How food “works”

College Eight Plenary
Wed., Oct. 10, 2012

How food works; work done by food; work to produce food

1. What does “work” mean in this talk
2. What did our ancestors eat?
3. Humans in food webs & food cycles
4. Energetics of food
5. Inputs into food production
6. Work from food, working for food

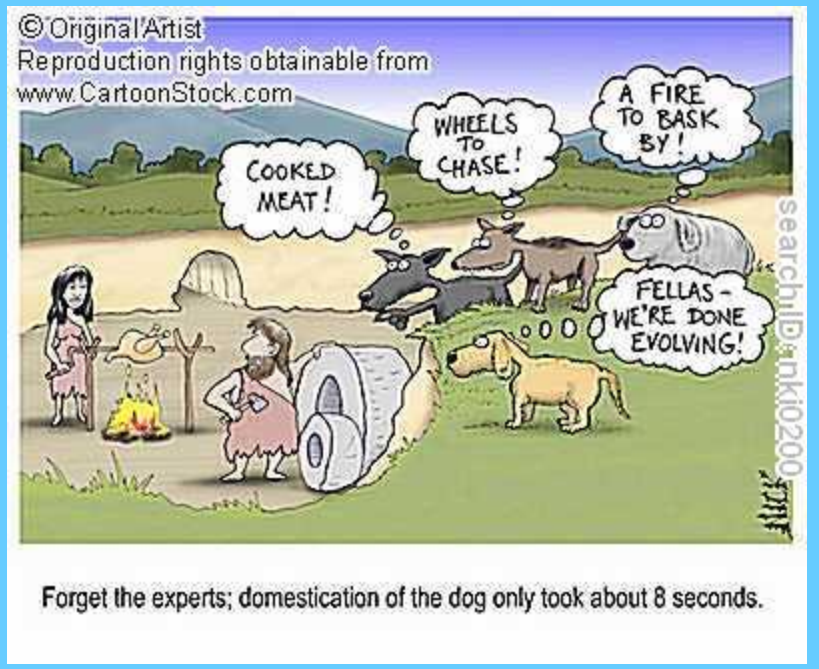
1. What does “work” mean?

- Energetics of food creation: physics, chemistry, biology
- “Food webs” are cycle of energy & minerals from producers to consumers to decomposers
- “Food chains” are human predation on food webs, to concentrate energy for societal reproduction
- “Food” is stored energy, in digestible form (which depends on location in food web)
- Food production operates against entropy (3rd Law of Thermodynamics) to allow biological organization
- But most human interventions rely on “fossil sources” of energy to concentrate food energy
- These sources are not renewable or infinite (“Waste equals food”)

2. What did our ancestors eat?

http://www.indianafoodreview.com/wp-content/uploads/2010/12/prehistoric.11310.jpg

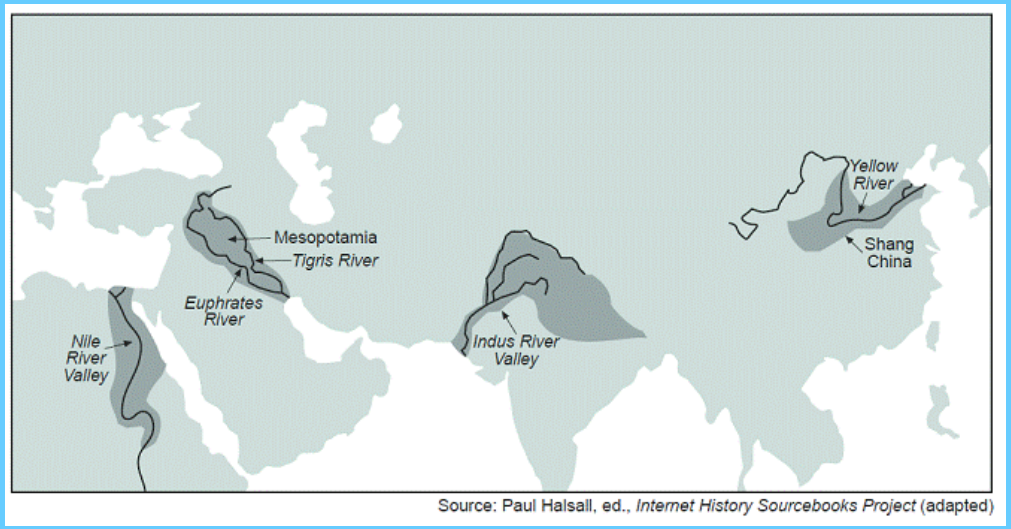
http://www.cookbookpeople.com/blog/wp-content/uploads/2009/07/food-timeline-family-cookbook.jpg



http://www.cartoonstock.com/lowres/nki0200l.jpg

http://images.photoresearchers.com/photos/preview/se/se9858.jpg

http://blogs.scientificamerican.com/guest-blog/files/2012/02/Wild-Wheat.jpg



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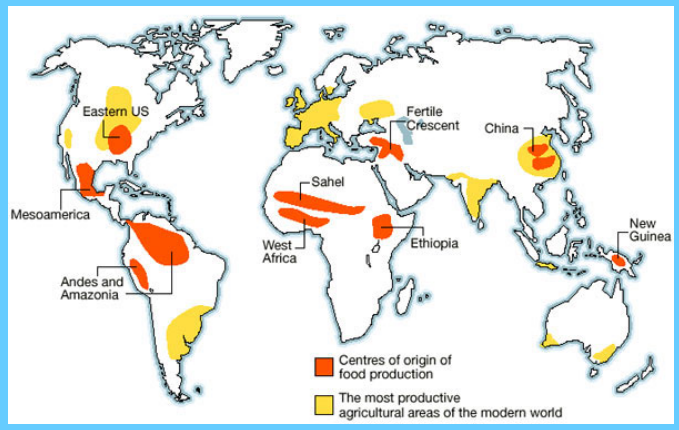
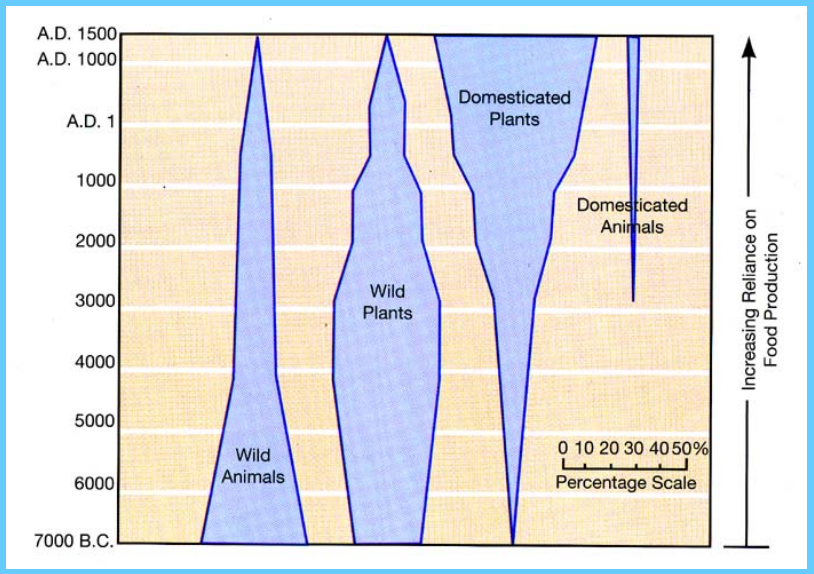
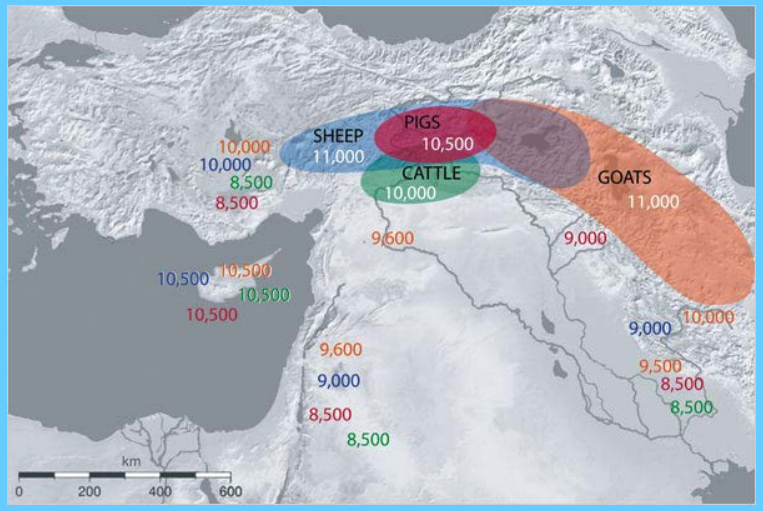


http://www.hort.purdue.edu/newcrop/history/lecture03/r_03-2-02.jpg

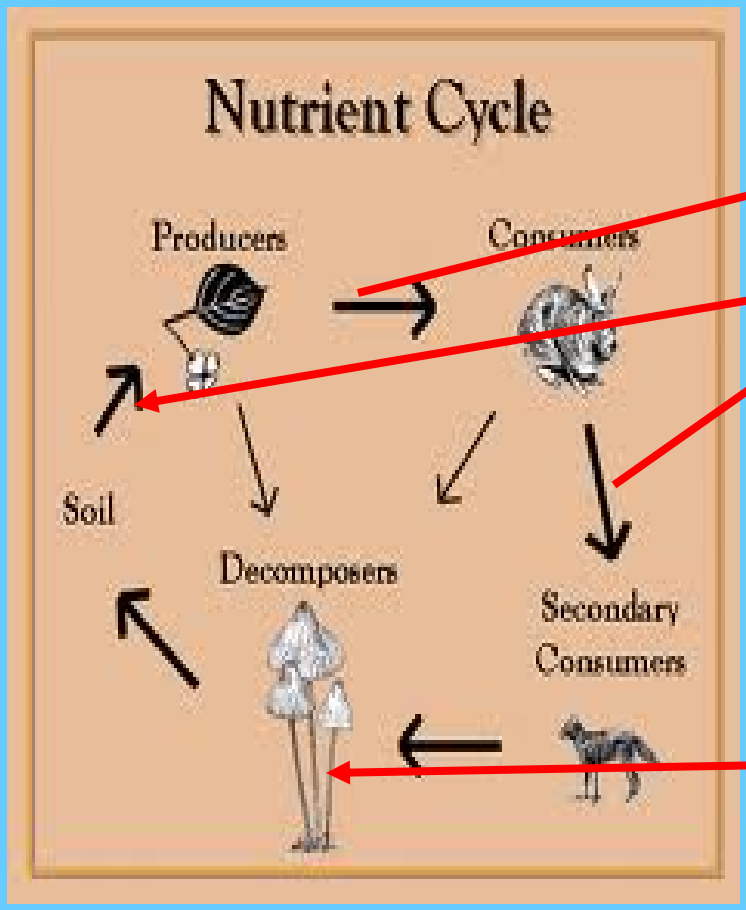


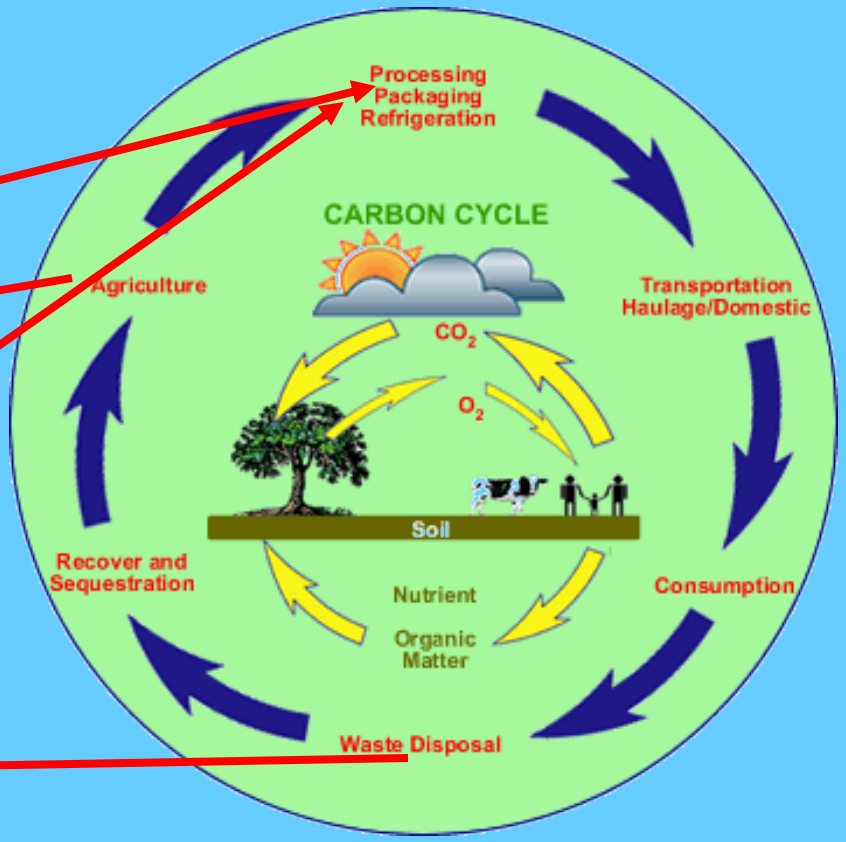
http://cognition.clas.uconn.edu/%7Ejboster/courses/anth1006_f10/lectures/neolithic/food.jpg



http://anthropologynet.files.wordpress.com/2008/08/animal-domestication-time-frame.jpg

