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Physics and General Engineering
Winona State University
https://ntmoore.github.io/

Everyone eats food, but the Calorie requirements associated with life never quite seem to make it into the Physics textbooks I've used. I think that talking about the food requirements of a family, city, or country can be an illuminating connection to make when talking about energy. Talking about food energy also allows for surprisingly powerful ethical claims about how people have been oppressed in the past.

The talk includes several classroom-ready discussions/problems, featuring: Cannibalism in Aztec culture (was it necessary because they were starving?), The Irish Potato famine (was it a "Natural Disaster"?), and the practicality of living off the land.

Detailed story: https://arxiv.org/abs/2301.06637

These stories have been used with:

- Winona State University students
- 18-22yo
- All majors (Engineering, ElemEd, Biology, Business)
- Math is mostly unit conversion.
- Story+data+question on the slide, “Now talk to the person next to you about what they think…”
- Sometimes graded as project or homework

- Data, figures, articles, slides are available at: https://github.com/ntmoore/food_energy_paper

First Half of the talk: What is energy?


Ice Cream
COUNTER
PIZZA
COUNTER
dolls
action figures
duplo
sports
color
color
APLI
paper

Physics

Electric Company

Hospital Dietician

Energy Unit Conversion Factors

		J	kWh	Btu
1 Joule (J)	Equals	1	2.78×10^{-7}	9.49×10^{-4}
1 kilowatt hour (kWh)	Equals	3.60×10^{6}	1	3,413
1 calorie (cal)	Equals	4.184	1.16×10^{-6}	3.97×10^{-3}
1 British thermal unit (Btu)	Equals	1,055	2.93×10^{-4}	1
1 foot-pound (ft lb)	Equals	1.36	3.78×10^{-7}	1.29×10^{-3}
1 electron-volt (eV)	Equa	1.60×10^{-19}	4.45×10^{-26}	1.52×10^{-22}

Semiconductors+ Chemistry

Gasoline engines

HVAC

1 **kilocalorie (kcal)** heats
1 kg Water by 1deg C

Or 1 **calorie** heats
1 gram of water 1deg C

1 kcal = 1 Calorie = 1000calories

Portioner per förpackning/pakke: 3 Portionsstorlek/Portionsstørrelse: 50g

Ernæringsinformation	/ 100g	/ 50g (%*)
Energi	2018kJ 481kcal	1009kJ (12%) 241kcal (12%)
Fett/fedt	23g	11g (16%)
Hvorav/Heraf mettet fett/mættede fedtsyrer	7.9g	4.0g (20%)
Kolhydrat/karbohydrater	61g	30g (12%)
Hvorav/Heraf sukkerarter	52g	26g (29%)
Protein	8.6g	4.3g (9%)
Salt	0.63g	0.31g (5%)

*Referensintag för en genomsnittlig vuxen/voksen gennemsnitsperson (8400 kJ/2000 kcal)

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1 kg Water by 1deg C

Or 1 **calorie** heats
1 gram of water 1deg C

1 kcal=1 Calorie = 1000 calories

An 85kg college student eats 3000kcals and his body burns it all, immediately…

1 **kilocalorie (kcal)** heats
1 kg Water by 1deg C

An 85kg college student eats 3000kcals and his body burns it all, immediately.

$$\frac{3000\ kcal}{85\ kg} \approx 35\frac{kcal}{kg} \approx +35\ \mathrm{deg}\,C$$

$$+35\ deg\ C \cdot \frac{9\ \mathrm{deg}\,F}{5\ \mathrm{deg}\,C} \approx +63\ \mathrm{deg}\,F$$

What's wrong with this story?

1 **kilocalorie (kcal)** heats
1 kg Water by 1deg C

An 85kg college student eats 3000kcals and his body burns it all, immediately.

$$\frac{3000\ kcal}{85\ kg} \approx 35\frac{kcal}{kg} \approx +35\ \mathrm{deg}\,C$$

$$+35\ deg\ C \cdot \frac{9\ \mathrm{deg}\,F}{5\ \mathrm{deg}\,C} \approx +63\ \mathrm{deg}\,F$$

His body temperature rises to … 98.6 + 63 = 162 deg F

Fat (molecules) we eat

common name	systematic name	formula	carbon atoms	double bonds	melting point (°C)
caprylic	octanoic	$C_7H_{15}COOH$	8	0	16.5
capric	decanoic	$C_9H_{19}COOH$	10	0	31.5
lauric	dodecanoic	$C_{11}H_{23}COOH$	12	0	44
myristic	tetradecanoic	$C_{13}H_{27}COOH$	14	0	58
palmitic	hexadecanoic	$C_{15}H_{31}COOH$	16	0	63
stearic	octadecanoic	$C_{17}H_{35}COOH$	18	0	72
arachidic	eicosanoic	$C_{19}H_{39}COOH$	20	0	77
oleic	cis-9-octadecenoic	$C_{17}H_{33}COOH$	18	1	13.4
linoleic	cis-9, cis-12-octadecadienoic	$C_{17}H_{31}COOH$	18	2	−5
linolenic	cis-9, cis-12, cis-15-octadecatrienoic	$C_{17}H_{29}COOH$	18	3	−11.3
eleostearic	cis-9, cis-11, cis-13-octadecatrienoic	$C_{17}H_{29}COOH$	18	3	49
ricinoleic	12-hydroxy-cis-9-octadecenoic	$C_{17}H_{33}COOH$	18	1 + OH	16

Most* food turns into CO2 and H20!

* 10-20%?

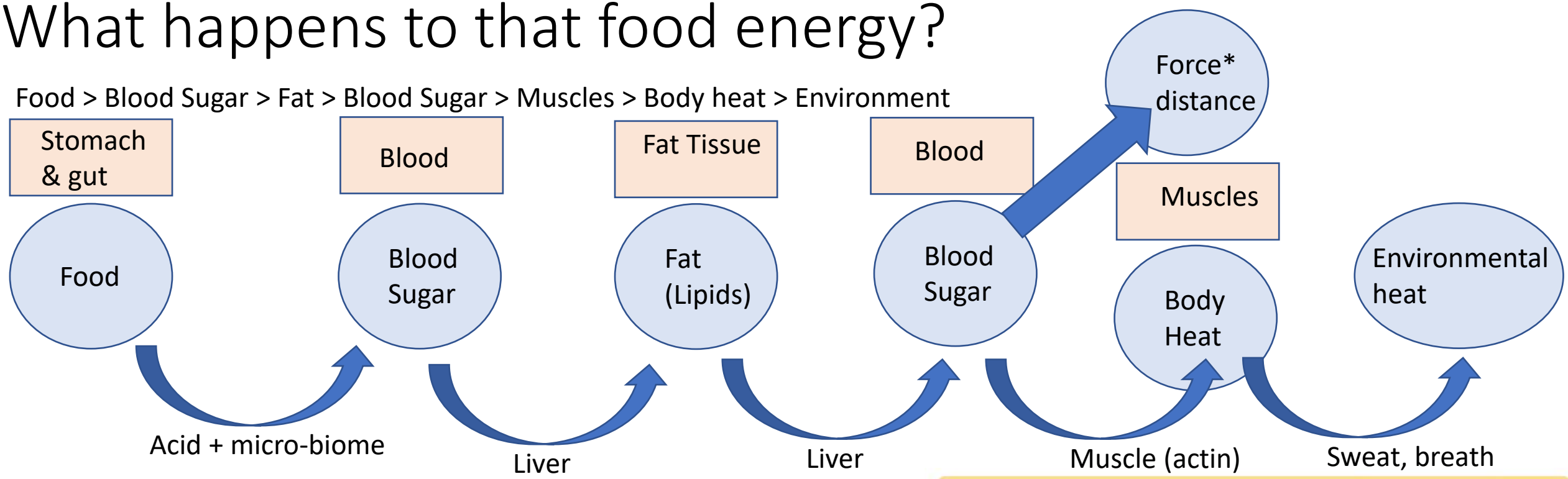
Table sugar

Sucrose, a disaccharide, is a sugar composed of glucose and fructose subunits. It is produced naturally in plants and is the main constituent of white sugar. It has the molecular formula $C_{12}H_{22}O_{11}$. For human consumption, sucrose is extracted and refined from either sugarcane or sugar beet. Wikipedia

Formula: $C_{12}H_{22}O_{11}$

What happens to that food energy?

Food > Blood Sugar > Fat > Blood Sugar > Muscles > Body heat > Environment



What are triglycerides?

