cretaceous Period 3

- Angiosperms are the flowering plants, an advanced group of vascular plants with floral reproductive structures and encapsulated seeds including flowering herbs and trees, first appear near the end of the Mesozoic (95 - 65 m.y.a.)
- The flowering mechanism increased the potential for genetic diversity (decreasing self pollination)
  - Diversity of the angiosperms increased through coevolution with insect species, making for rapid adaptive radiation

Cretaceous Period 4

- During the Cretaceous angiosperms spread to build forests of increasing complexity, and took over the dominant land plant role after the K/T (Cretaceous/Tertiary) extinction
- New econiches opened and old ones expanded
  - Frugivory: flowers and fruits are new food sources
  - Gramnivory: encased seeds from the new plants
  - Insectivory: bugs that co-evolved with flowering species multiply increasing bug eating opportunities

Cretaceous/Tertiary Event

- Comet collision represented by the Chicxulub impact crater off the north west coast of the Yucatan Peninsula
  - Combined effects of terrestrial and marine impact
  - Dust and debris cause cooling, break down of food webs

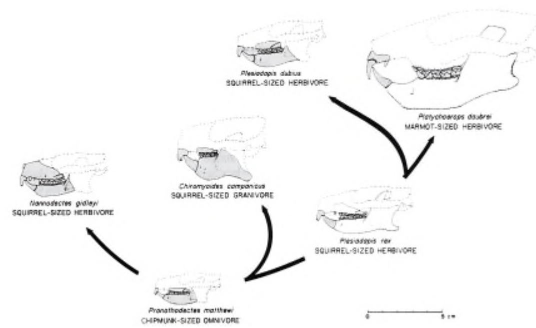
K/T

- There is also a lot of volcanic activity on the Deccan Flats of the Indian subcontinent at this time, adding to cooling
- More than 50% of species disappear at this time
  - Terrestrial reptiles and marine invertebrates most heavily affected
    - No land vertebrate larger than **50 pounds** in body weight survived the K/T
  - Terrestrial ecosystems, especially in North America, heavily devasted
    - Repopulated by Angiosperms
      - More fruit, flowers, and bugs for our ancestors

Primate Origins: Paleocene

- Of living mammals, there were no carnivores (dogs, cats), no rodents (mice, squirrels), no modern herbivores (cows, goats)
  - Primarily small, primitive insect eating animals (like living moles and shrews)
- Archonta (Superorder including Primates)
  - Plesiadapiformes: close relatives
  - Scandentia: Tree Shrews
  - Dermoptera: Flying Lemurs
  - Chiroptera: Bats
  - Primates: ?

Fleagle Figure 10.7



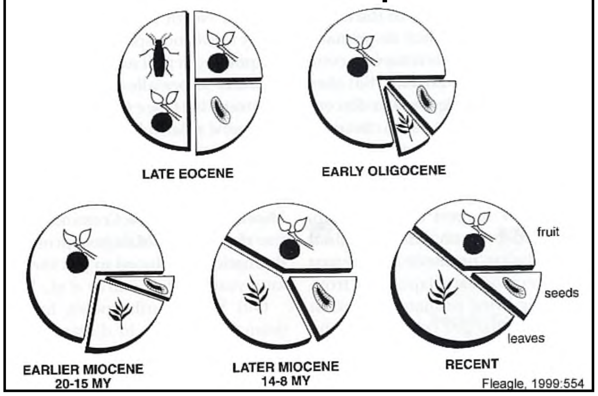
Dental diversity of Paleocene mammals, Plesiadapiforms, indicates Ominivory, Herbivory, Gramnivory

Group is less insectivorous than most other contemporary mammals

Paleocene

- The Plesiadapiform Radiation shows full range of dietary diversity
  - The Plesiadapiformes shows considerable dental variability comparable to modern primate dietary patterns from insectivore to frugivore, folivore, gramnivore, and possibly gummivore
    - The only missing element is probably small game hunters