3. Food webs, food chains, food cycles



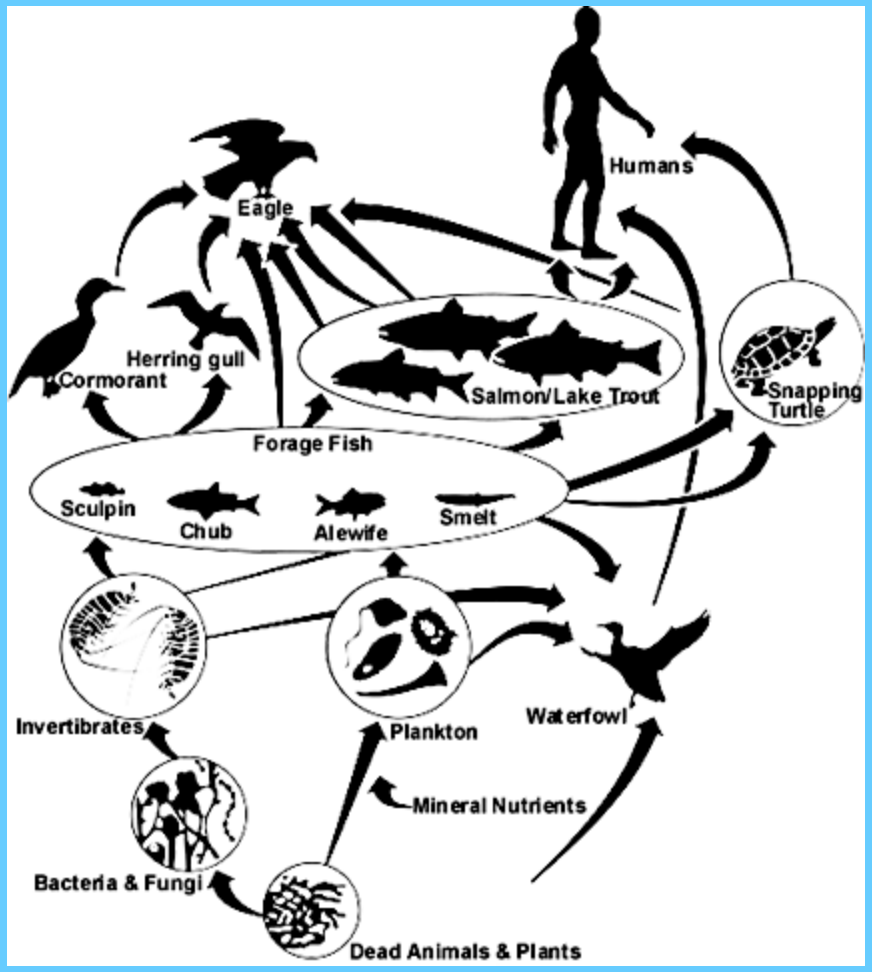


Food Web

Food Cycle

http://www.rbnc.org/schoolunits/soildecomp-old.htm

Humans are predators on food webs



http://www.mindfully.org/Food/Food-Web-Simply.htm

Food cycle: what goes in and what comes out?

Food cycle = (CO_2 + energy + water + soil)

+ (farming + labor + technology)

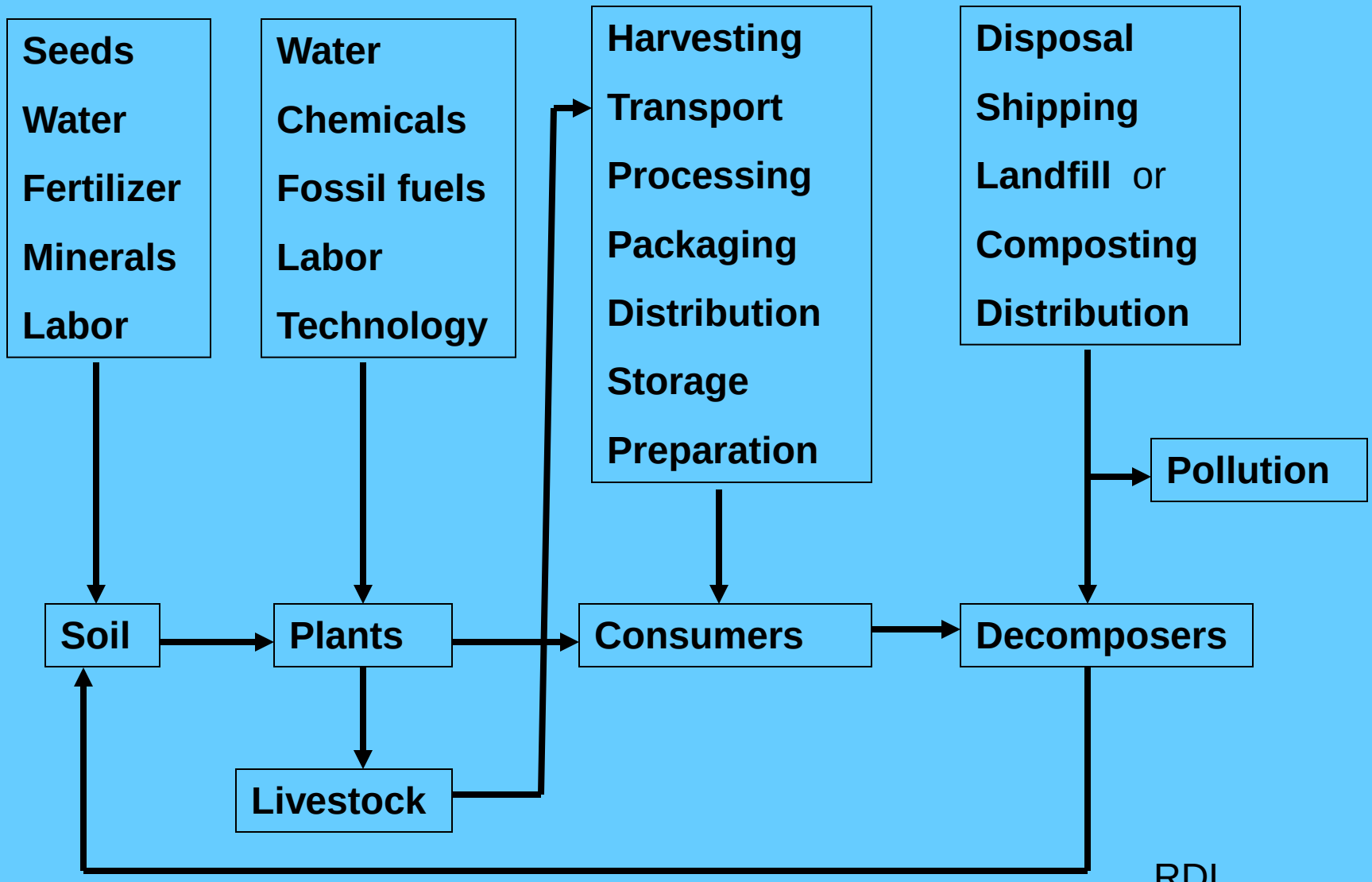
+ (extraction + processing + conversion)

+ (shipping + distribution + marketing)

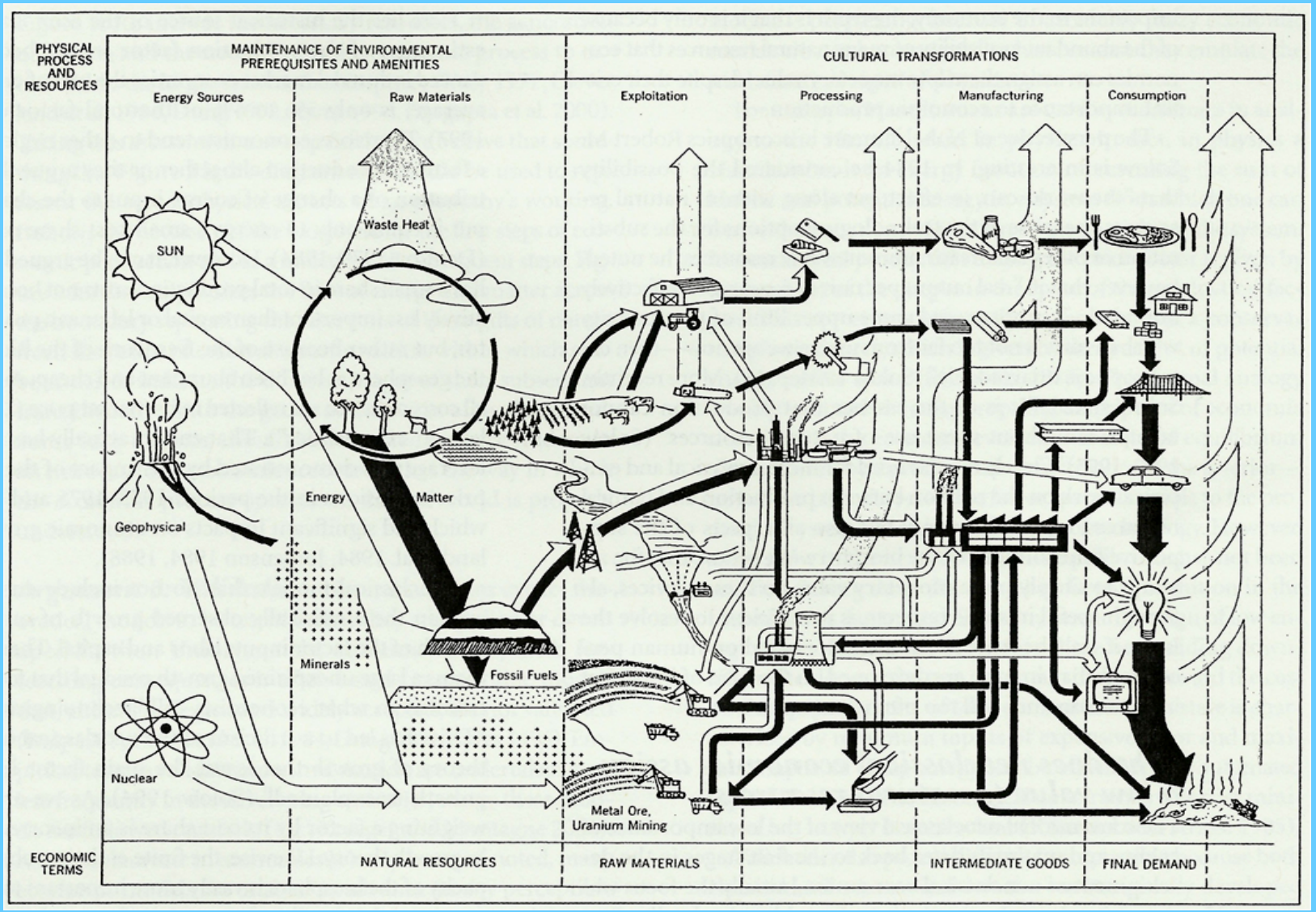
+ (acquisition + preparation + leftovers)

+ (garbage + compost + sewage)