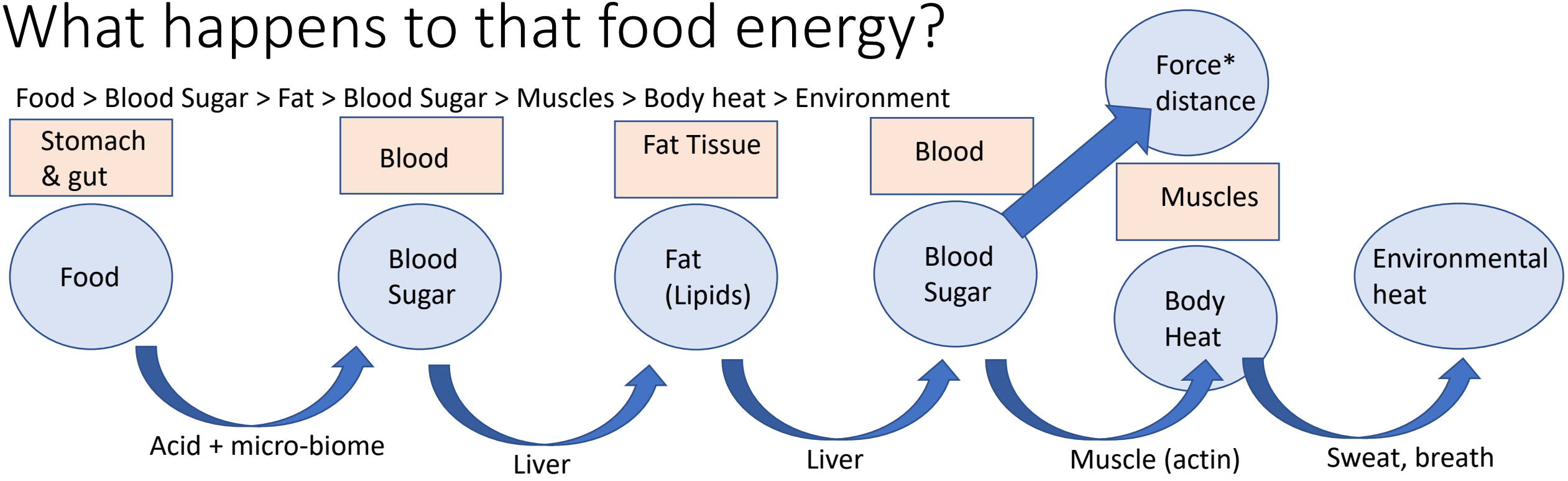
Triglycerides are a type of fat (lipid) found in your blood.

When you eat, your body converts any calories it doesn't need to use right away into triglycerides. The triglycerides are stored in your fat cells. Later, hormones release triglycerides for energy between meals.

If you regularly eat more calories than you burn, particularly from high-carbohydrate foods, you may have high triglycerides (hypertriglyceridemia).

What happens to that food energy?

Food > Blood Sugar > Fat > Blood Sugar > Muscles > Body heat > Environment



If you don't have Fat tissue, how often do you need to eat?

Lipodystrophy

Lipodystrophy is a condition that's characterized by a complete or partial loss of and/or abnormal distribution of adipose (fat) tissue in certain areas of your body. While there's no cure for the condition, certain treatments can help with its symptoms and associated health conditions.

A jar of peanut butter is not a joke!

Arrowhead 135

HOME NEWS GALLERIES RACE INFO/REGISTRATION RESULTS BLOG

Recommended Gear

- In the past Trackleaders has made spot trackers available to racers on a voluntary basis at a nominal cost. **We strongly encourage the use of spot trackers**. Arrowhead 135 Inc. does not offer Spot trackers. It is your choice to use one. **Do not** have a friend/family member call us in a panic because your spot stopped moving while you were sleeping or eating. This will cost you a time penalty.
- Helmet for bikers
- Extreme conditions mittens, head gear and outerwear..
- Down sweater, spare undershirt/socks etc.
- Over-boots, Gaitors.
- Duct tape, vasoline, sunglasses, lipbalm, moleskin, ibuprofin, etc.
- Map/compass/gps. The maps provided with your racer bag do you no good in you truck.
- Reflective vest good idea.
- 5,000-7,000 calories of food, preferably items which remain chewable at way below zero and colder.
- Sleds or backpack for runners and snowshoers. Assorted tools/waxes as needed - carried from start to finish.
- VERY IMPORTANT: Improved cell phone coverage especially on course highpoints makes carrying phone smart, preferably off and in a warm spot to so it works, use for emergencies.

16. Racers required to carry/tow all required gear all times on the course and must finish with at least 1 day or 3000 calories of readily edible food and 8 oz. of fuel. Racers may share gear and assist each other; however, each participant must have their own mandatory gear at all times. **Gear checks may**

190kcal * 34 servings ~ 6400kcal

Brown fat, also called brown adipose tissue, is **a special type of body fat that is turned on (activated) when you get cold**. Brown fat produces heat to help maintain your body temperature in cold conditions. Brown fat contains many more mitochondria than does white fat.

https://www.mayoclinic.org › brown-fat › faq-20058388

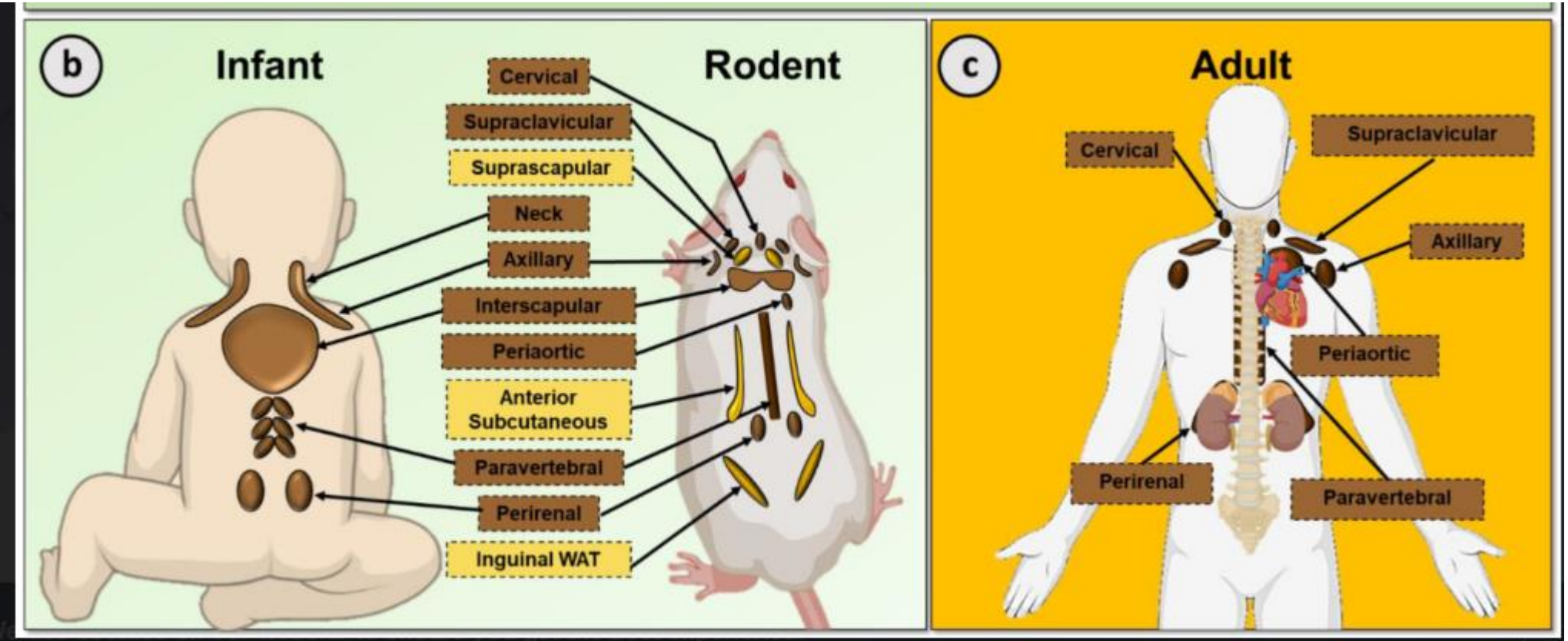
How is brown fat different from other fat? - Mayo Clinic

The Occurrence of Brown Adipose Tissue in Outdoor Workers

P. Huttunen, J. Hirvonen, and V. Kinnula

Departments of Forensic Medicine and Physiology, University of Oulu, Kajaanintie 52D, SF-90220 Oulu 22, Finland

Eur J Appl Physiol (1981) 46: 339–345



What We Talk About When We Talk About Fat*

Evan D. Rosen[1,2,3] and Bruce M. Spiegelman[2,4]

Adipose tissue also has important mechanical properties, serving to protect delicate organs (the eye, for example, is surrounded by fat in a manner analogous to the way one might pack a teacup in bubble wrap) and to cushion body parts exposed to high levels of mechanical stress (the heel and toe pads, for example, are filled with fat). Additionally, fat plays an important role in streamlining aquatic mammals and in providing insulation; the role of adipose tissue in the latter may be overblown, however, as arctic and tropical mammals display a similar distribution of subcutaneous and visceral fat (Pond, 1992). Fatty tissues are also used as displays for sexual selection, such as the cheek pads of the male orangutan, and (in some cultures) the human female buttocks (Singleton, 2008).