Evolution of Anthropoid Diet



Notes about Table on Next Slide

- Sussman is contrasting the diet of several large bodied, diurnal primates
  - Lemurs, langurs, colobus, macaques, vervets, chimps, and hunter/gatherers
- Note especially the differences in the percent of animal prey

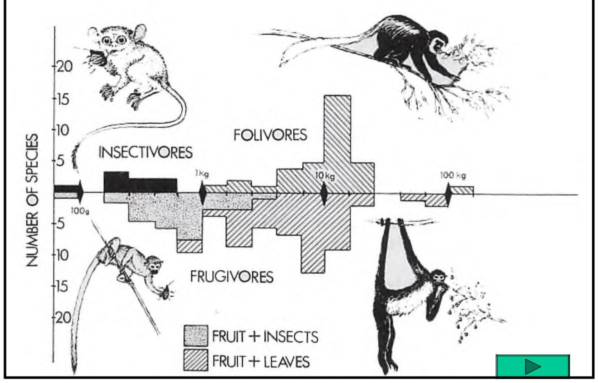
Sussman Table 9.10

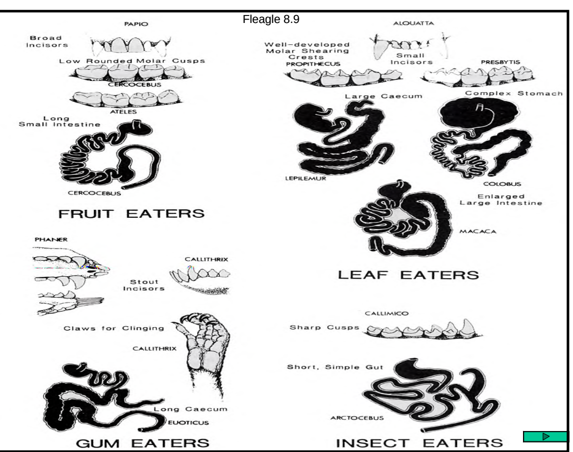
Table 9.10. Dietary patterns among some diurnal, large-bodied primates

Species	Species of plants: No. of plant species eaten	Species of plants: % of most utilized species	Species of plants: No. of plant species comprising majority of diet	Parts of plants and animal prey: % of mature leaves	Parts of plants and animal prey: % of other plant material (fruit)	Parts of plants and animal prey: % of animal prey	References
1) Specialized folivores							
Brown lemur (*Lemur fulvus*)	8, 11	>60	3 (85%)	@70	30 (24)	0	Sussman (1977)
Purple-faced langur (*Presbytis senex*)	12 (>90%)	41	3 (70%)	60	40 (28)	0	Hladik (1977)
Black-and-white colobus (*Colobus guereza*)	6, 8	>70	3 (90%)	@60	40	0	Clutton-Brock (1975)
2) Folivore–frugivores							
Ring-tailed lemur (*Lemur catta*)	24	23	8 (70%)	34 (young & mature	66 (46)	0	Sussman (1977)
Gray langur (*Presbytis entellus*)	25 (>90%)	@10	10 (70%)	21	79 (45)	0	Hladik (1977)
Red colobus (*Colobus badius*)	20 (>90%)	11	9 (70%)	20	80	0	Clutton-Brock (1975)
3) Omnivores							
Cebus monkey (*Cebus capucinus*)	54	Unspecified	36 (60%)	Small	80 (65)	20	Hladik and Hladik (1969) Oppenheimer (1968)
Toque macaque (*Macaca sinica*)	>40	Unspecified	22	Small	96 (77)	4	Hladik and Hladik (1972) Dittus (1974)
Vervet monkey (*Cercopithecus sabaeus*)	>65	7.2	12 (50%)	Small	87 (50)	13	Harrison (1984)
Chimpanzee (*Pan troglodytes*)	78	Unspecified	18 (80%)	Small	96 (68)	4	Suzuki (1969, 1975)
4) Human hunter/gatherers ≠Kadi San Bushman	79	Unspecified	13	Small	96.4	3.6	Tanaka (1976)