We actively intervene in food webs & cycles

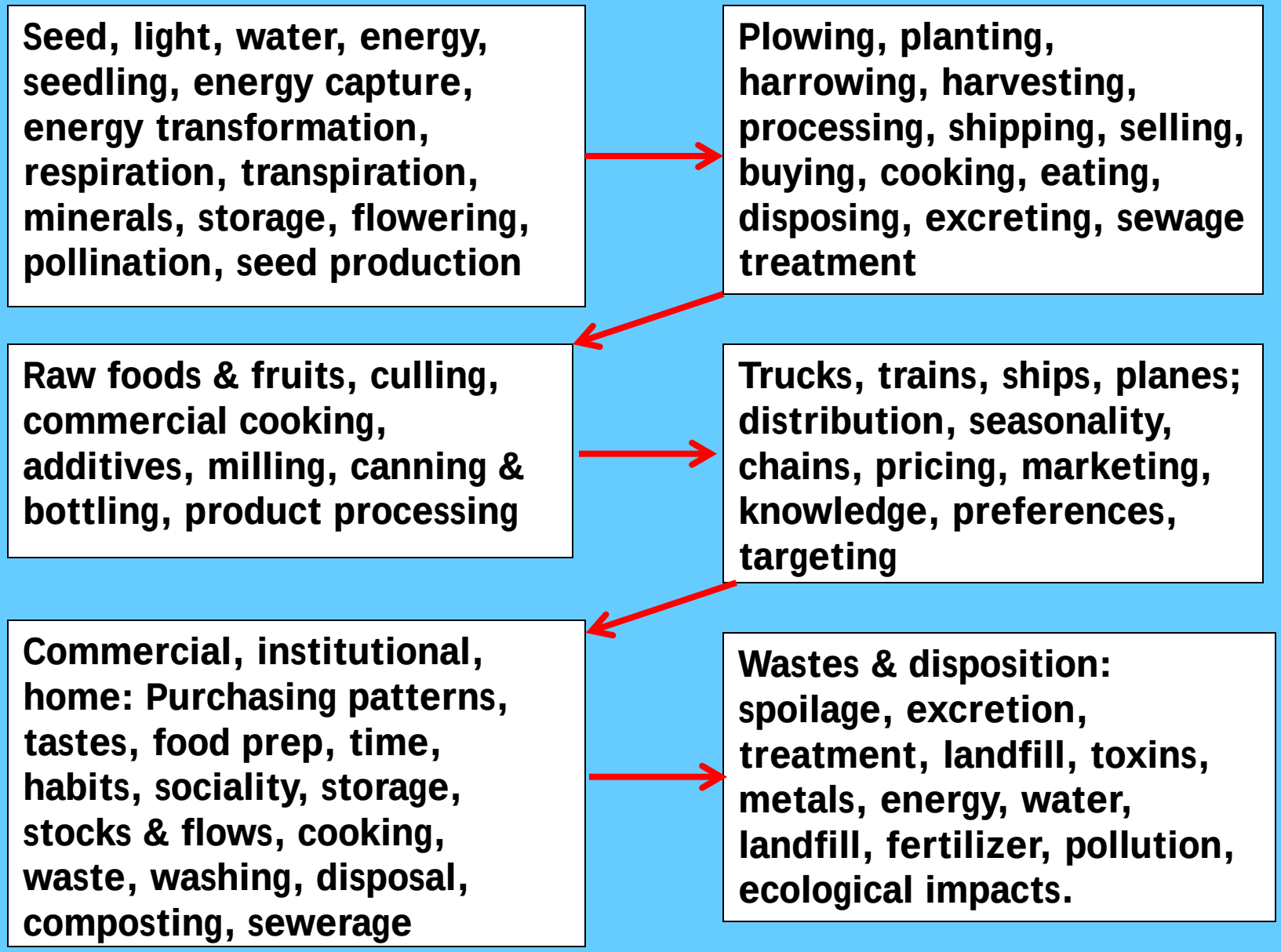


RDL



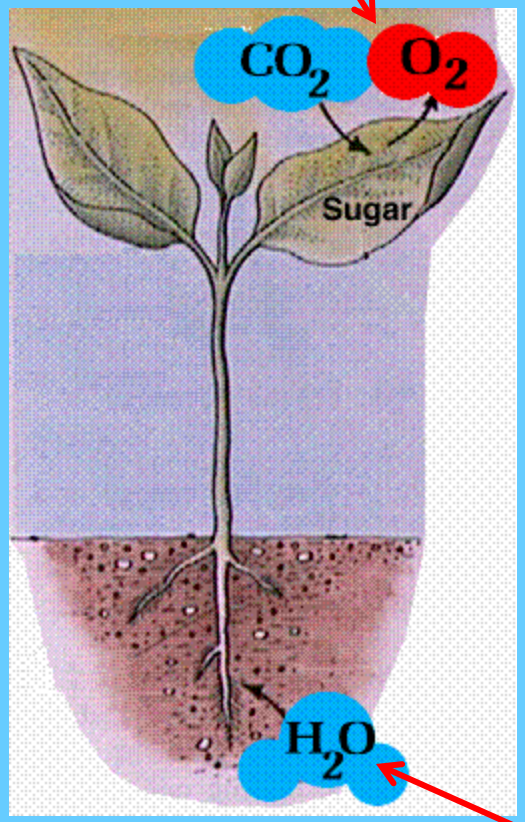
The industrial food cycle

http://www.todaysengineer.org/2012/Jun/Energy-and-the-Economy-Pt1.asp


Seed, light, water, energy, seedling, energy capture, energy transformation, respiration, transpiration, minerals, storage, flowering, pollination, seed production
Plowing, planting, harrowing, harvesting, processing, shipping, selling, buying, cooking, eating, disposing, excreting, sewage treatment
Raw foods & fruits, culling, commercial cooking, additives, milling, canning & bottling, product processing
Trucks, trains, ships, planes; distribution, seasonality, chains, pricing, marketing, knowledge, preferences, targeting
Commercial, institutional, home: Purchasing patterns, tastes, food prep, time, habits, sociality, storage, stocks & flows, cooking, waste, washing, disposal, composting, sewerage
Wastes & disposition: spoilage, excretion, treatment, landfill, toxins, metals, energy, water, landfill, fertilizer, pollution, ecological impacts.

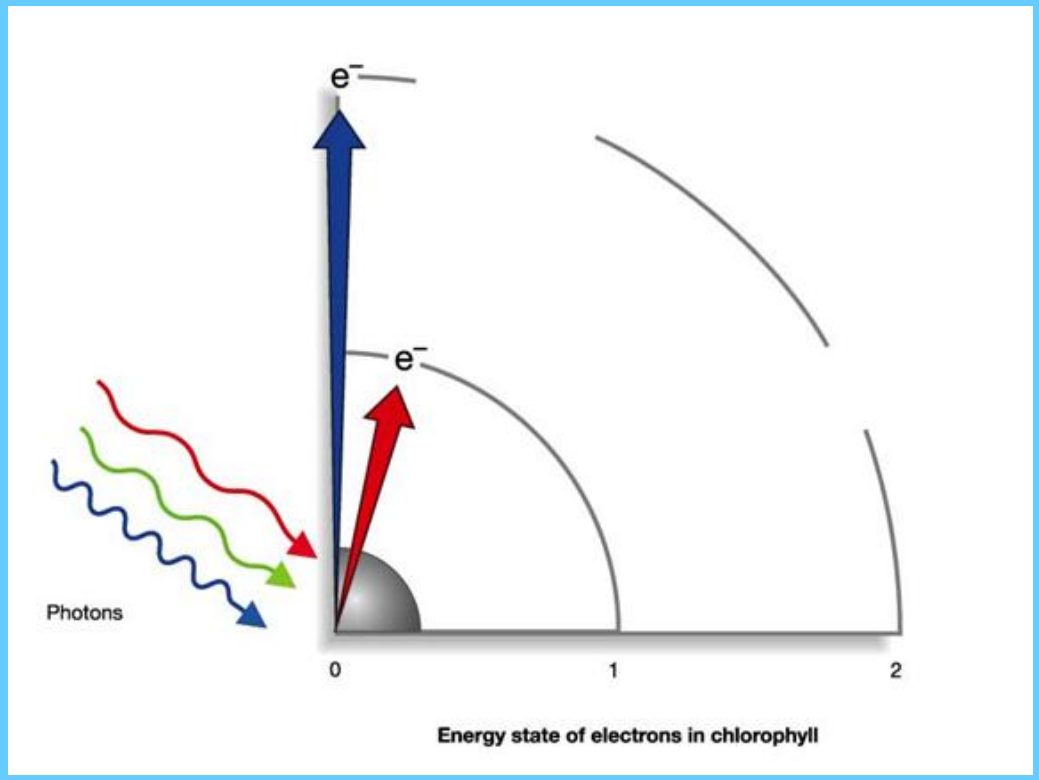
4. Energetics of food
Photosynthesis captures solar energy

Respiration



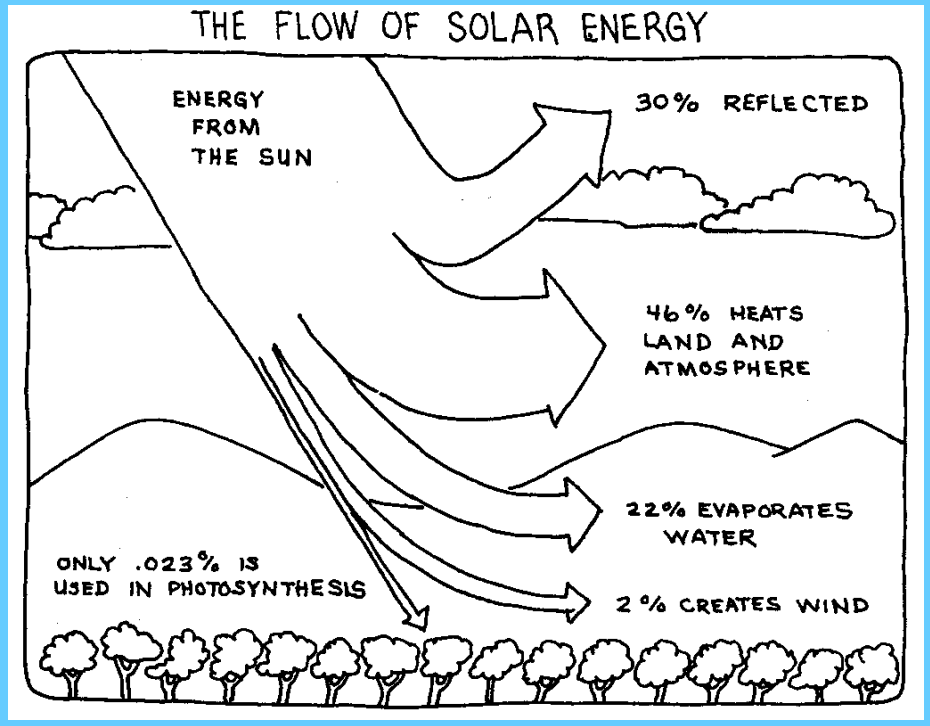
Transpiration

http://www.cartage.org.lb/en/themes/sciences/botanicalsciences/photosynthesis/photosynthesis/photosynthesis.htm

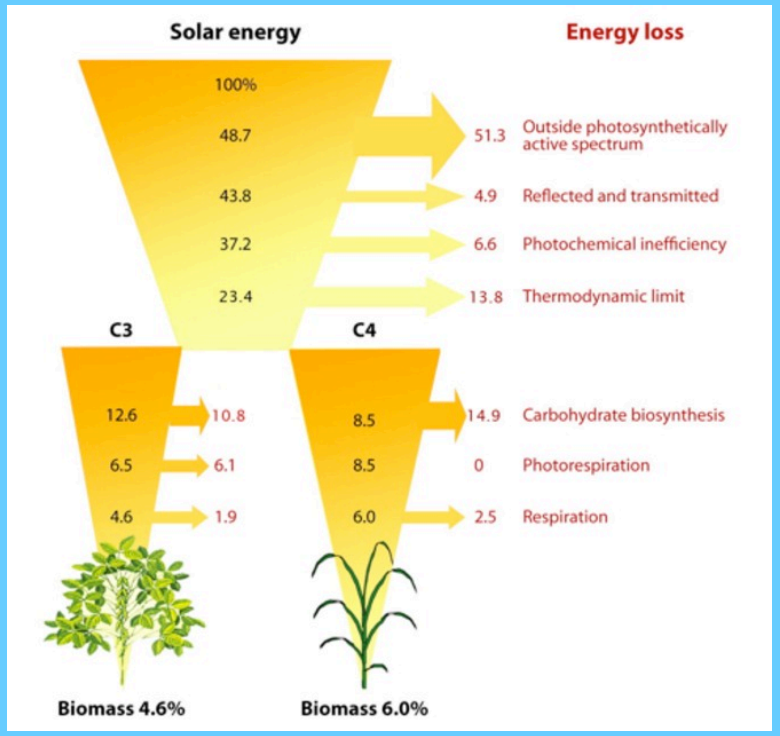


For more, see: http://chemistry.about.com/od/lecturenotesl3/a/photosynthesis.htm

Photosynthesis is low efficiency—but there is so much solar energy!



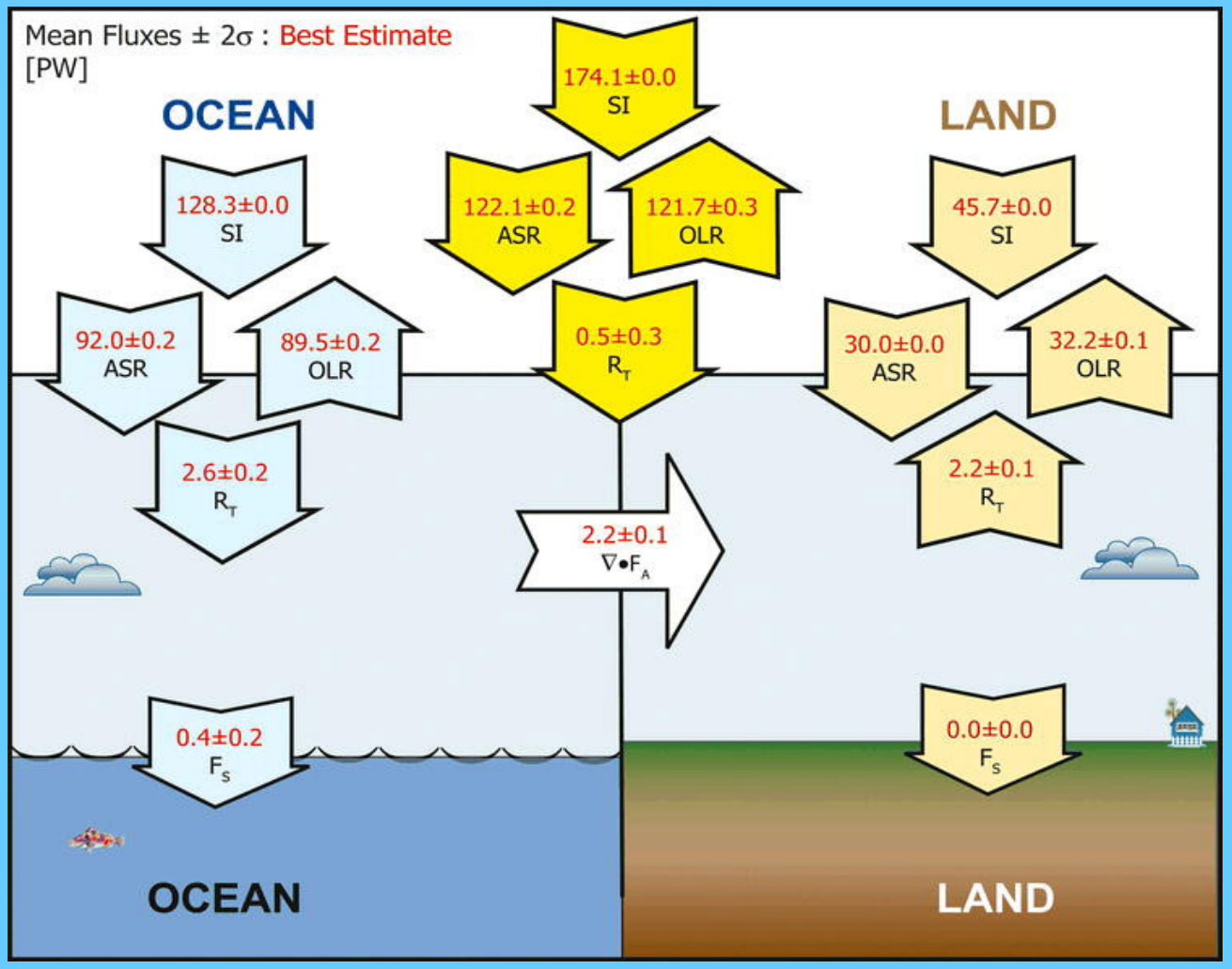
http://www.cd3wd.com/cd3wd_40/vita/envegypr/en/envegypr.htm



http://theconversation.edu.au/for-efficient-energy-do-you-want-solar-panels-or-biofuels-9160

How much?

Solar energy flows to Earth & food



Total food energy:

18.6 quad kWh/yr.