Cell

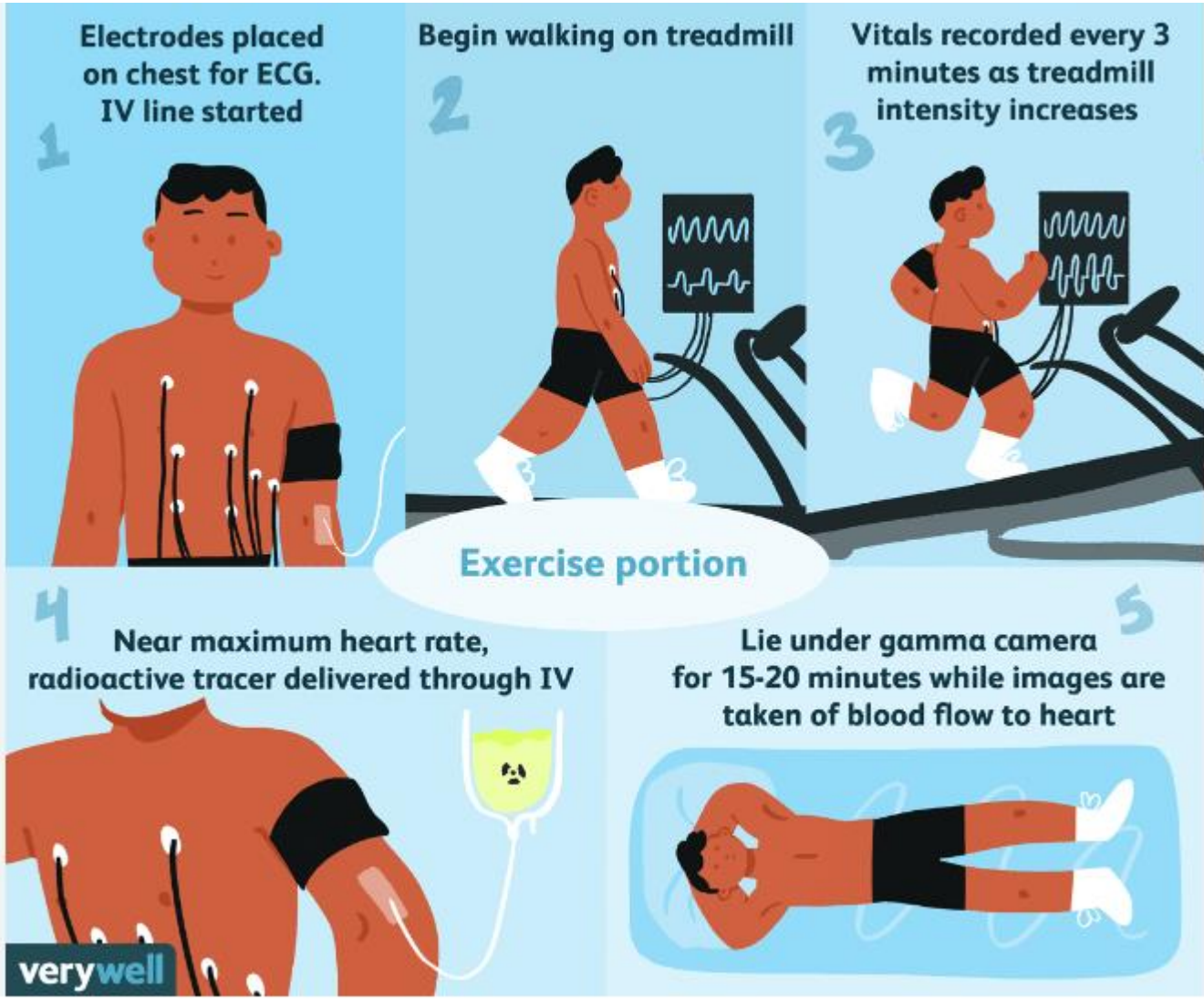
REVIEW | VOLUME 156, ISSUE 1-2, P20-44, JANUARY 16, 2014

Metabolic Equivalents (METS) in Exercise Testing, Exercise Prescription, and Evaluation of Functional Capacity