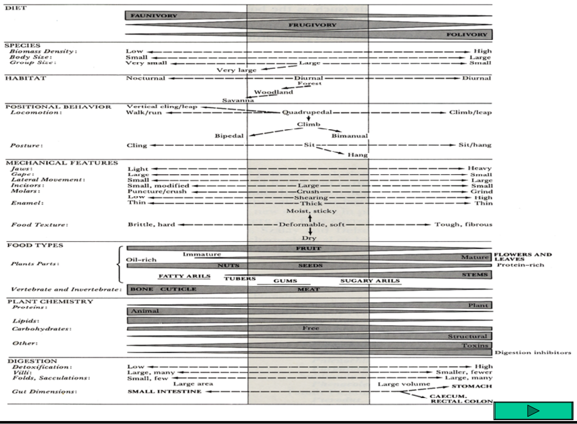
Data represent yearly averages (Adapted from Sussman 1978)

Body size and diet and number of species exploited (Fleagle figure 8.4)





Conroy Appendix C



Correlates of primate diets

- Fruit eaters tend to have relatively large incisors for ingesting fruits, simple molar teeth with low cusps for crushing and pulping soft fruits, and relatively simple digestive tracts without any elaboration of either the stomach or the large intestine.
- Leaf eaters have relatively small incisors, molar teeth with well-developed shearing crests, and an enlargement of part of the digestive tract for the housing of bacteria for the breakdown of cellulose.

Correlates of primate diets

- Gum eaters usually have specialized incisor teeth for digging holes in bark and scraping exudates out of the holes and claws or clawlike nails for clinging to the vertical trunks of trees. Many also have an enlarged caecum, suggesting that they may use bacteria in the gut to breakdown the structural carbohydrates in gums or resins.
- Insect eaters are characterized by molar and premolar teeth with sharp cusps and well-developed shearing crests and a digestive tract with a simple stomach and a short large intestine.

Summary of Primate Diets

- Diverse diets – insectivores, frugivores, omnivores, folivores
- Chimpanzees will hunt in groups and consume meat
- As an order, we have very diverse diets

So How about Hominids?

A Gentle Reminder

- Last common ancestor with other primates: 5-7 mya
- Adaptive radiation of hominids: 3-1.5 mya
- First appearance of *Homo* species: ~2.5 mya

Trends in Hominid Evolution

- **Bipedalism**
- ***Reduction*** of face, teeth, and jaws
- ***Increased*** reliance on meat protein
- ***Increased*** brain size and complexity
- ***Increased*** Tool making and tool use

Early Studies on Diet and Evolution in Anthropology

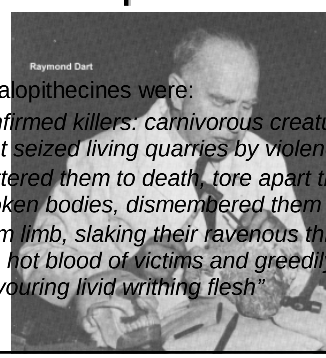
- Explanations for the origins of hominids
- Underlying theory – natural selection and adaptation
- Used comparative analogy to other animals or people
- Looked for explanations for these 'new' hominid traits (esp. bipedalism)

The Ecological Approach

(1950s)

- Humans are animals – subject to same pressures to survive
- Emphasis on the importance of FOOD ACQUISITION in human evolution
- Analogies with primates and modern H/G populations
- Main method of food acquisition – hunting
- Important in development of social behavior and sexual division of labor
- Changes in tooth shape and size related to use of tools

Dart (1953) "The predatory transition from ape to 'Man' "



Australopithecines were:

"confirmed killers: carnivorous creatures, that seized living quarries by violence, battered them to death, tore apart their broken bodies, dismembered them limb from limb, slaking their ravenous thirst with the hot blood of victims and greedily devouring livid writhing flesh"

Dart (1953) (continued..)