Total solar flux on land:

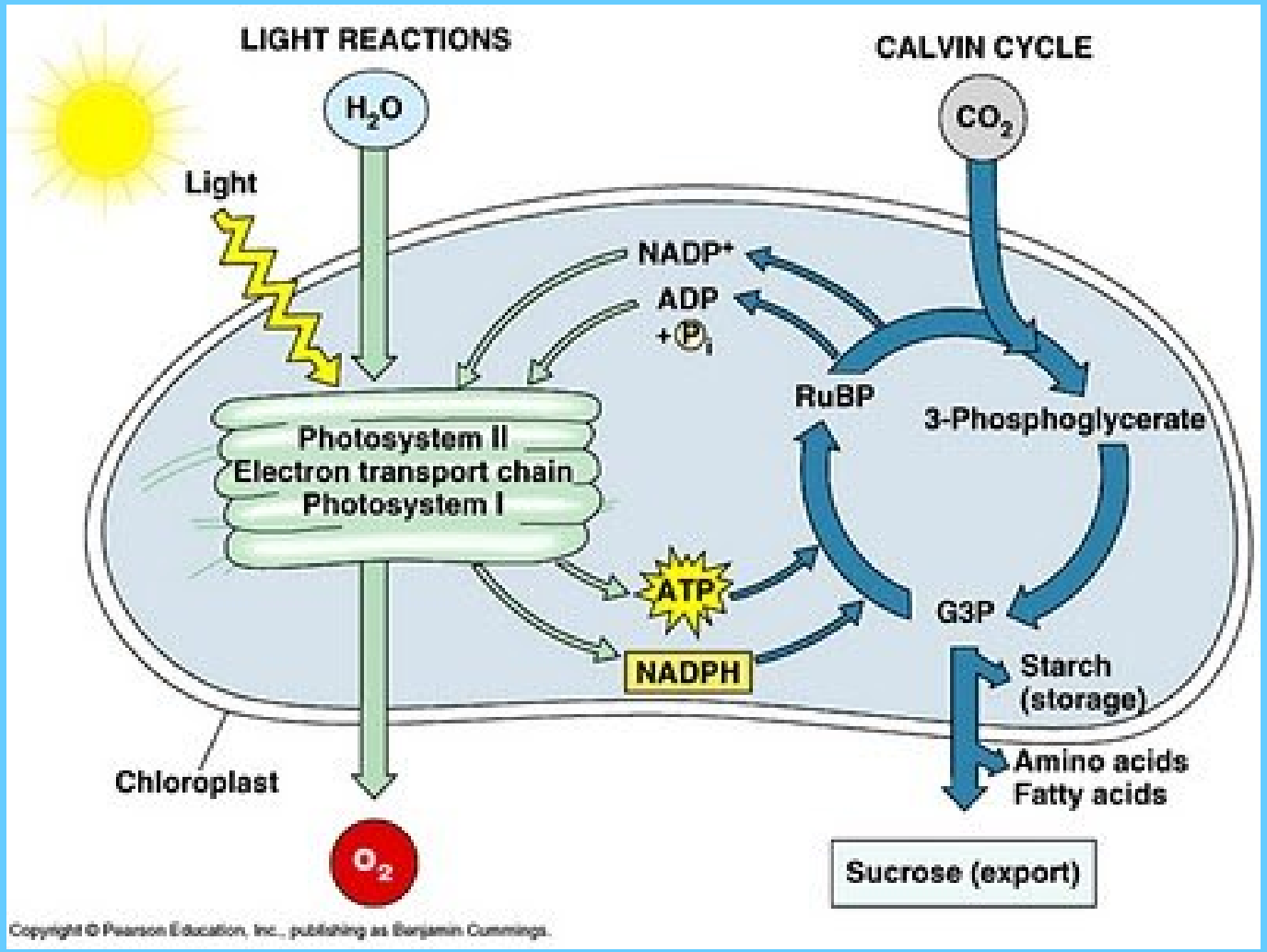
6,000 quad kWh/yr.

But all that solar energy also drives climate & other essential systems

1 PW = 10 billion gigawatts =10 trillion kilowatts *per second!*

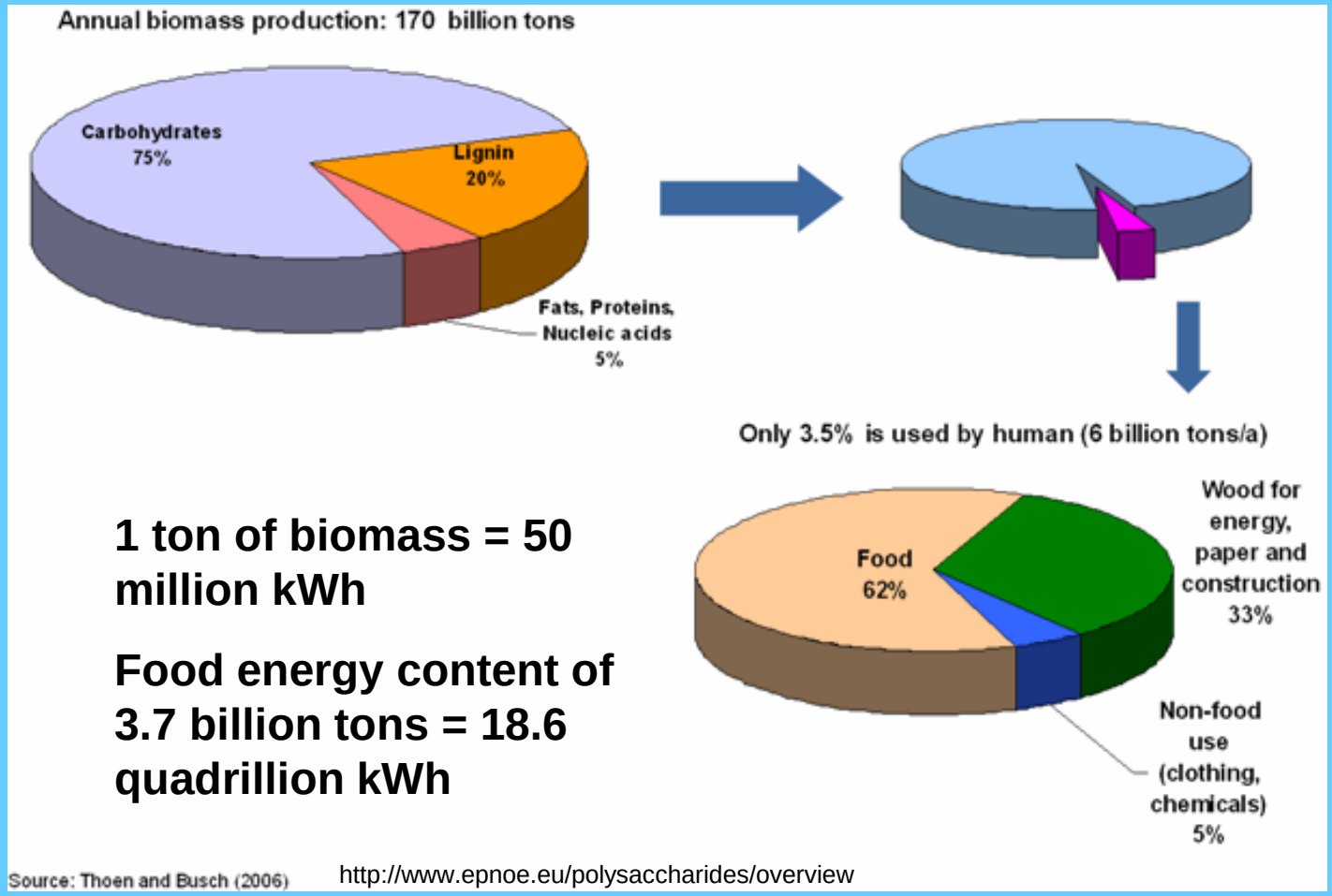
Chemical reactions

$$6CO_2 + 12H_2O + light \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$$



http://www3.sympatico.ca/n.rieck/docs/world_population_limit.html

Carbohydrates constitute the bulk of energy carriers in biomass



1 ton of biomass = 50 million kWh

Food energy content of 3.7 billion tons = 18.6 quadrillion kWh

Source: Thoen and Busch (2006)

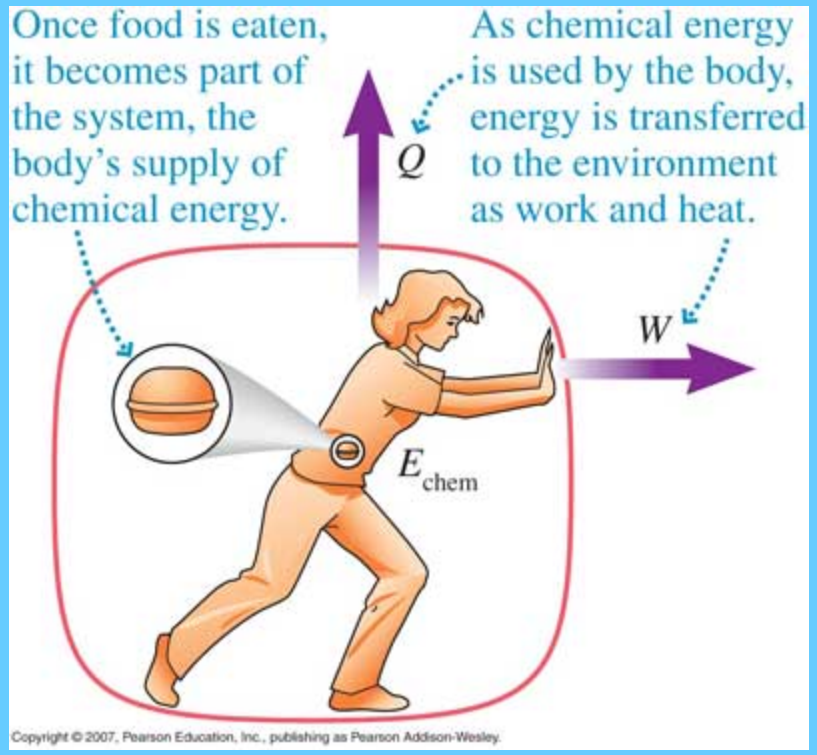
http://www.epnoe.eu/polysaccharides/overview

carbon is our friend!

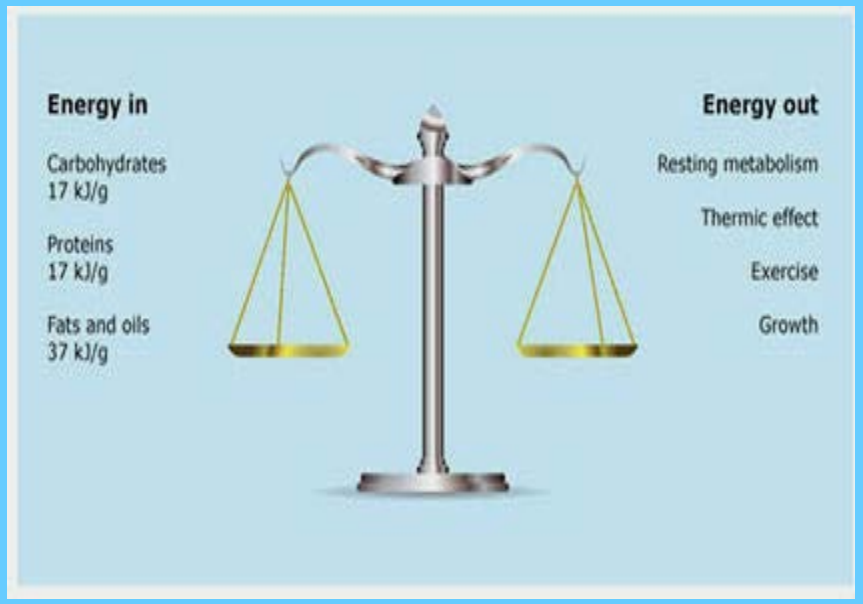
What are energy conversion efficiencies of other devices?

- Solar photovoltaic: ~5-20%
- Wind turbine: less than 59%
- Gas turbine: 40% (combined cycle: 60%)
- Fuel cell: up to 85%
- Internal combustion engine: 10-50%
- Electricity generation: ~35%
- Electric motor: 30-90%
- Incandescent light bulb: 5%
- LED: 15-35%
- Electricity or fuel must be mined or pumped, moved, processed or generated—all require energy

Work *from* food

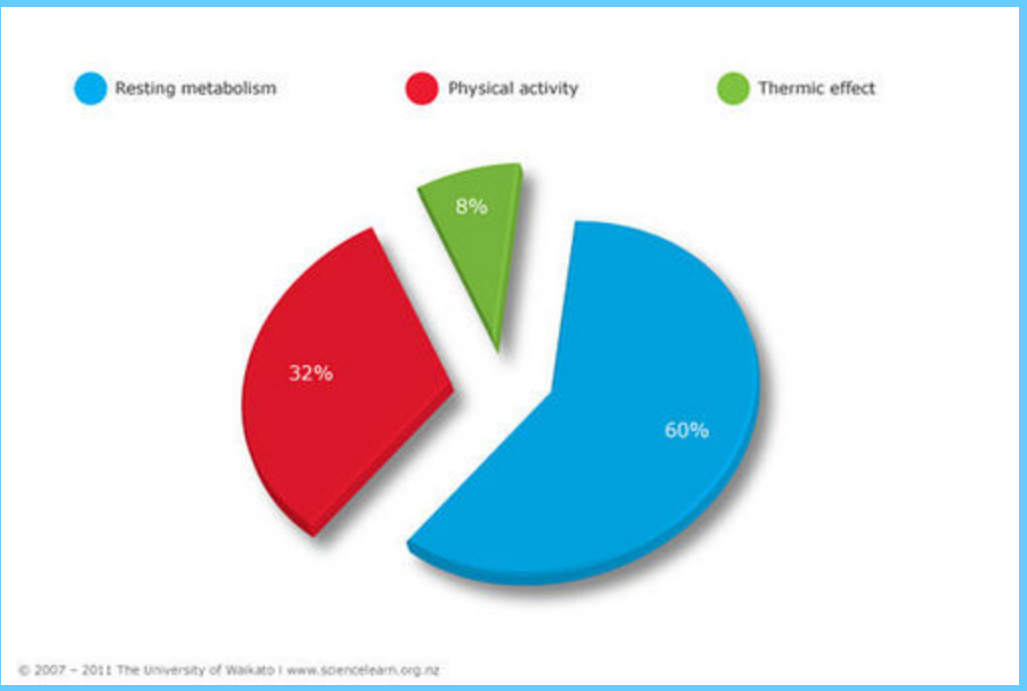


http://whs.wsd.wednet.edu/Faculty/Busse/MathHomePage/busseclasses/apphysics/studyguides/chapter11_2008/Chapter11StudyGuide2008.html



http://www.sciencelearn.org.nz/Contexts/Digestion-Chemistry/Sci-Media/Images/Energy-balance