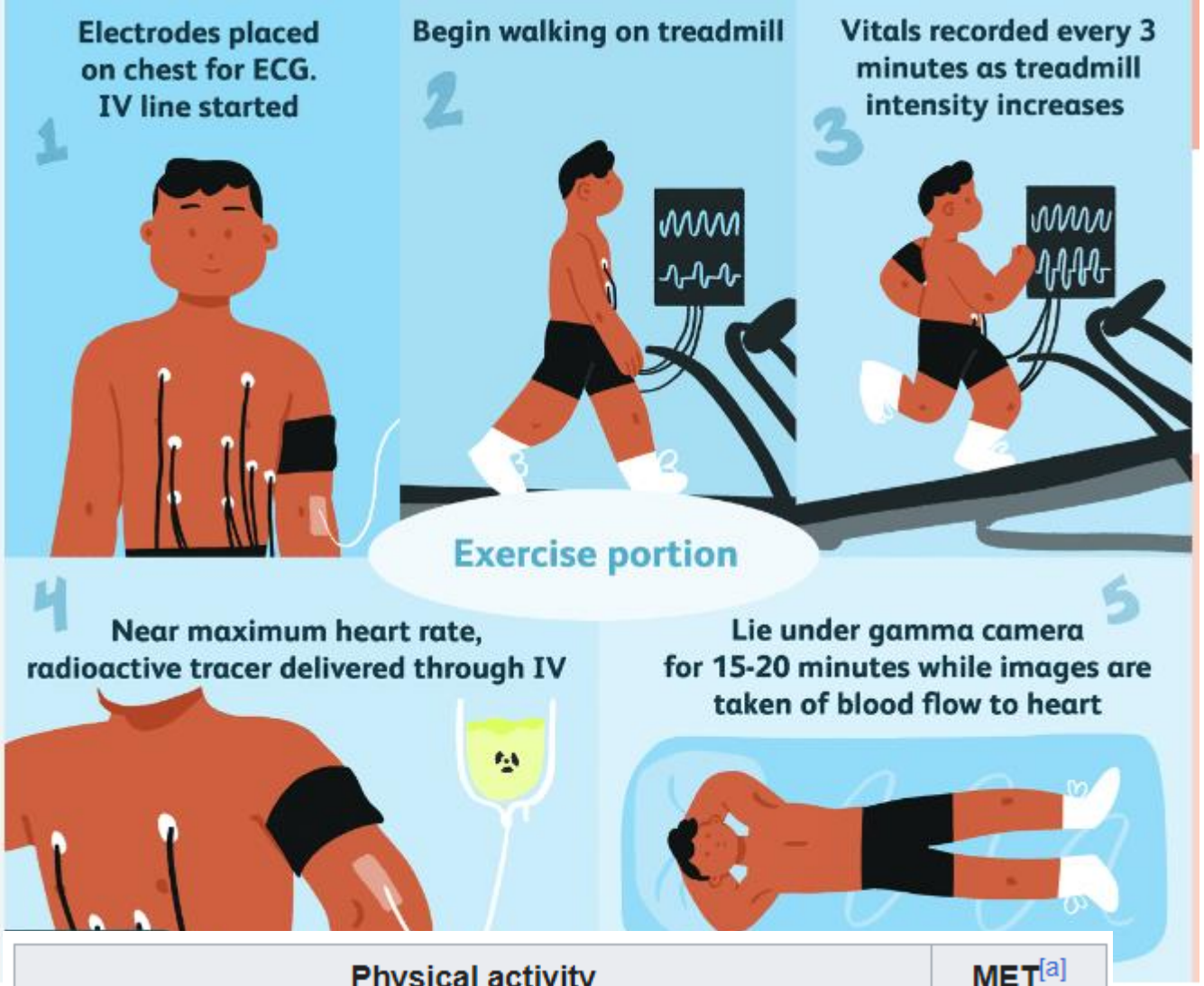
M. JETTÉ, K. SIDNEY,* G. BLÜMCHEN†

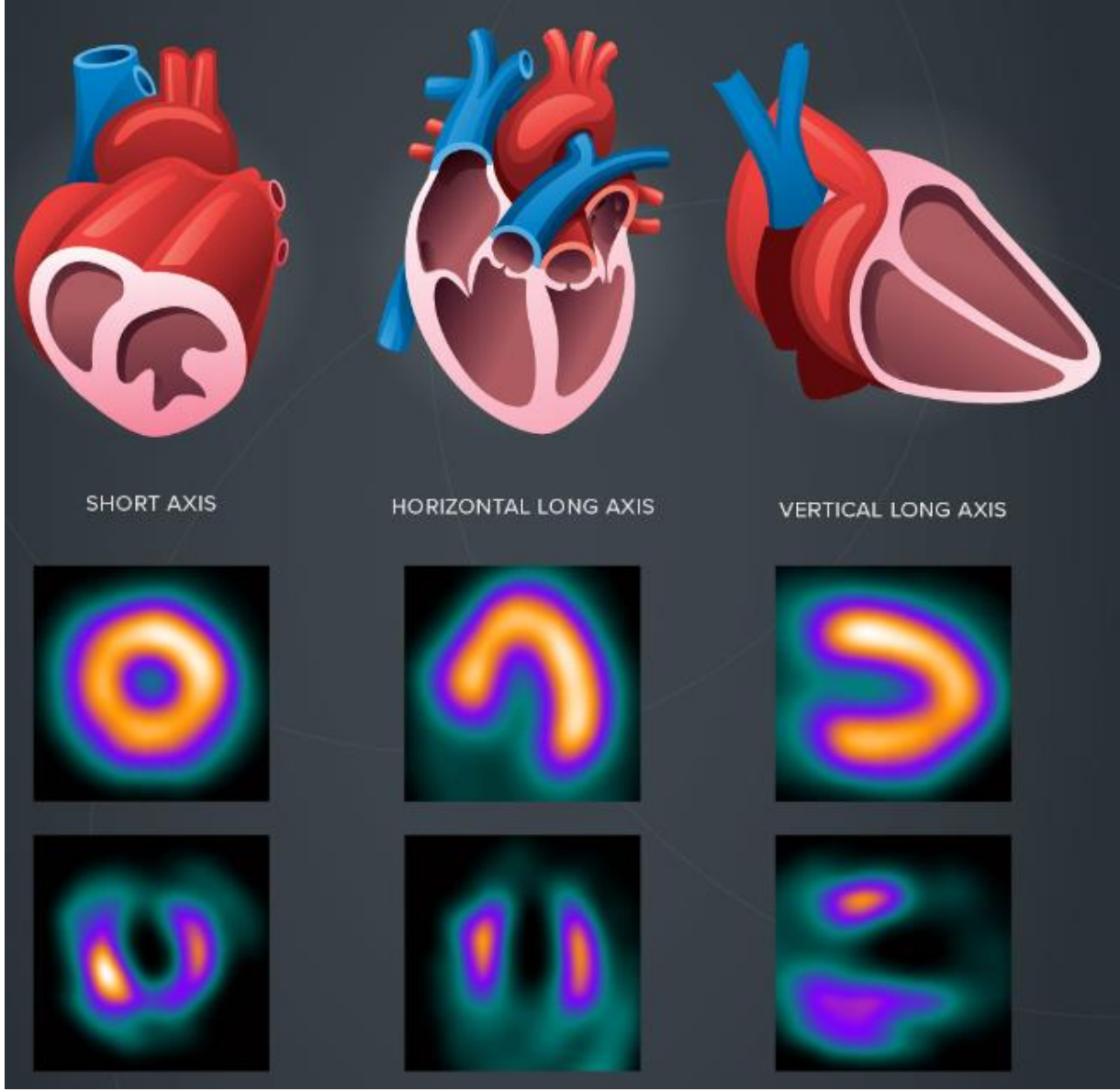
Clin. Cardiol. 13, 555-565 (1990)

Physical activity	MET[a]
Light-intensity activities	**< 3**
writing, desk work, using computer	1.5[10]
walking slowly	2.0[10]
Moderate-intensity activities	**3 to 6**
walking, 3.0 mph (4.8 km/h)	3.0[10]
sweeping or mopping floors, vacuuming carpets	3 to 3.5[10]
yoga session with asanas and pranayama	3.3[11]
Tennis doubles	5.0[10]
Weight lifting (moderate intensity)	5.0[12]
sexual activity, aged 22	5.8[13]
bicycling, on flat, 10–12 mph (16–19 km/h), light effort	6.0[10]
swimming moderately to hard	8 to 11[10]
jogging, 6.8 mph (10.9 km/h)	11.2[12]



$$1MET = \frac{1\ kcal}{kg \cdot hour} = \frac{85kcal}{85kg \cdot hour} = \frac{2040kcal}{85kg \cdot \boldsymbol{day}}$$





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jogging, 6.8 mph (10.9 km/h)	11.2[12]

Where did 3000kcal/day come from?

DEFENSE LOGISTICS AGENCY
THE NATION'S COMBAT LOGISTICS SUPPORT AGENCY

What's in it?

The twenty-four different varieties of meals can be seen in the menu table. Components are selected to complement each entree as well as provide necessary nutrition. Each meal also contains an accessory packet. The contents of one MRE meal bag provides an average of 1250 kilocalories (13 % protein, 36 % fat, and 51 % carbohydrates). It also provides 1/3 of the Military Recommended Daily Allowance of vitamins and minerals determined essential by the Surgeon General of the United States.

Each year?

$$\frac{2500\ kcal}{person \cdot day} \cdot \frac{365\ days}{year} \approx 1{,}000{,}000 \frac{kcals}{person \cdot year}$$