- The Killer Ape hypothesis
  - 'Osteodontokeratic' culture – used bones as weapons
  - Social behavior related to hunting
  - Hunting required weapons and bipedalism to carry weapons
  - Making weapons required learning and bigger brains
- Selective pressures of ***hunting*** made us human

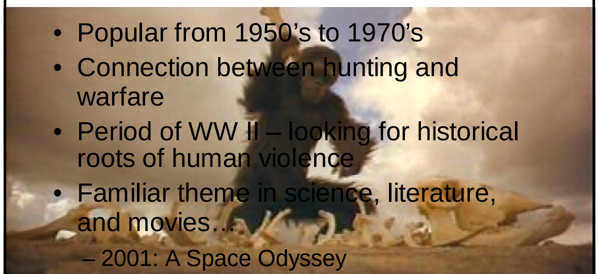
Dart's Victorian Sentiments

Man...
Who trusted God was love indeed
And love Creation's final law --
Tho' Nature, red in tooth and claw
With ravine, shrieked against his creed.

– Alfred, Lord Tennyson

- Tennyson's quote comes from canto LVI in "In Memorium A.H.H." (1850).

The Hunting Hypothesis



- Popular from 1950's to 1970's
- Connection between hunting and warfare
- Period of WW II – looking for historical roots of human violence
- Familiar theme in science, literature, and movies…
  – 2001: A Space Odyssey

Opposition to the Hunting Hypothesis

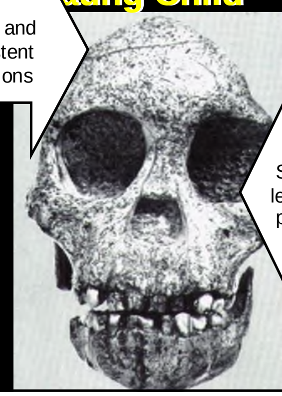
- **Zilhman and Tanner (1979) –** *"it promotes the idea of male aggression as necessary for hunting and for protecting the weak and passive females and children and assumes male dominance over females inherent to the hunting way of life"*
- **Eldredge and Tattersall (1982) –** a cop-out *"blaming our wars and violent crimes on some remote ancestor (to)….absolve us from responsibility for man's inhumanity to man"*

Evidence Against Hunting Hypothesis

- 1960's – 1st observations of chimpanzees as predators
  – Later baboon predation was described also
- C.K. Brain showed that bones in caves with Dart's 'killer apes' were more likely caused by carnivore activity (leopards and hyenas)
- Wounds in Australopithecine skull were caused by leopard, not another 'killer ape'
- January 2006 more evidence for "Man the Hunted" based on descriptive work of skull damage done by eagles preying on primates
  – Identical marks shown on Taung orbits

Taung Child

Skull fracture and marks consistent with raptor talons



Skeletal damage left by eagle beak pecking out eyes

What hunters do for a living, or, how to make out on scarce resources

- Lee (1968) input/output analysis of !Kung subsistence
  – Ethnographic analogy of !Kung bushmen
  – Showed quantitatively that gathering is more productive
    • 67% of their calories came from gathering plant foods versus 33% of their calories from hunting
- Hunting is not as important as assumed

Alternatives to Hunting: "Gathering as the hominid adaptation"

- Feminist theory of late 1970s
- Food gathering is the motivating force in evolution
- Use of tools and bipedalism needed to gather (vs. hunting)
- Hunting likely came much later as an activity with high risk/low return
- Predatory behavior is a fundamental part of our hominoid background

Alternatives to Hunting: Scavenging

- Bipedalism an adaptation to scavenging for meat
- More energy efficient over large distances
- Better view to locate food
- Hands free to carry scavenged food

1980’s to Present

- Ongoing debate on importance of meat in the hominid diet
- New variations on hunting/gathering models

How Can We Reconstruct Early Hominid Diet?

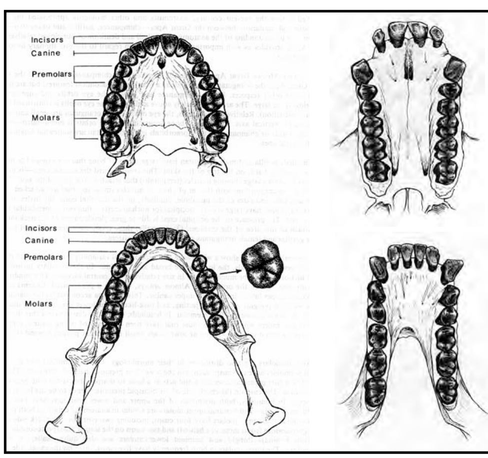
What evidence do we have?