Energy in the body

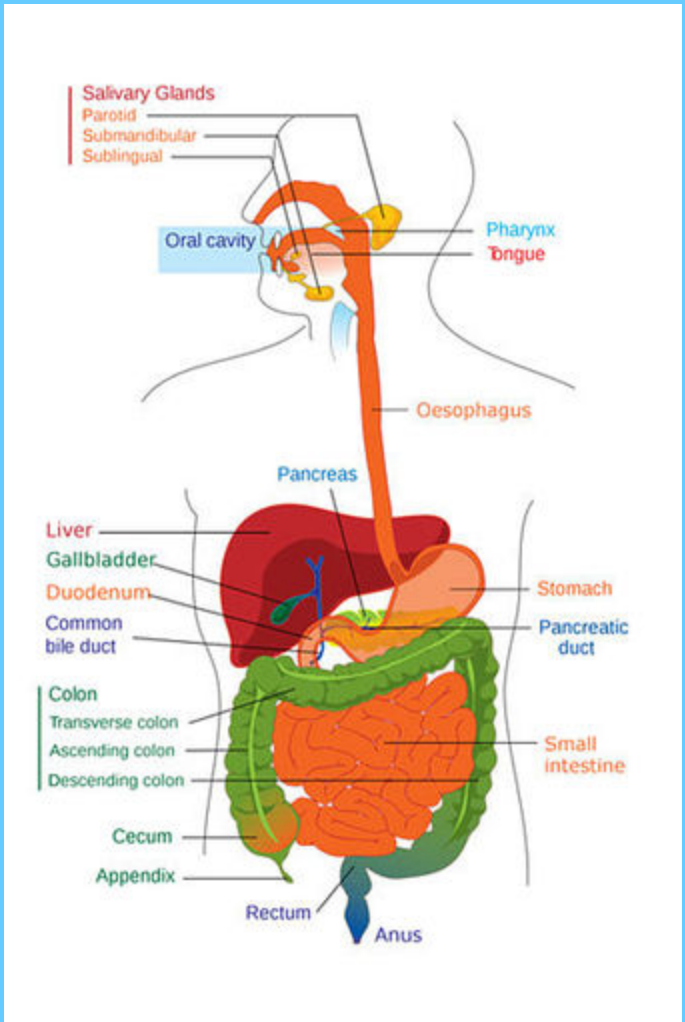


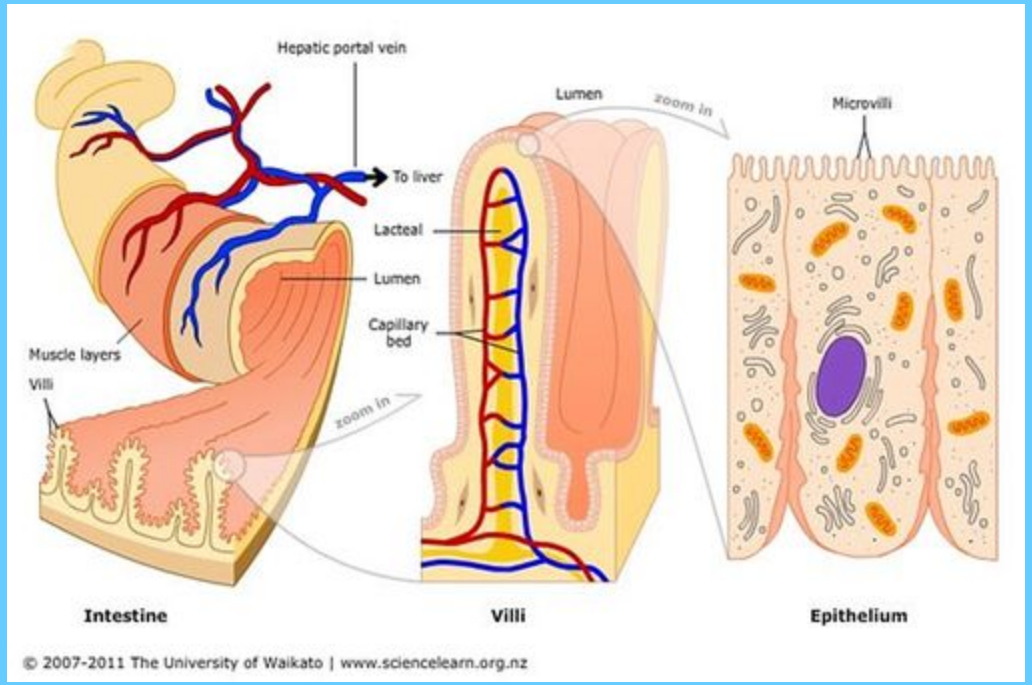
http://www.sciencelearn.org.nz/Contexts/Digestion-Chemistry/Sci-Media/Images/Total-daily-energy-expenditure

http://www.insidethearts.com/scanningthedial/2011/11/08/jack-allen/4166/light-bulb-idea-hand-3/

At rest, the body emits energy roughly equal to a 100 watt incandescent light bulb

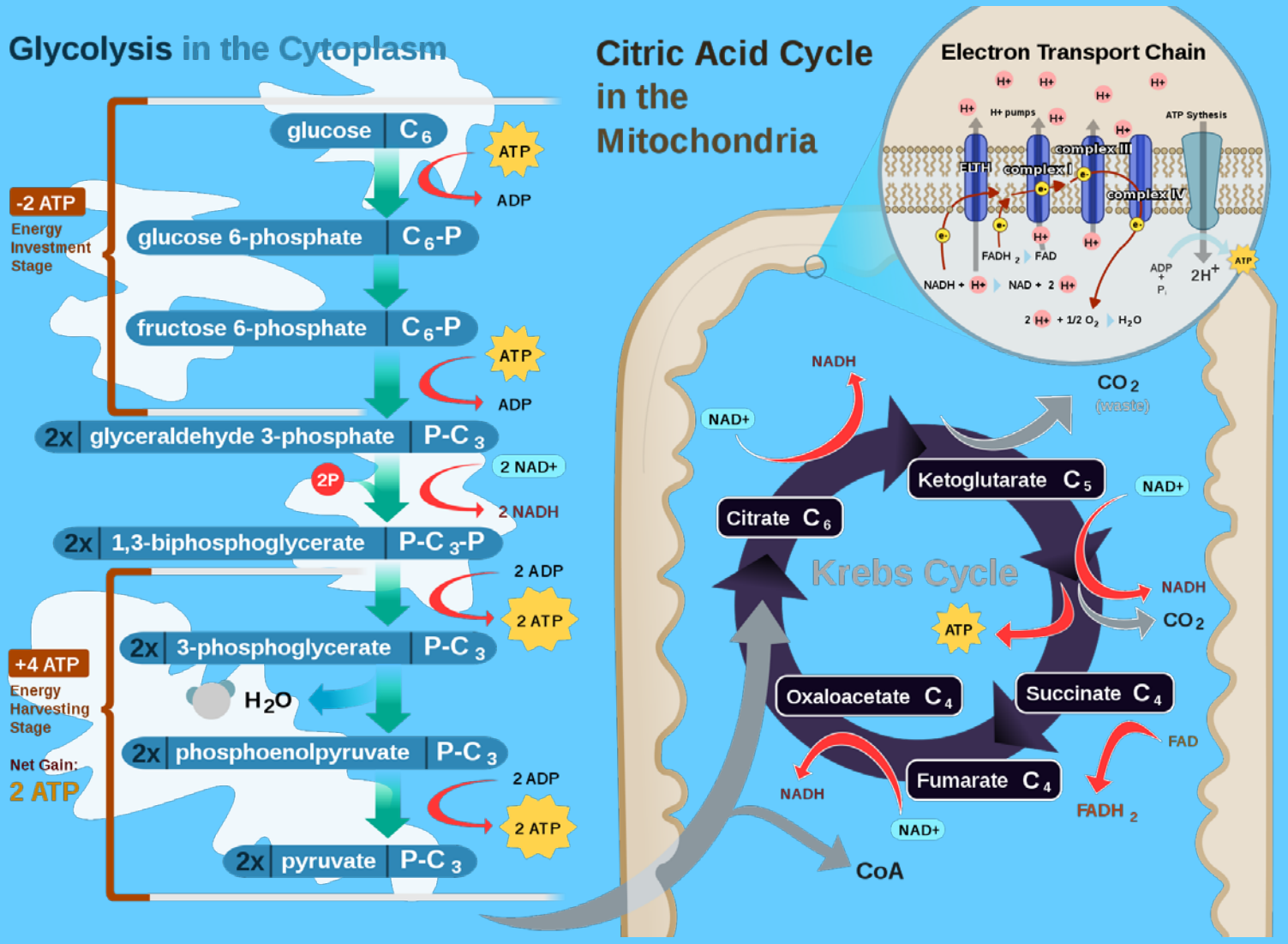
Digestion breaks food down





http://www.sciencelearn.org.nz/Contexts/Digestion-Chemistry

Conversion of food to energy in body



http://inoxx.net/wp-content/uploads/2010/08/2000px-CellRespiration.svg_.png

Energy content of foods

Main meal items	Portion size (g)	Energy (kJ)	Protein (g)	Fat (g)	CHO (g)
Roast potato	200	866	5.0	1.0	44.0
Chicken (roast)	150	1010	36.9	10.4	0.0
Asparagus	80	88	2.8	0.2	2.0
Carrot	50	55	0.4	0.1	2.8
Butter chicken sauce	40	240	1.0	4.0	3.9
Ice cream (low fat)	120	706	5.8	4.0	29.6
Peaches (canned)	120	270	1.1	0.12	15.0
Orange juice	250	364	1.9	0.3	21.5
Total		**3,599**			

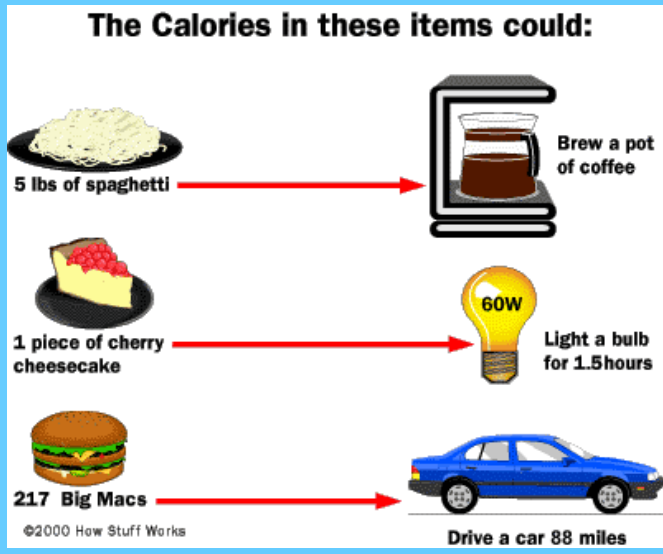
1 kJ = 0.24 kcal; 3,600 kJ = 864 (k)calories