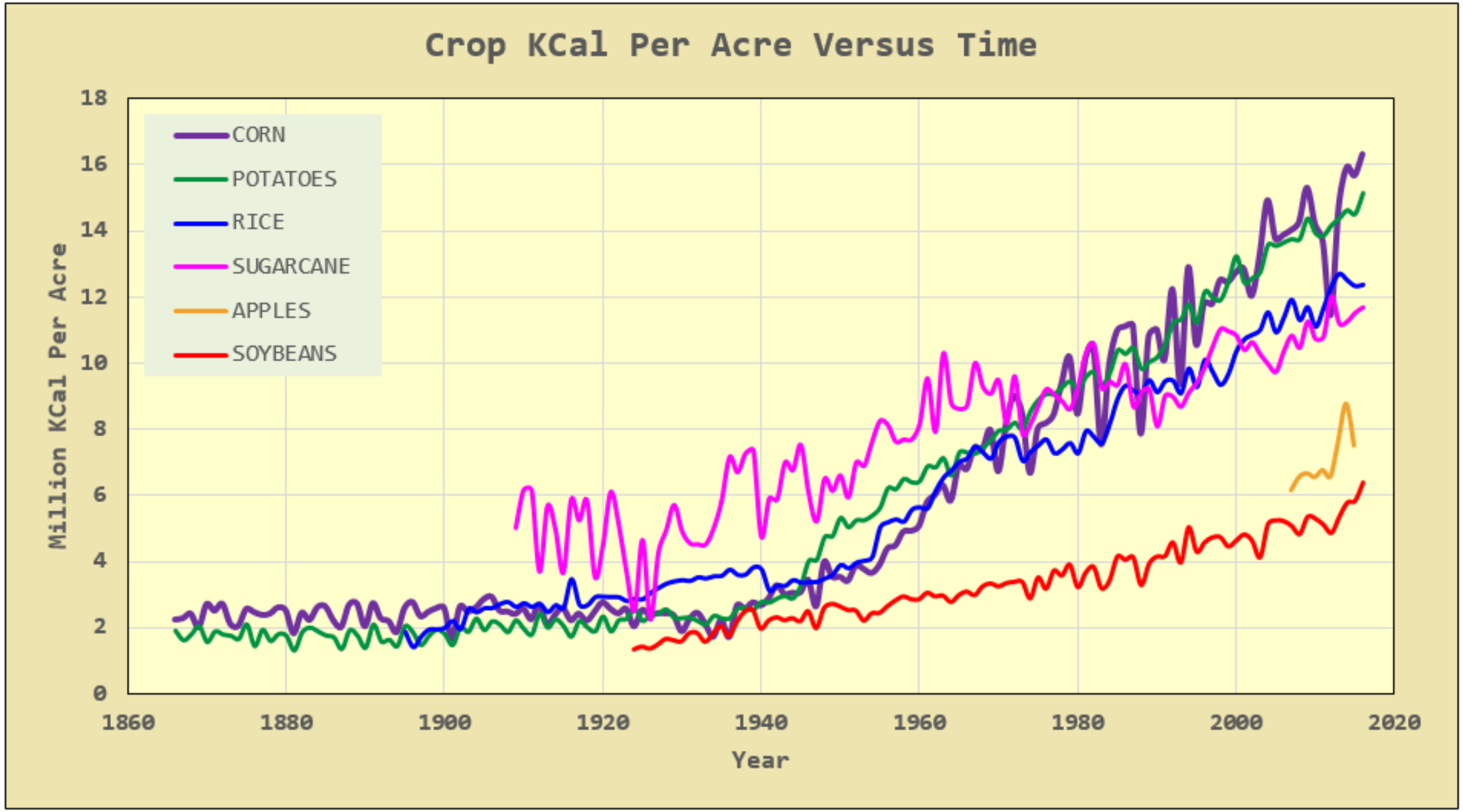
About one million kcals per person

365 * 2500 =

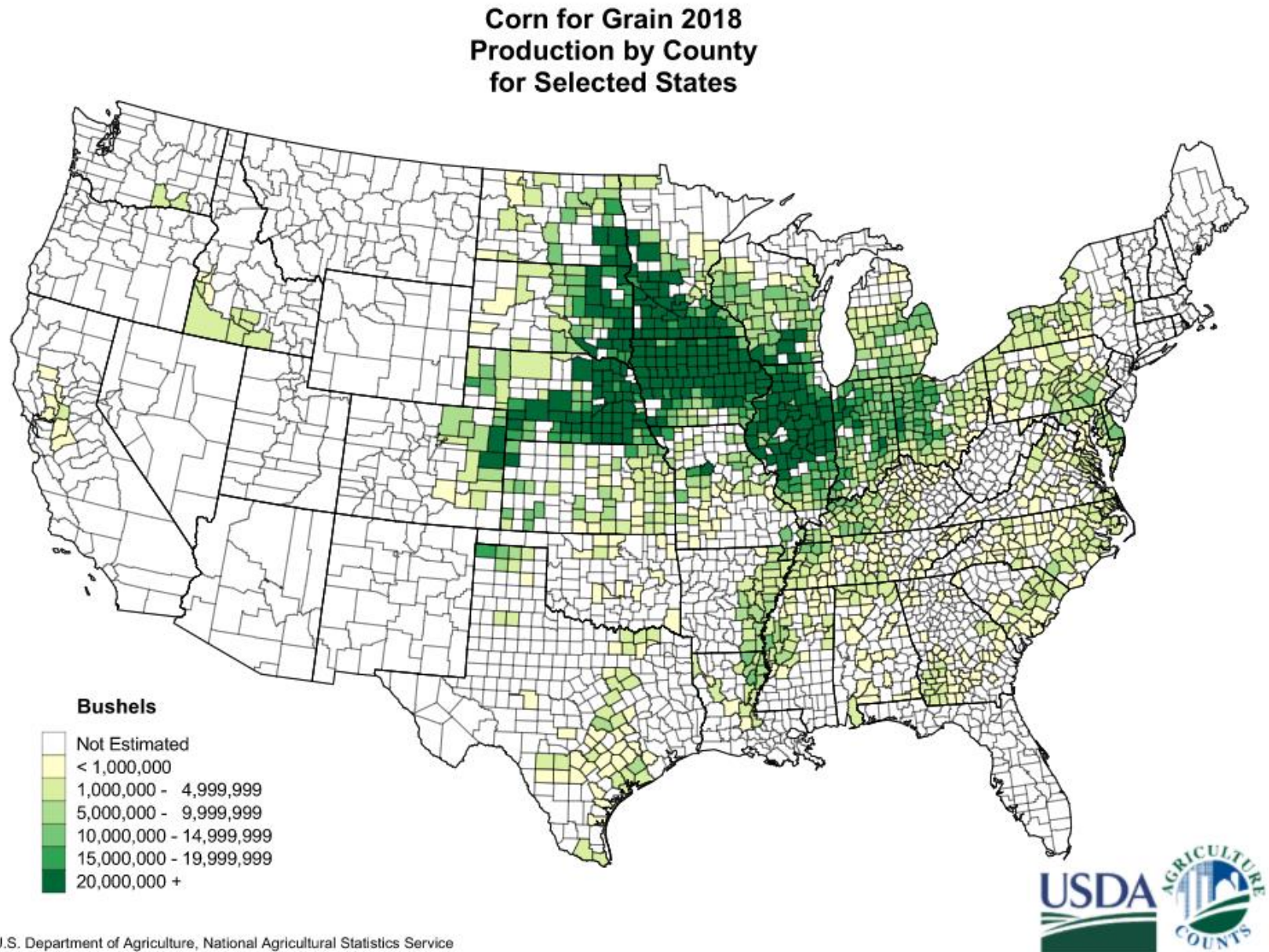
912500

How do we get those kcals?

People fed per acre



@15M kcal/acre: if we only fed the US corn, how much area would be needed?



This GIF represents a mixed emotion of incomprehension and surprise (the infamous 'what the fuck' moment), expressed by musician Tom Delonge in a video clip by American punk band Blink 182 (See https://www.reactiongifs.com/. Accessed 22 June 2020.)

Iowa, 36M acres

So why do we grow so much corn?