Evidence of diet

- Early hominids don’t leave many hints about diet
  - No tools
  - No middens (paleo-garbage)
- Paleoenvironment
- Skeletal and dental evidence
  - Tooth Size and Shape
  - Enamel structure
  - Dental Wear and Microwear
  - Mandibular and Facial Biomechanics
  - Bone/tooth chemistry

Tooth Size and Shape

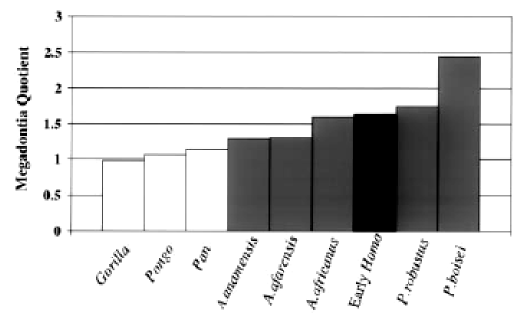
- Gorillas and chimpanzees have large incisors
- Early hominids - smaller incisors
- Less emphasis on foods that required substantial incisor use
- Avoided foods with thick husks and large, hard seed



Canines and Molars

- Hominid hallmark – large, relatively flat molars
- Smaller canines
- Robust australopithecines (e.g., *A. boisei*) have massive premolars and molars

Molar area relative to body size



More Dental Clues

- In general - large, blunt teeth (adapted to processing small, hard, brittle foods)
- No shearing crests (good for cutting and slicing)
- Would not be eating tough foods
- Probably some difficulty in processing meat
- Ate fruits, nuts, flowers, buds

Enamel Structure

- Thick enamel correlated with eating hard/abrasive foods
- Australopithecines had relatively thick molar enamel
  – Helped to protect against breakage when eating hard objects

Microwear Studies

- Microscopic wear on teeth reflect diet and tooth use
- Patterns are used to infer diet in fossil forms
  – Folivores – long narrow scratches
  – Frugivores – more pits
  – Hard object feeders – even more pits

Small jaw vs. big jaw

- Gracile forms – less pitting than robust forms
  – More long, narrow scratches
- Robust australopithecines – more pits
  – Eating hard, gritty food requiring lots of grinding

Mandibular Biomechanics

- Mandible fragments commonly found
- Architecture adapted to withstand stresses and strains related to food processing
  - Buttressing at symphysis, height of body of ramus relative to thickness

Putting it all Together

- Gracile australopithecines – increased abrasiveness in food
- Less pitting than typical hard object feeder
- Thick enamel
- Broad incisors
- Increase postcanine tooth size
- Dietary breadth
- Hard abrasive foods become more important

Putting it all Together

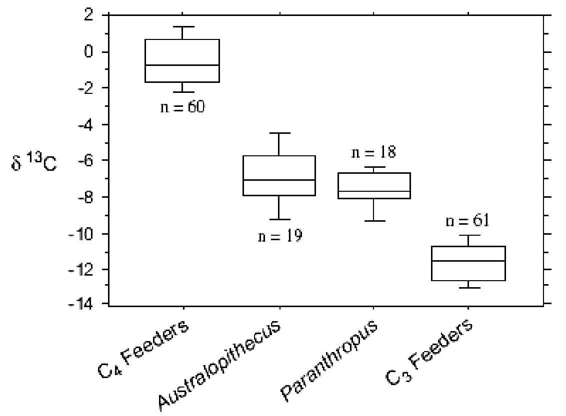
- Robust australopithecines – extremely large teeth
- Microwear – hard-object diet
- Craniodental specialization – thick jaw, sagittal crest, wide cheek bones
- Substantial difference in feeding
- Evidence suggests mainly vegetarian diet