1 food calorie = 1,000 energy calories = 0.0012 kWh

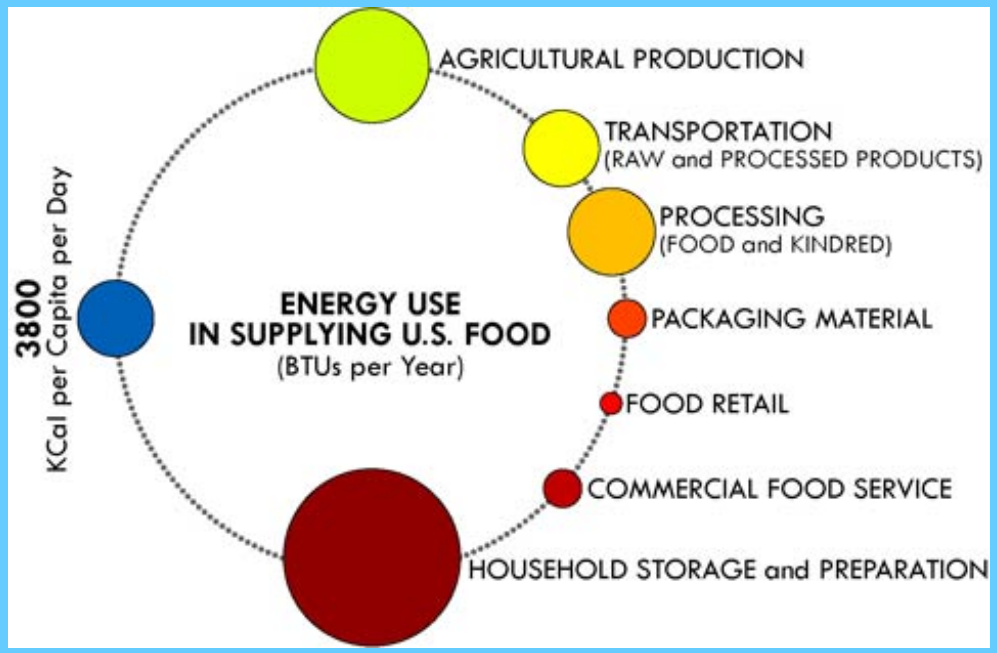
1,000 food calories = 1.16 kWh

Daily U.S. diet = 2,000 food calories

http://www.myfitat50.com/real-life-diets-that-work/

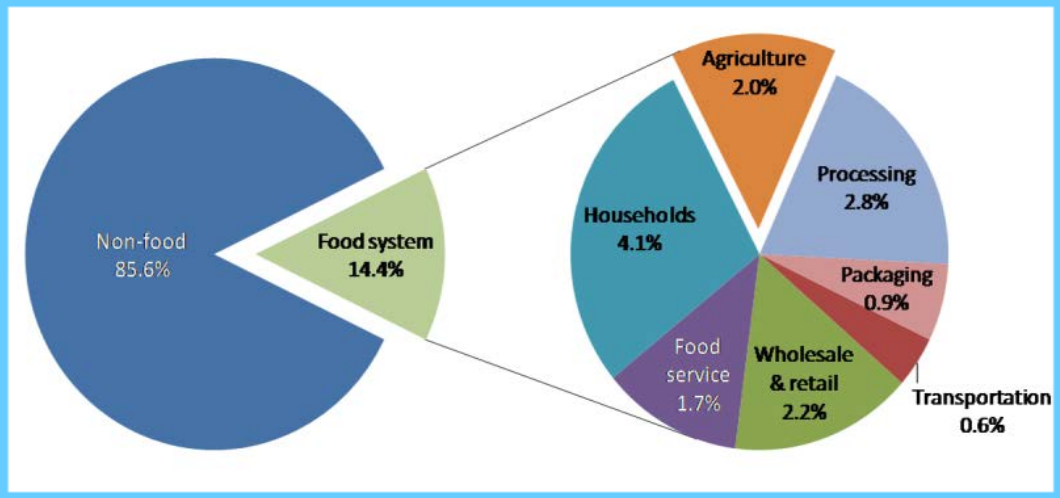


5. Other inputs *into* food production



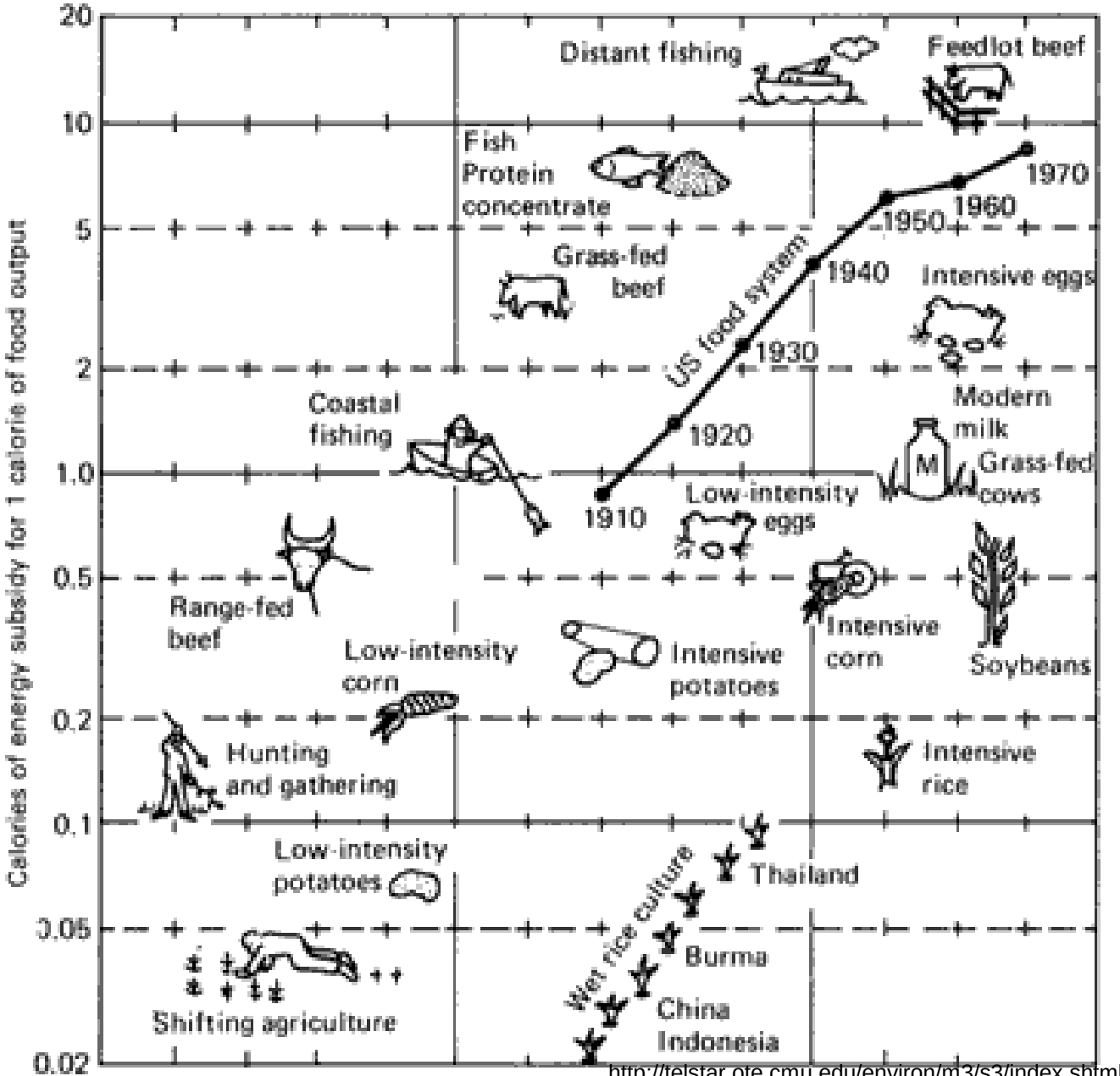
http://www.myclearwater.com/gov/depts/planning/divisions/LRplan/plans/greenprint/food_production.asp

http://www.postcarbon.org/article/273686-beyond-food-miles



Humans provide energy “subsidies” to grow food

Logarithmic graph



http://telstar.ote.cmu.edu/environ/m3/s3/index.shtml

A considerable amount of energy & food are simply wasted

Food Category	Total Energy (Trillions of Btu's)	% of total	% wasted	Amount Wasted (Trillions of Btu's)
Grains	838	10.5	32	271
Vegetables	1580	19.7	25.3	379
Fruit	1040	13	23.4	243
Dairy	1360	17	32	441
Meat, Poultry & Fish	1950	24.4	16	316
Eggs	229	2.8	31.4	72.9
Dry beans, peas, & lentils	35.6	.04	15.9	5.74
Tree nuts and peanuts	40.9	.05	15.9	6.58
Caloric Sweeteners	566	7	30.5	175
Fats and oils	353	4.4	33.4	119
Totals	**7980**			**2030**

Table 2. Food Losses at the Retail, Foodservice and Consumer Levels, 1995

Commodity	Edible Food Supply* (million pounds)	Percent Loss
Grain Products	45,606	32%
Fruit	48,338	23
Vegetables	63,077	25
Dairy Products	76,276	32
Meat, poultry & fish	51,466	16
Eggs	7,918	31
Caloric Sweeteners	38,827	31
Other	24,374	30
Total	355,883	27%

* Excludes non-edible food parts.

Source: Economic Research Service, USDA

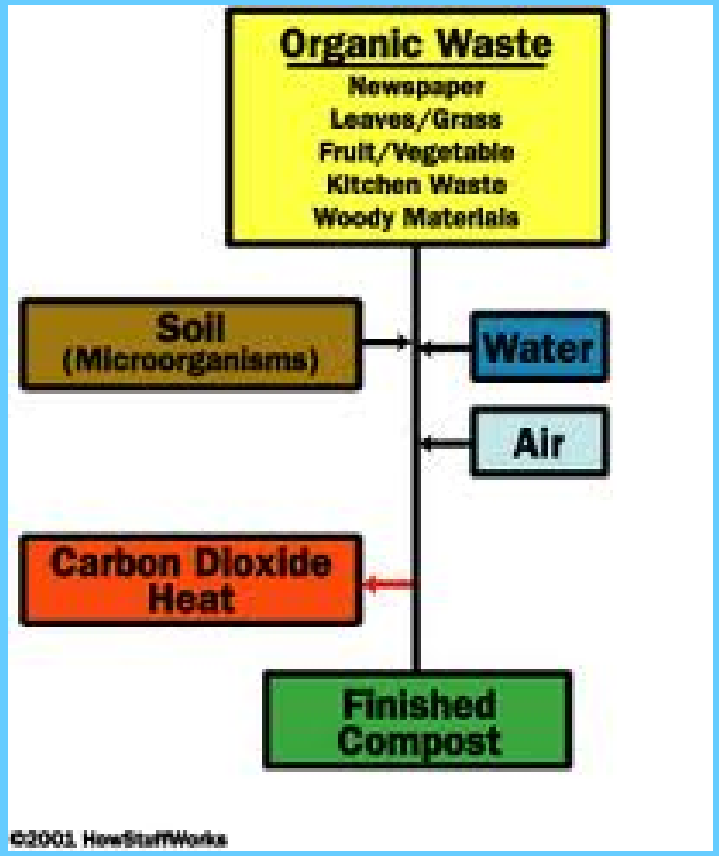
http://www.extension.iastate.edu/agdm/articles/hof/HofOct07.html

Wasted food contains energy & minerals

Type of food waste	pH	Total nitrogen (%)	Phosphate (%)	Potassium (%)	Salt (%)	Moisture (%)
Wet food waste	4.98	3.40	1.10	0.60	4.10	78.5
Food waste compost	7.84	1.70	1.20	1.00	2.90	55.0
Earthworm excrement	7.48	1.89	1.60	0.50	0.43	65.0

Annual US food waste contains 150 trillion kCal of residual energy

Closing the food cycle?



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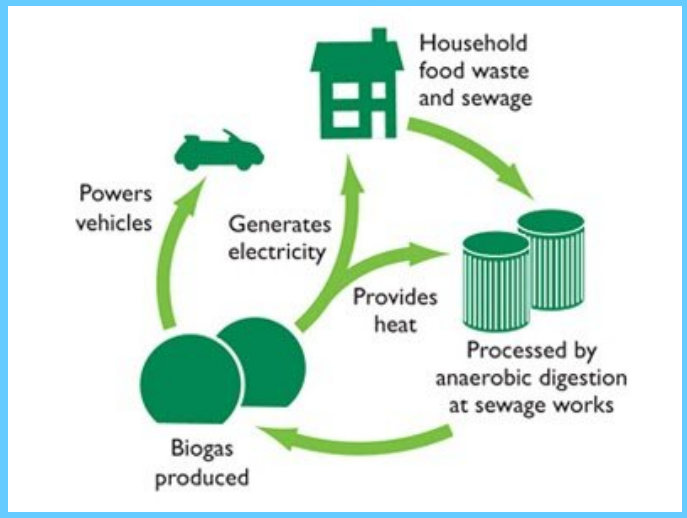
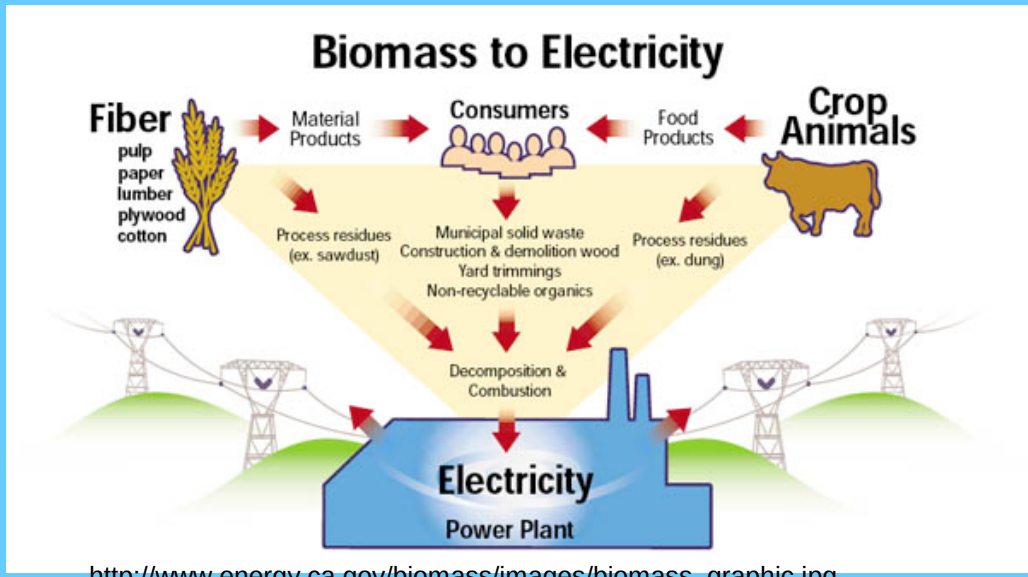
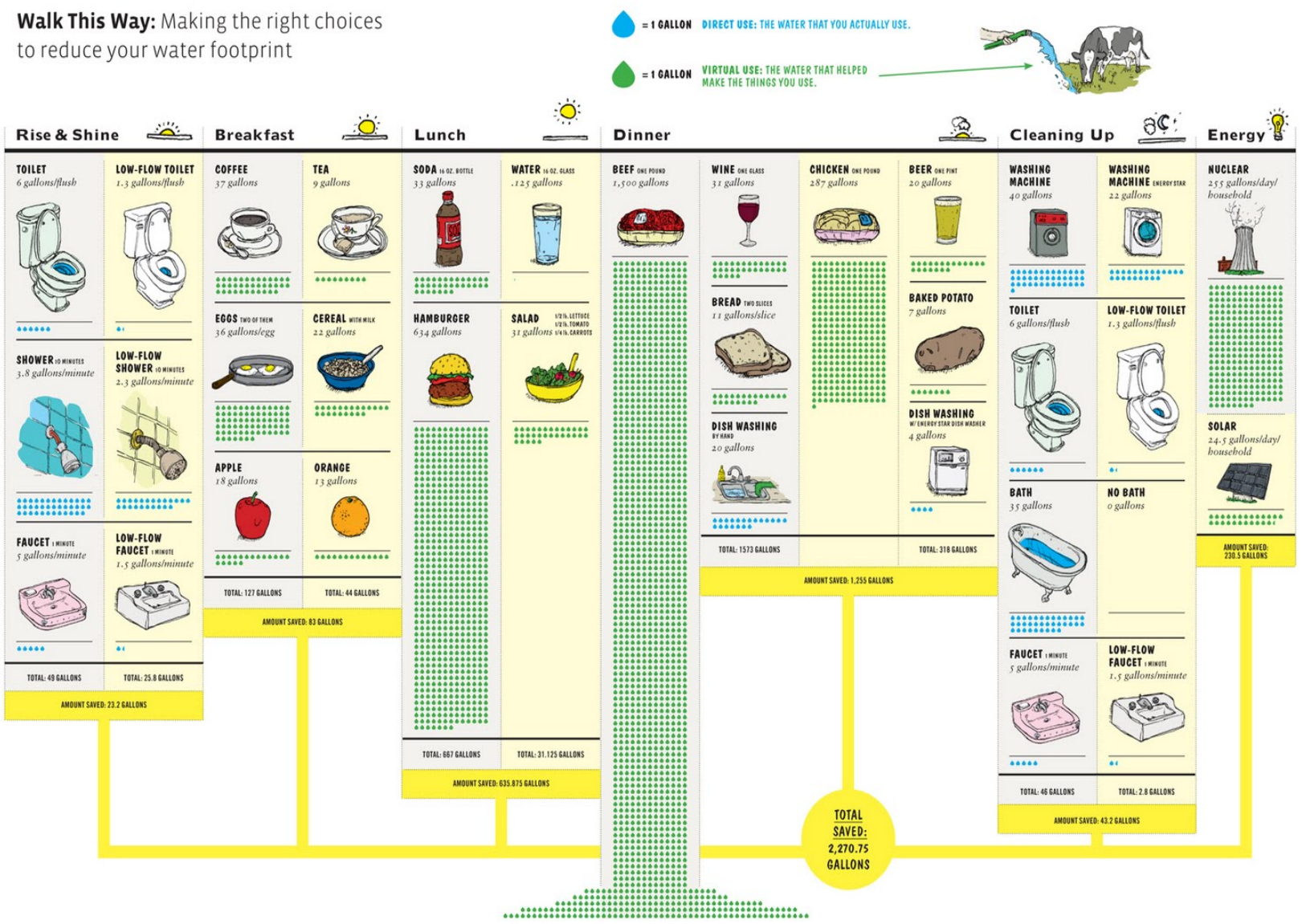