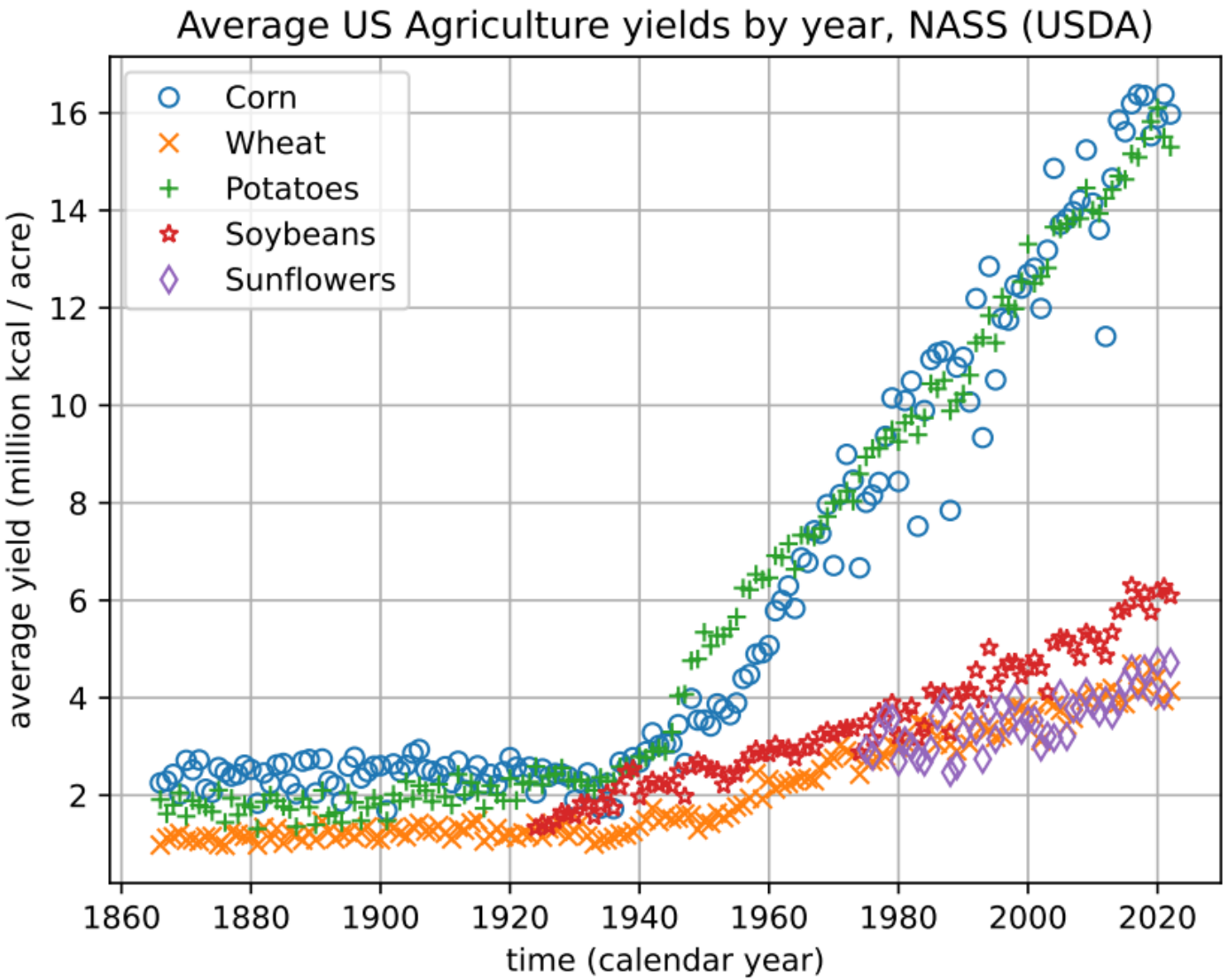

MAKE AMERICA
GREAT AGAIN

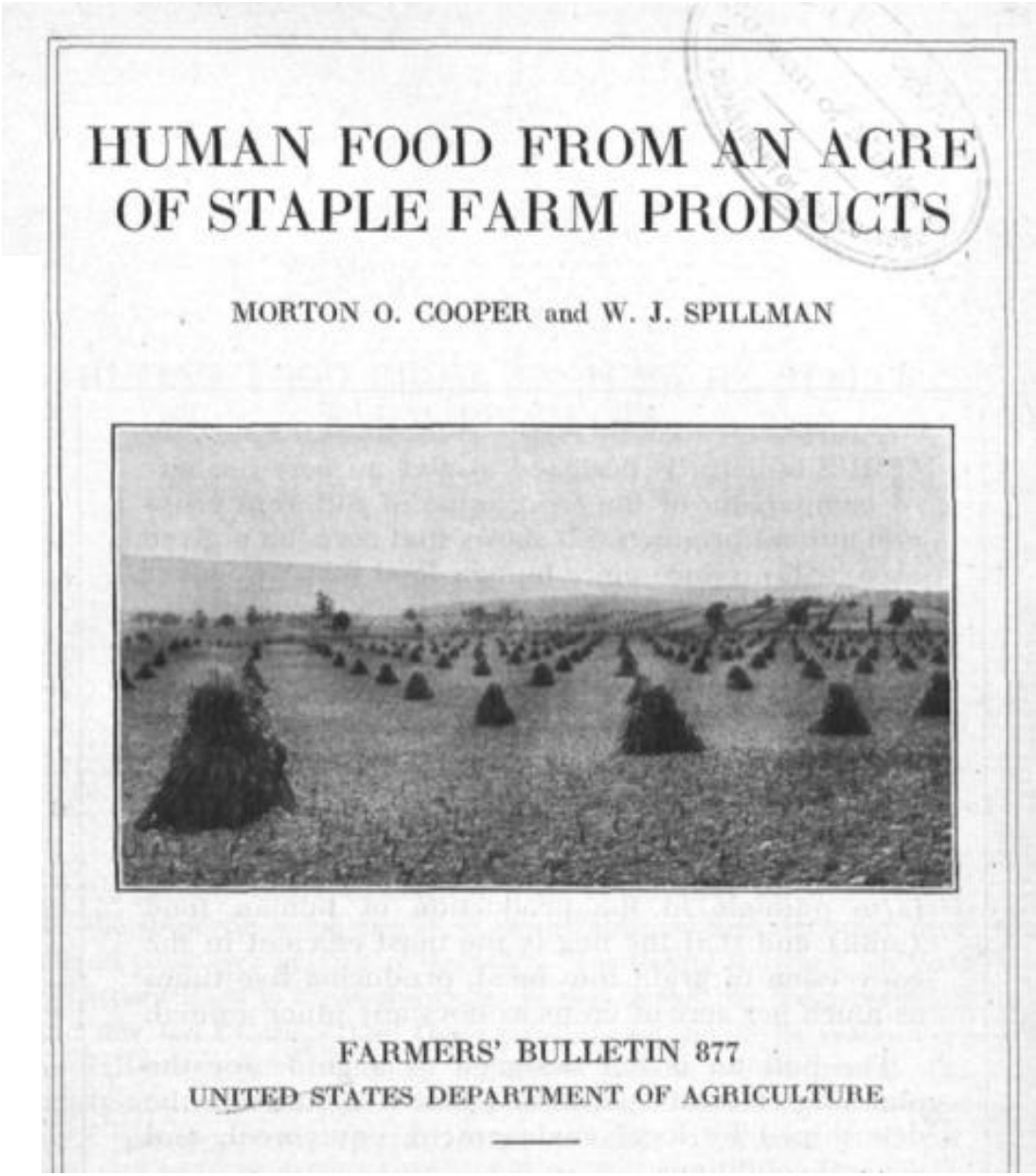

PRETZELS

February
Super Tuesday
March
April
May
June


CORN DOGS

What if you want to DIY?





HUMAN FOOD FROM AN ACRE OF STAPLE FARM PRODUCTS

MORTON O. COOPER and W. J. SPILLMAN

FARMERS' BULLETIN 877

UNITED STATES DEPARTMENT OF AGRICULTURE

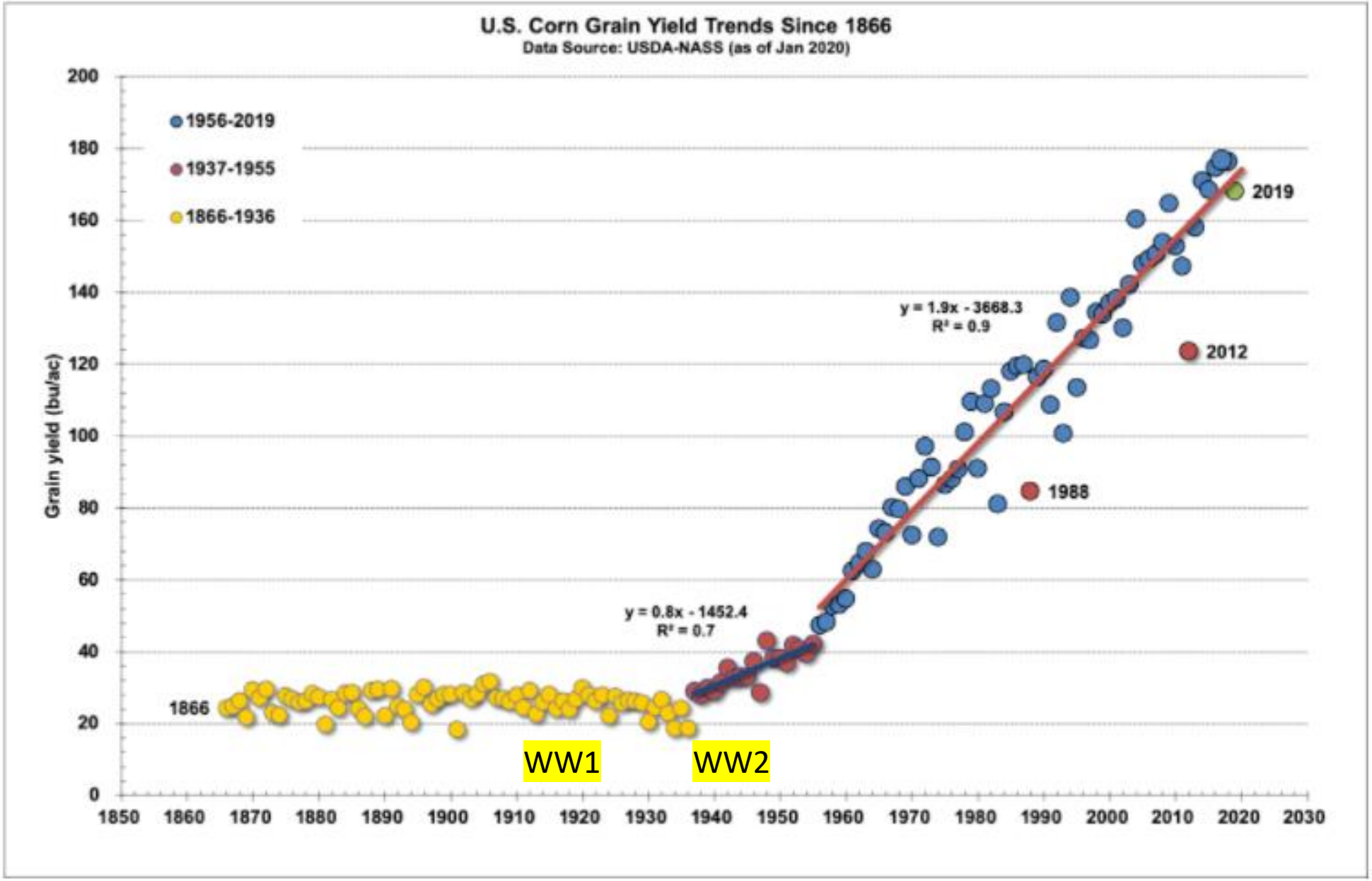


Fig. 1. Annual U.S. Corn Grain Yields and Historical Trends Since 1866. Data derived from annual USDA-NASS Crop Production Reports.

How long can this go on?