Bone and Tooth Chemistry

- Destructive process
- Fossils are rare
- Relatively small amount required
- Problems with diagenesis (post-mortem alteration of bones and teeth)
- Teeth generally more reliable

Carbon Isotope Analysis

- Carbon isotopes from tooth enamel of A. africanus and A. robustus
- Animals eating fruit, leaves, and roots (C3 plants): δ13C -16 to -10‰
  - Bovids, giraffids, and chalicotherids in Plio/Pleistocene South African context
  - Modern chimpanzees and gorillas both have essentially pure C3 signatures
- Animals eating tropical grasses (C4 plants): δ13C -2 to 2‰
  - bovids, equids, and suids in Plio/Pleistocene South African context
- Mixed feeders – values in between the two categories



A. africanus

- N = 19 as of 2005
- $\delta^{13}C$: - 4.0 to -11.3‰, average: - 7.1‰
- Highly variable diet
- Mixed feeders
- Habitually eating C_4 plants or animals that ate C_4 plants (bovids and bugs?)

A. (*Paranthropus*) *robustus*

- N = 18 as of 2005
- $\delta^{13}C$ Average: – 7.6‰
- Statistically not different from *A. africanus*
- Craniodental evidence indicates a tough, fibrous diet (crushing, grinding)
  - Orally processed foods
- ^{13}C Conclusion: *A. africanus* may have used tools instead of teeth to process food
  - But *robustus* could have, too

A. (*Paranthropus*) *robustus*

- Traditional view of *A. robustus:*
  - 'Uber-vegetarian'
  - Based on tooth and jaw morphology
    - Massive grinding molars, strong chewing musculature
  - Microwear patterns on molar suggests low meat consumption
- Isotopic data suggest an omnivorous, not strictly vegetarian diet

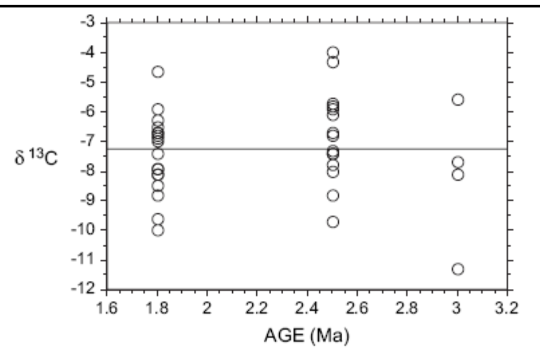


Fig. 6. $\delta^{13}C$ of South African hominins through time. No temporal trend is evident, despite abundant evidence that South African hominin environments changed during this time.

Re-examining the diet of South African Australopithecines

- The range of $\delta^{13}C$ values are so great in specimens of *A. africanus* that they may represent two different taxa
  - One highly dependent on C_4 foods and one on C_3
- Analysis of C_4 foods in modern context suggests that termites and sedges are unlikely sources for Australopiths
  - Especially significant for USO hypothesis of Wrangham and colleagues (also see cooking)

Earliest evidence for genus *Homo*?

- *Homo habilis*
- 2.5 – 1.5 m.y.a.
- Kenya and Ethiopia
- Increased cranial capacity
- Loosely associated with primitive stone tools: “Oldowan”

Homo erectus

- First appeared in Africa, then spread to Asia and Europe
- Date: ~ 1.8 m.y.a – 30,000 y.a.
- Associated with Acheulian tool industry
  - Possible use of fire
  - Key controversy: fire starting at 1.8 mya or 0.4 mya?
    - Evidence suggests consistent use .4 - .2 mya

Connection between dietary shift to meat eating and brain expansion?

Were *H. erectus* big game hunters?

- Did they expand out of Africa because they were following herd animals?
- Did increased meat consumption contribute to brain expansion?

OR

- Did the use of fire for cooking increase the nutrient density of vegetable foods like tubers and roots?

Cooking ↔ Hunting

- Possible synergy between the two:
  - Cooking released more nutrients
  - Regular hunting of big game increased nutrients

Scavengers or Hunters?