http://www.eco-rally.org/sites/default/files/tips/recycling-food-waste.jpg

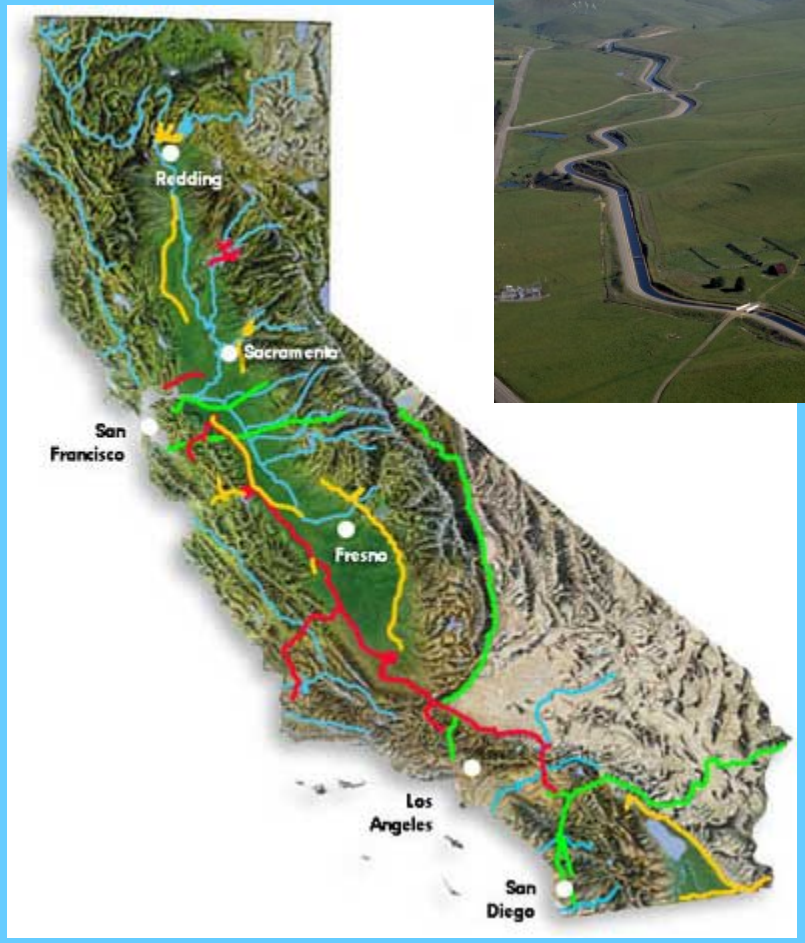


http://www.energy.ca.gov/biomass/images/biomass_graphic.jpg

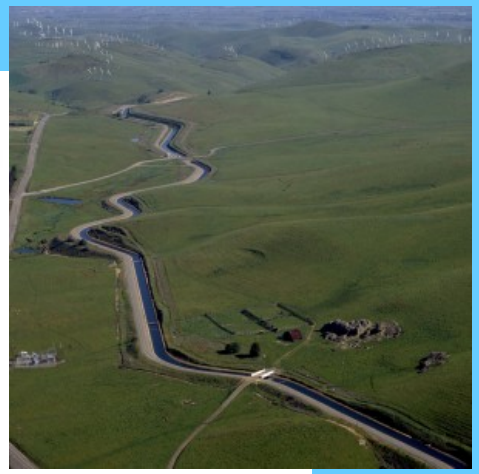
A Few Words about Water & Food



California has a substantial hydraulic system for irrigating food crops



http://www.aquafornia.com/where-does-californias-water-come-from/



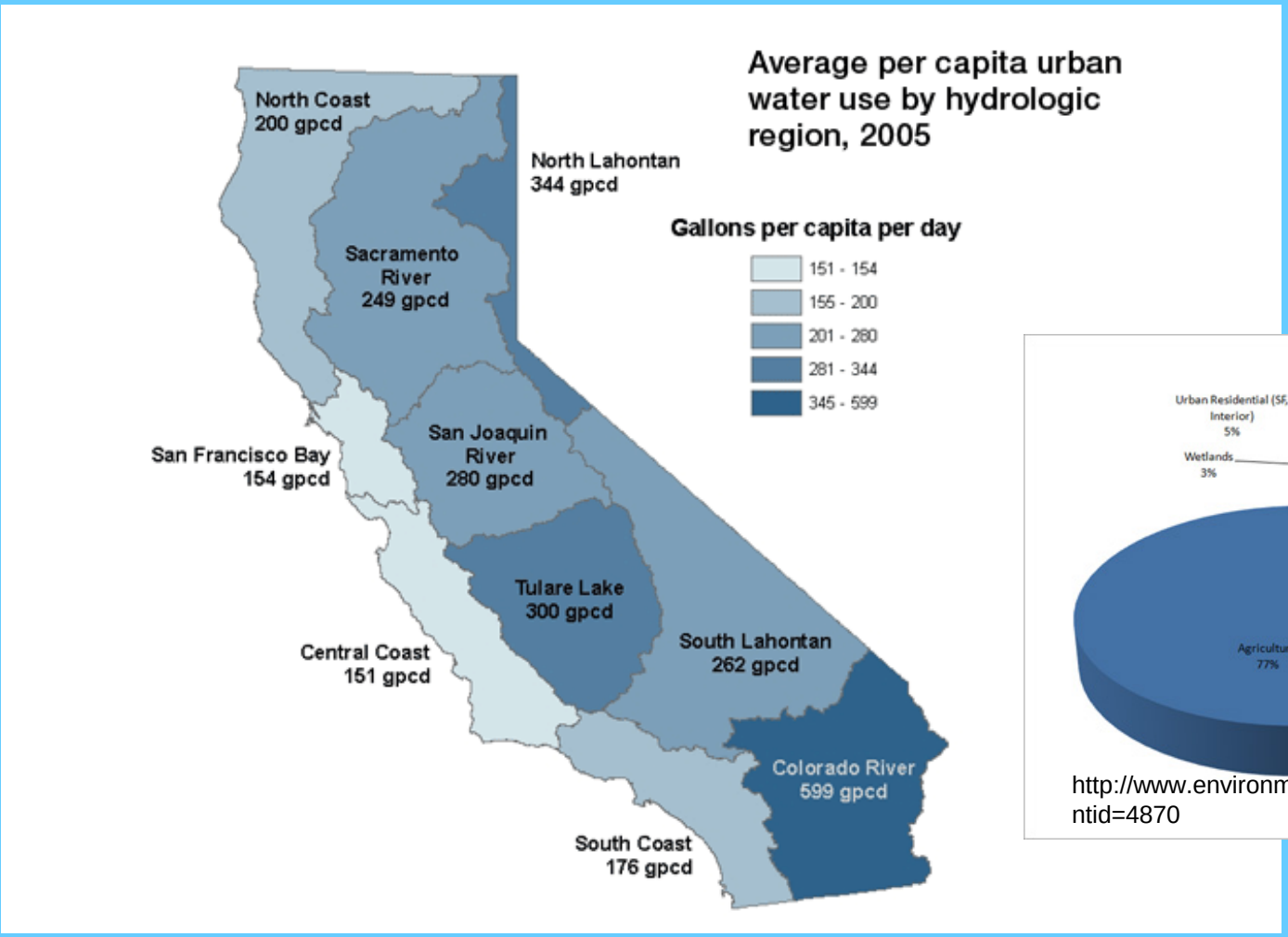
http://www.californiabusinesshistory.com/Agribusiness.html

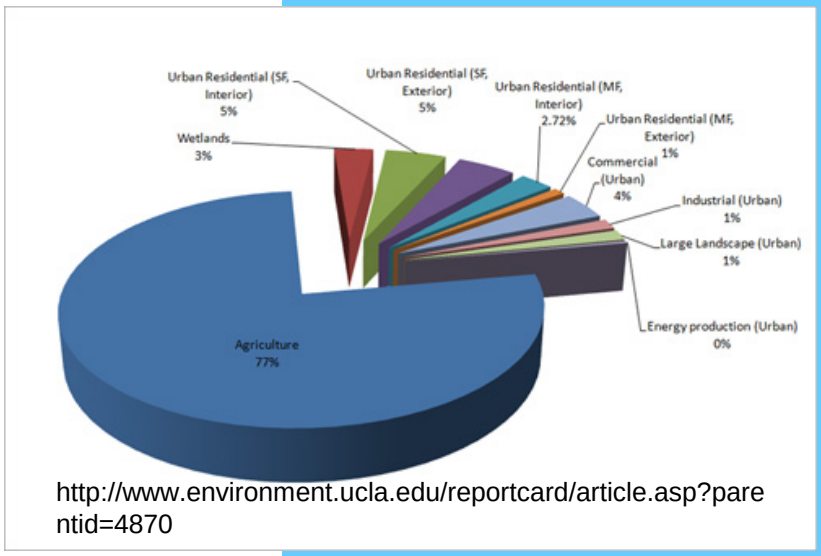
Marijuana crop = $14 billion/yr.

	Sacramento	San Joaquin
Alfalfa	121.9	137.2
Corn	121.9	121.9
Cotton	76.2	76.2
Melons	152.4	152.4
Safflower	7.6	61.0
Sunflower	73.8	73.8
Tomatoes	106.7	106.7
Wheat	15.2	50.9

Irrigation rates (cm) for California's Sacramento and San Joaquin Valleys.
http://www.plantsciences.ucdavis.edu/Agroecology/Outreach/Modeling.html