Idle speculation, In Minnesota:

$$\text{Daily Sunlight} \approx 4\ \frac{kW \cdot hr}{m^2 \cdot day}$$

$100\ day$ growing season

$1kW \cdot hr \approx 860\ kcal$

$1\ acre \approx 4047 m^2$

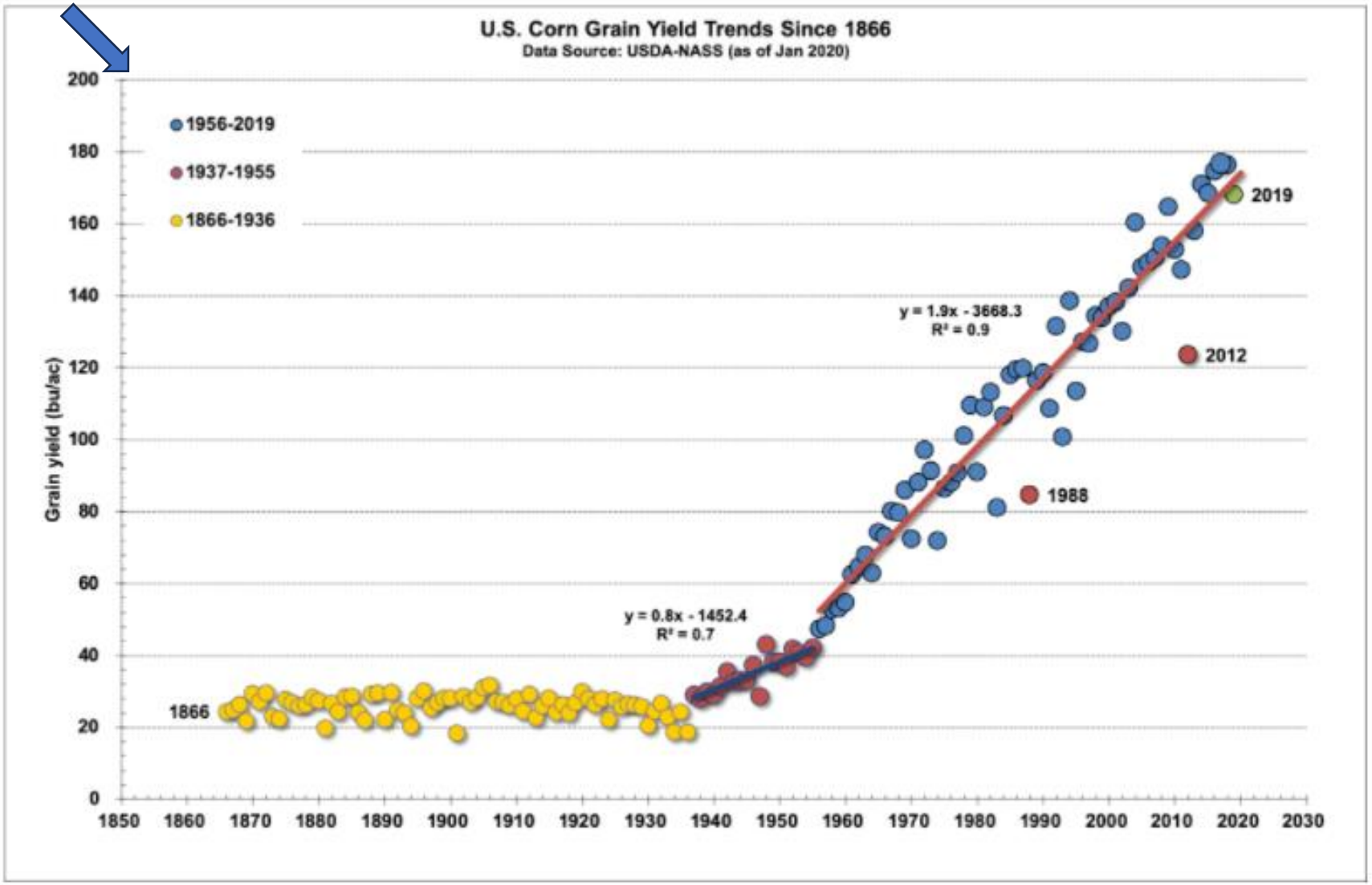
$1\ bu\ corn\ =\ 56lbs$

$1lbs\ corn \approx 1566\ kcal$

Raw MN sunlight (as corn, 100day) is about $16{,}000\ \frac{bu}{acre}$

So corn is about 1.1% efficient?

200 bu/acre



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$$4\ \frac{kWh}{day \cdot m^2} \times 100 days \times \frac{860 kcal}{1 KWh} \times \frac{1\ lbs\ corn}{1566 kcal\text{-}corn}$$

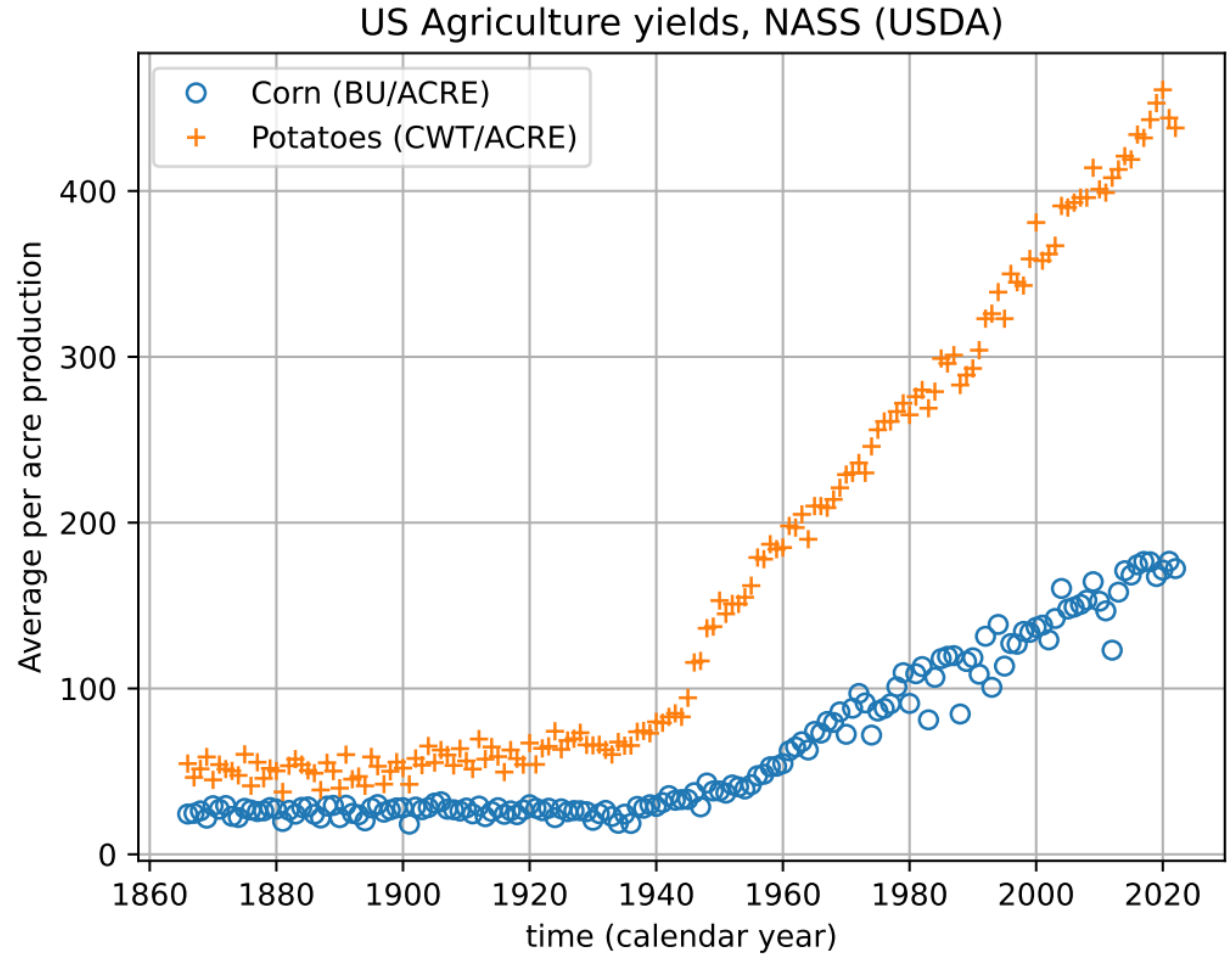
$$\times \frac{1\ bu\ Corn}{56\ lbs\ Corn} \times \frac{4047 m^2}{1\ acre} = 15\,874\ \frac{bu}{acre}$$

So corn is currently

$$\frac{180}{15874} \approx 1.1\%$$ efficient at storing sunlight as food

TABLE I.—*A comparison of the food produced annually by an acre of land when utilized in the production of various food crops and live-stock products.*

Food products.	Yield per acre.		Calories per pound.	Pounds protein per acre (digestible).	Calories per acre.
	Bushels.	Pounds.			
Food crops:					
Corn	35	1,960	1,594	147.0	3,124,240
Sweet potatoes	110	[a] 5,940	480	53.5	2,851,200
Irish potatoes	100	6,000	318	66.0	1,908,000
Rye	20	1,200	1,506	118.8	
Wheat	20	1,200	1,490	110.4	
Rice, unpolished	40	1,154	1,460	55.4	
Rice, polished	.....	1,086	1,456	50.0	
Soy beans	16	960	1,598	294.7	
Peanuts	34	524	2,416	126.2	
Oats	35	[b] 784	1,600	89.4	
Beans	14	840	1,337	157.9	
Cowpeas	10	600	1,421	116.4	
Buckwheat	24	[c] 600	1,252	34.5	
Dairy products:					
Milk	.....	2,190	325	72.3	
Cheese	.....	219	1,950	56.7	
Butterfat	.....	98.55	3,605	1.0	
	Live (pounds).	Dressed (pounds).			
Meat:					
Pork	350	273	2,465	22.7	
Mutton	205	113	1,215	14.7	
Beef	216	125	1,040	18.5	
Poultry: [d]					
Meat	103	66	1,045	12.7	
	Dozen.	*Pounds.*			
Eggs	73.8	110.7	720	14.8	



6 people, 1 year, how many acres of potatoes?