- Australopithecines and early *Homo* were most definitely scavengers
- *Homo erectus* probably engaged in organized hunting
- Some argue that *Homo* must have increased meat consumption in order to sustain massive growth in brain relative to body size

Expensive Tissue Hypothesis

- Explanation for brain expansion in *H. erectus*
  - Bigger brain consumes more energy
- Humans show mosaic evolution of increased brain size and smaller ‘guts’ (intestines)
- Smaller gut freed energy for brain
  - Requires higher quality diet – meat
  - More on this from Mr. Brown

Paleolithic Diet

Table 5. Comparison of the Late Paleolithic Diet,* the Current American Diet, and U.S. Dietary Recommendations.

	Late Paleolithic Diet*	Current American Diet[78]	U.S. Senate Select Committee Recommendations[78]
Total dietary energy (%)			
Protein	34	12	12
Carbohydrate	45	46	58
Fat	21	42	30
P:S ratio †	1.41	0.44	1.00
Cholesterol (mg)	591	600	300
Fiber (g)	45.7	19.7 ‡	30–60[79]
Sodium (mg)	690	2300–6900[80]	1100–3300[80]
Calcium (mg)	1580	740 §	800–1200 ¶
Ascorbic acid (mg)	392.3	87.7 §	45 ¶

*Assuming the diet contained 35 per cent meat and 65 per cent vegetables.
†P:S denotes polyunsaturated: saturated fats.
‡British National Food Survey, 1976.
§U.S. Department of Agriculture Food Consumption Survey, 1977–1978.
¶Recommended Daily Dietary Allowance, Food and Nutrition Board, National Academy of Sciences–National Research

Paleolithic Diet Revisited, 1997

Table 3 Estimated daily paleolithic intake of selected nutrients compared to recommended and current levels

	Paleolithic intake[a]	*U.S. RDA*[b]	*Current U.S. intake*[b]
Vitamins, mg/d			
Riboflavin	6.49	1.3–1.7	1.34–2.08
Folate	0.357	0.18–0.2	0.149–0.205
Thiamin	3.91	1.1–1.5	1.08–1.75
Ascorbate	604	60	77–109
Carotene	5.56	—	2.05–2.57
(retinol equivalents)	(927)	(342–429)	—
Vitamin A	17.2	4.80–6.00	7.02–8.48
(retinol equivalents)	(2870)	(800–1000)	(1170–429)
Vitamin E	32.8	8–10	7–10
Minerals, mg/d			
Iron	87.4	10–15	10–11
Zinc	43.4	12–15	10–15
Calcium	1956	800–1200	750
Sodium	768	500–2400	4000
Potassium	10500	3500	2500
Fiber, g/d	104	20–30	10–20
Energy, kJ/d	12558	9209–12139	7326–10465
(*kcal/d*)	(3000)	(2200–2900)	(1750–2500)

[a] Based on 913 g meat and 1697 g vegetable food/d yielding 12558 kJ (3000 kcal). See Appendix for method.
[b] Food and Nutrition Board, 1989.

My take on the Paleolithic

- Eaton and Konner retrodict very high meat intakes
  - 1997 table is based on 913 g meat and 1697 g vegetables for a 3,000 Kcal diet
  - **913 g meat = 2 pounds of meat per day!**
  - Can you say SUPERSIZE!

A Skeptical View

- Marion Nestle (2000) Paleolithic diets: a skeptical view. Nutrition Bulletin, 25:43–47.
  - Evidence for proportions of animal and plant foods in the diets of early humans is circumstantial, incomplete, and debatable
    - Available data are insufficient to identify the composition of a genetically determined optimal diet
  - Despite our current consumption of non-Paleolithic diets, the lifespans of adults in most industrialized countries are lengthening, and populations are remaining relatively healthy into ripe old age

More skepticism

- The evidence related to Paleolithic diets can best be interpreted as supporting the idea that ***diets based largely on plant foods promote health and longevity***, at least under conditions of food abundance
- Substantial evidence supports recommendations that people in industrialized economies could reduce risks for chronic disease if they increased their intake of fruits, vegetables, and grains in proportion to animal foods, and kept as active as our hunter-gatherer ancestors