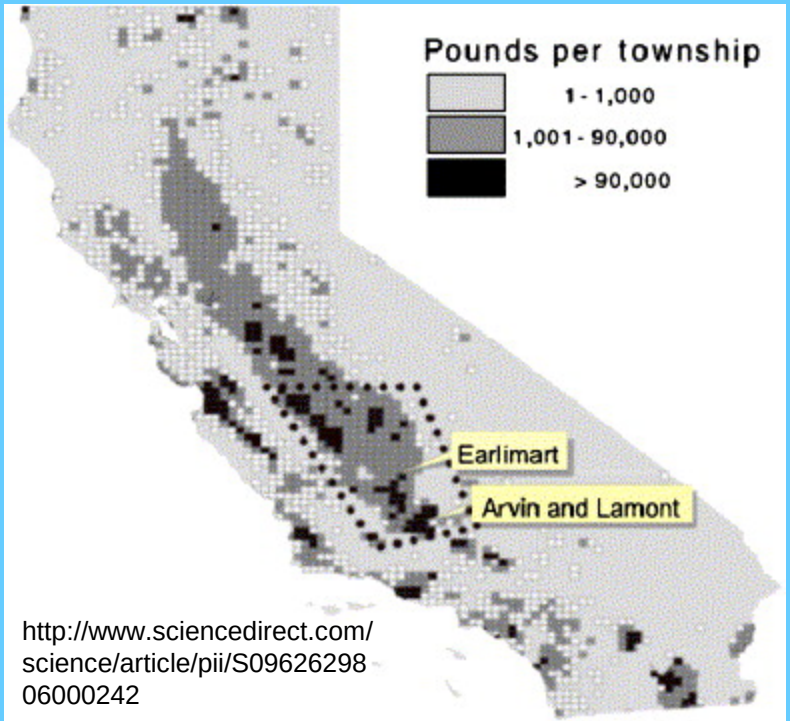
Relative water use in California



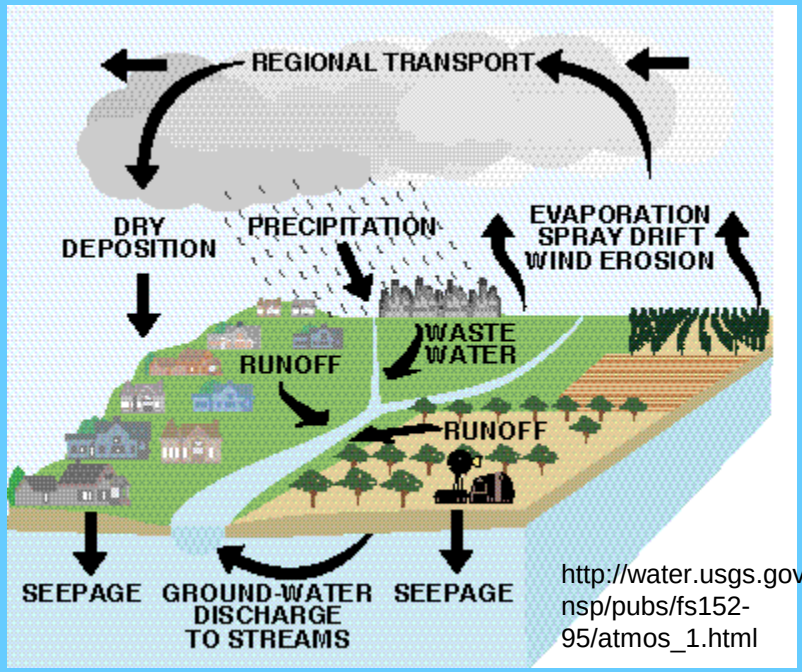


http://www.environment.ucla.edu/reportcard/article.asp?parentid=4870

Pesticide inputs



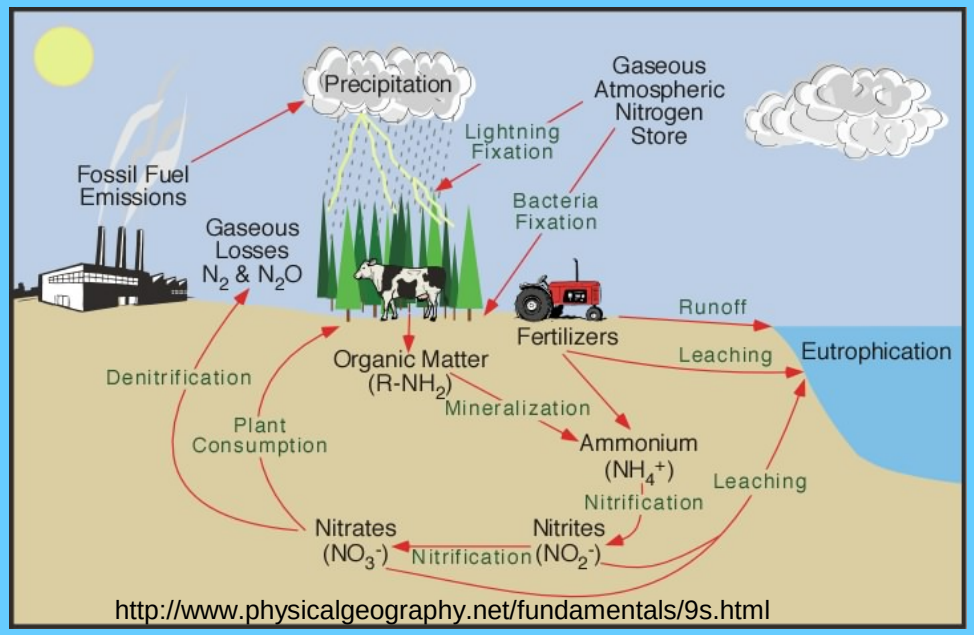
http://www.sciencedirect.com/science/article/pii/S0962629806000242



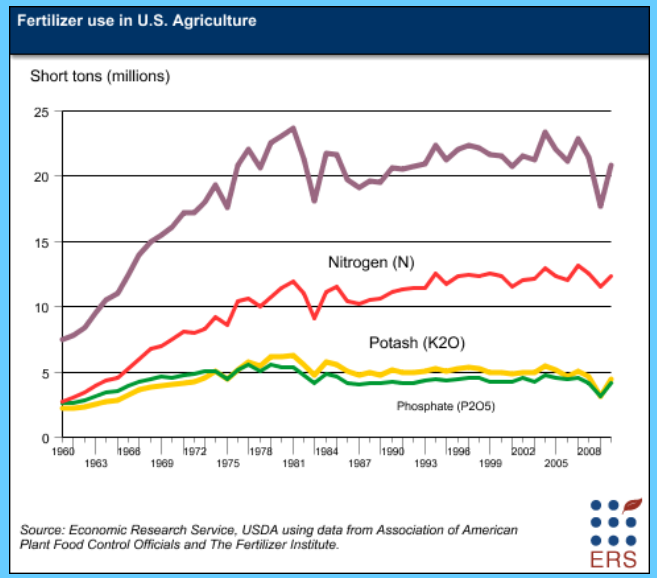
http://water.usgs.gov/nawqa/pnsp/pubs/fs152-95/atmos_1.html

http://www.coloradofarmworkers.com/RTF1.cfm?pagename=Legal%20Rights%20of%20Farm%20Workers

Chemical fertilizers

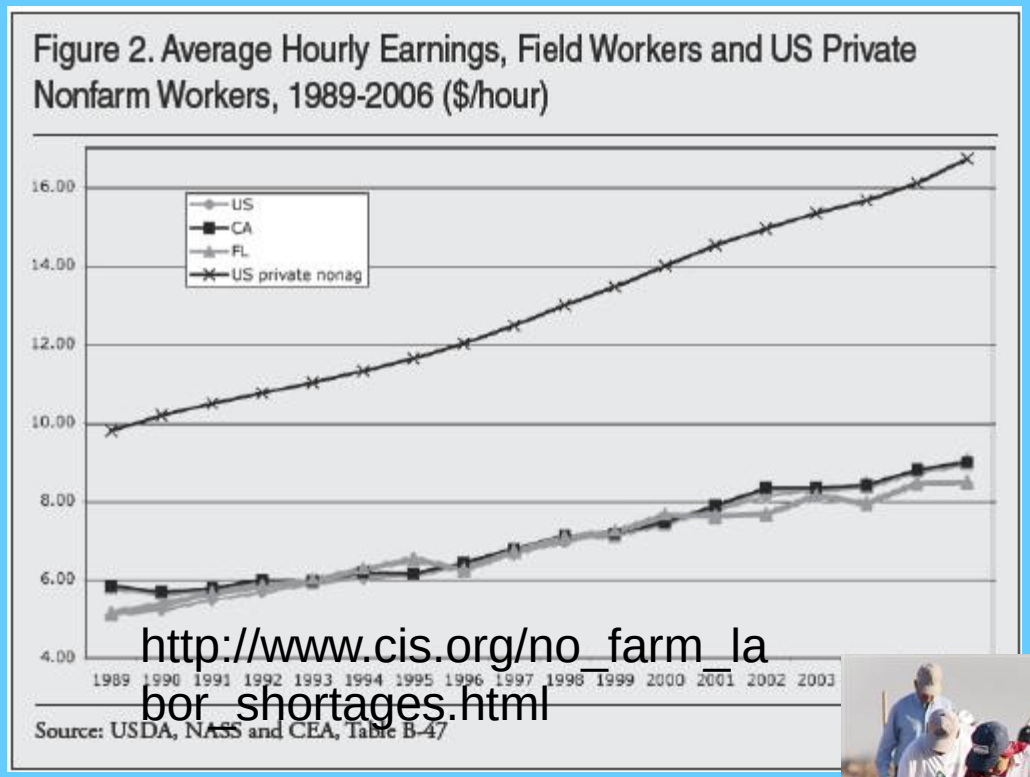


http://www.physicalgeography.net/fundamentals/9s.html



http://www.ers.usda.gov/topics/farm-practices-management/chemical-inputs/nutrient-use-markets.aspx

http://www.cdfa.ca.gov/is/ffldrs/about_fertilizer.html

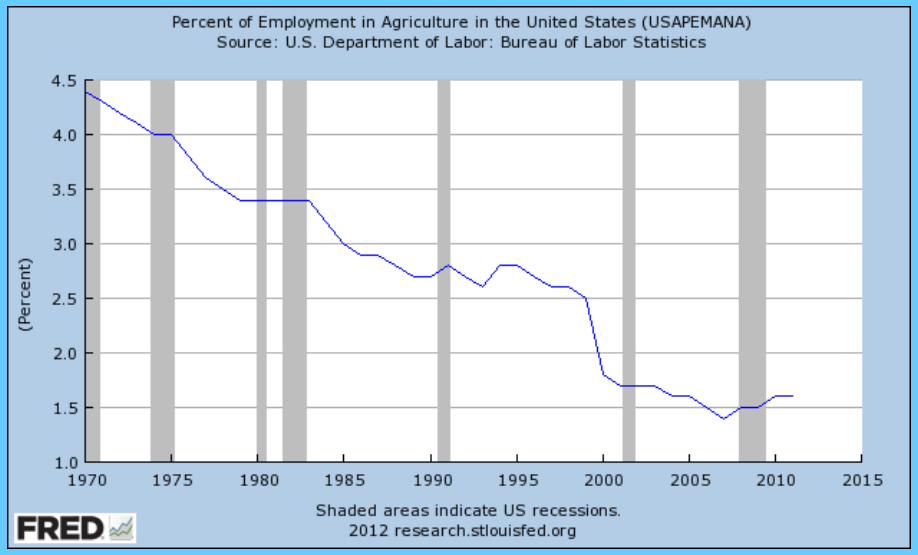


http://www.cis.org/no_farm_labor_shortages.html

http://are.berkeley.edu/~howardrr/pubs/lmd/html/wintspring_99/LMD.8.1.laborisks.html

http://bigteaparty.com/farm-workers-in-the-us/

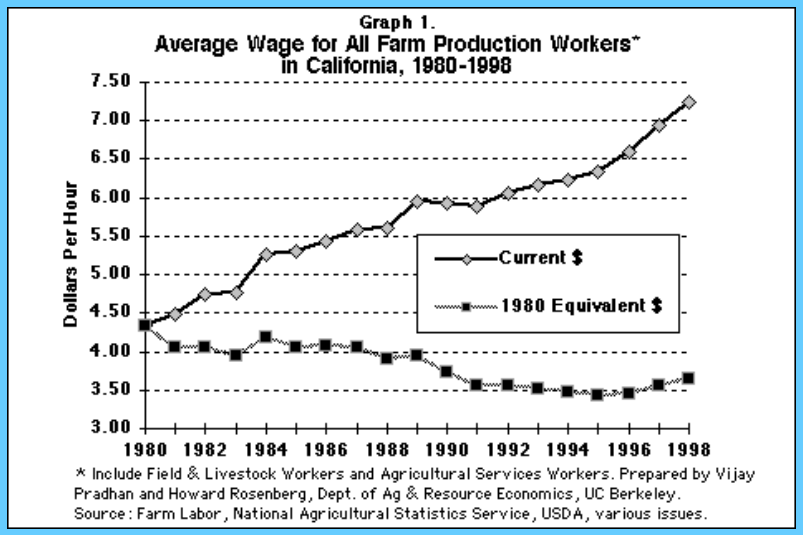
Who does the work?



http://research.stlouisfed.org/fred2/graph/?s[1][id]=USAPEMANA

- 80% of 2.5 million farm workers in the US are foreign born (2,025,000)
- 77% are from Mexico / 2% from Latin America / 1% from Asia
- 20% U.S.-born – 9% Hispanic, 7% white, 1% blacks, 3% other
- 52% undocumented workers
- < 5% of Mexican & Latin American-born speak English "well"
- 20% have less than 4th grade education
- 38% have only 4-7 years of school
- ½ of all farm-workers earn <$15,000 per yr
- 61% of all farm-workers live below the poverty level
- 4 out of 5 are men
- Median age is 29
- 45% have children
- 290,000 farm-workers are 15-17 yrs old

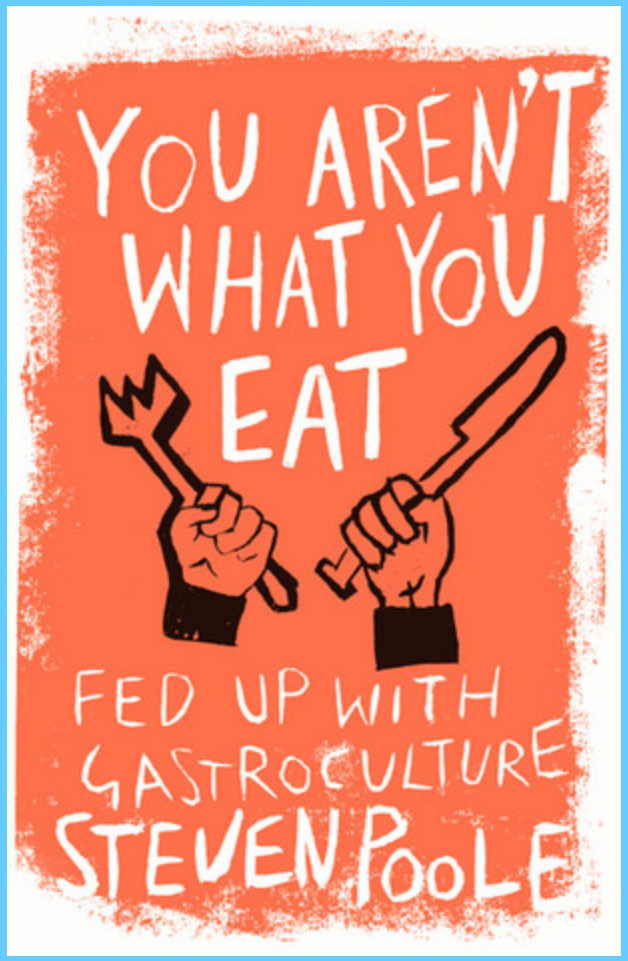
http://best.berkeley.edu/research/farmworkers/support/IWT_SEGURO_print.pdf



http://are.berkeley.edu/~howardrr/pubs/lmd/html/wintspring_99/LMD.8.1.laborisks.html

Why food fetishism?

- The well-off can afford more expensive food
- They are also more in charge of their “wellness” (health)
- Efforts by health sector to reduce expenditures
- Rise of identity politics since the 1960s
- Profit opportunities in specialized food sectors
- What about those who cannot afford such food?



What have we left out?

- Who benefits from the existing food system?
- How is the food system subsidized, and by whom?
- Why is industrial food cheaper than hand-raised food?
- Who provides the labor for industrialized agriculture?
- Where do energy inputs into food production come from?
- What about turning food into energy?
- Can the industrial food system feed the world?
- Could local organic agriculture feed the world?
- Are there limits to industrial food production?
- How much arable land is there in the world?
- Who owns it? Who is acquiring it? Why?
- Is closed cycle agriculture possible? What would it cost?