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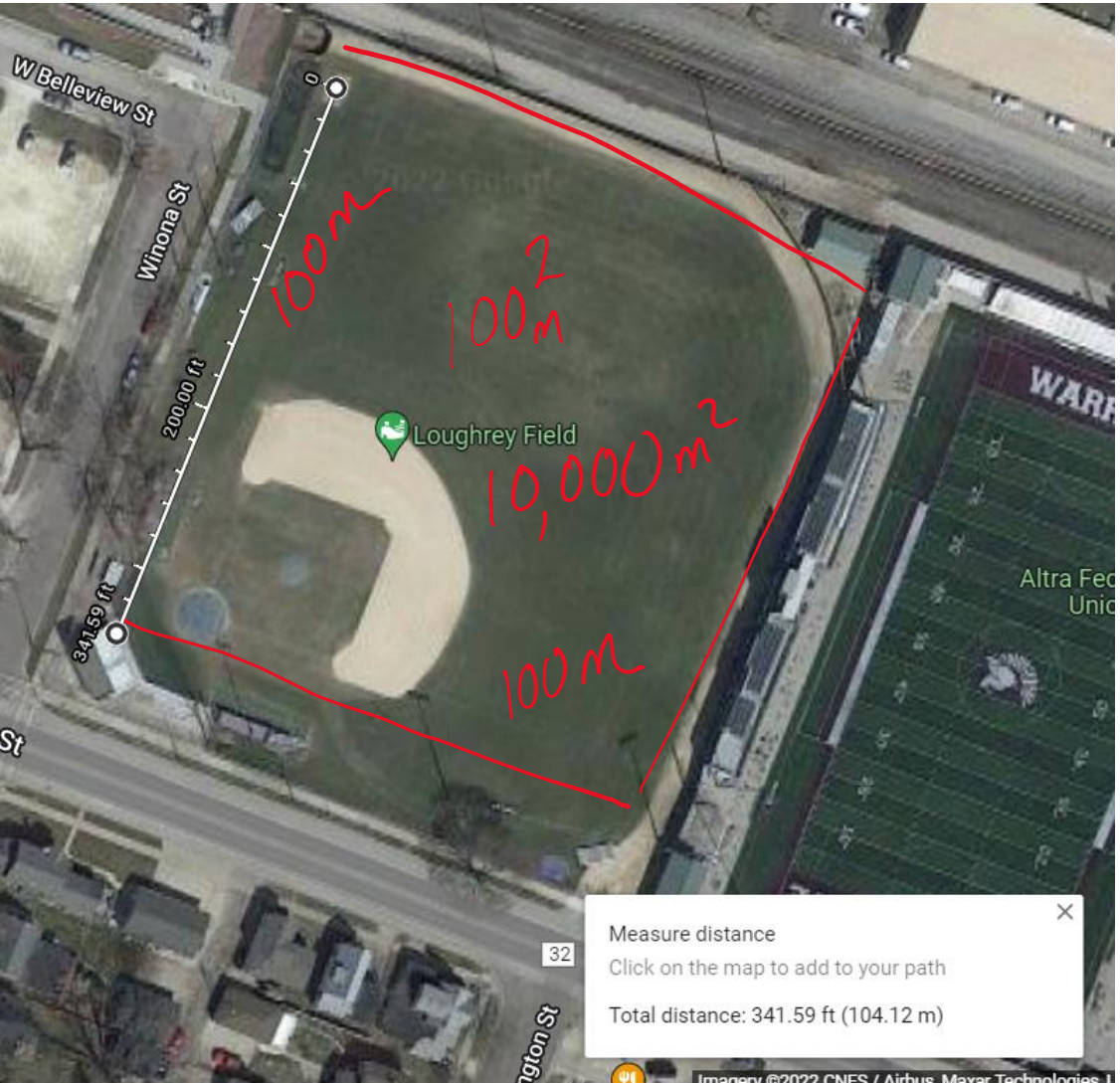
Rye	20	1,200	1,506	118.8	1,807,200
Wheat	20	1,200	1,490	110.4	1,788,000
Rice, unpolished	40	1,154	1,460	55.4	1,684,840
Rice, polished					

In terms of Winona 6 people need:



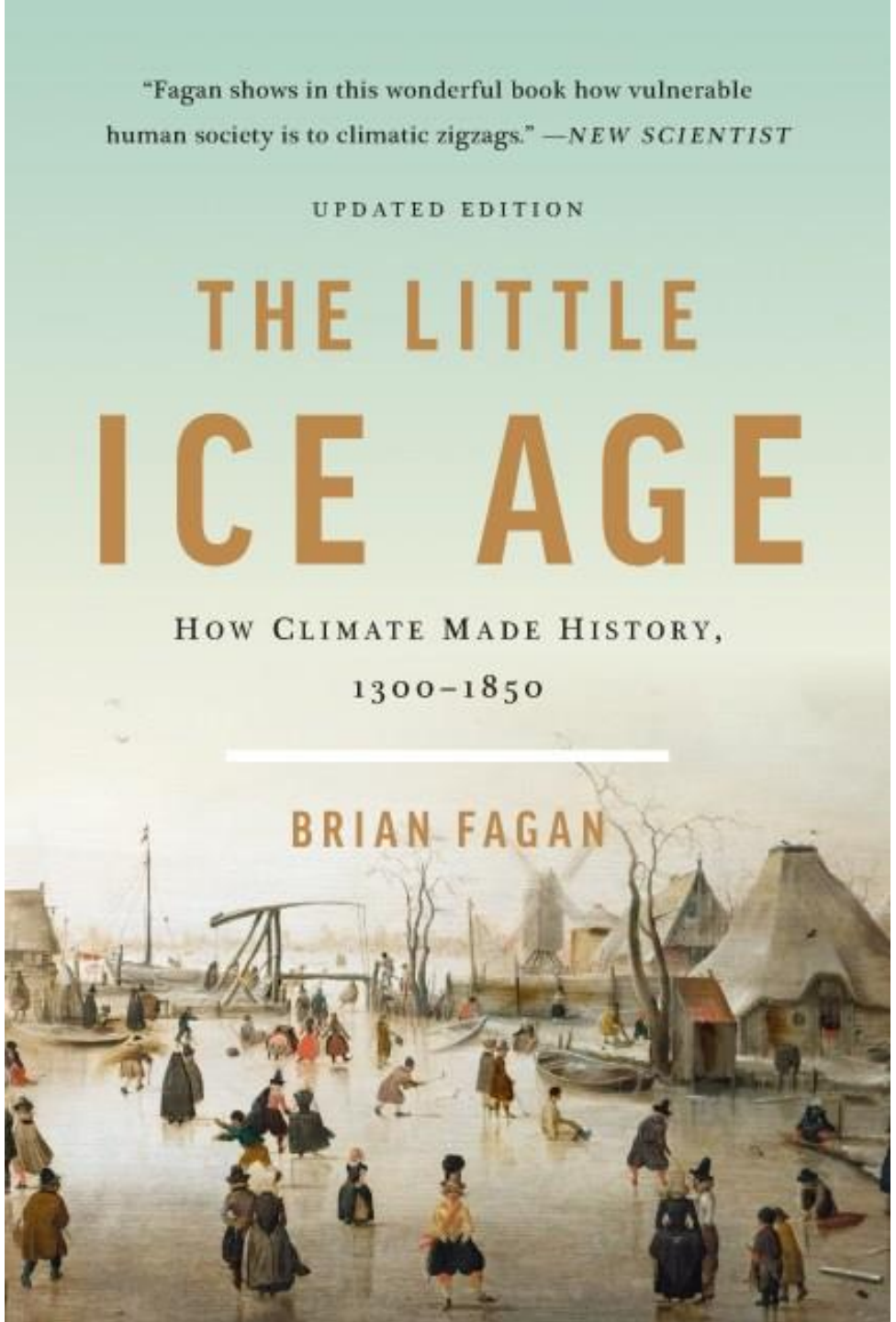
In 1917 “Irish” Potatoes yield $\mathbf{1.9}M\ \frac{kcal}{acre}$

6ppl need $\mathbf{6}M\ \frac{kcal}{year}$

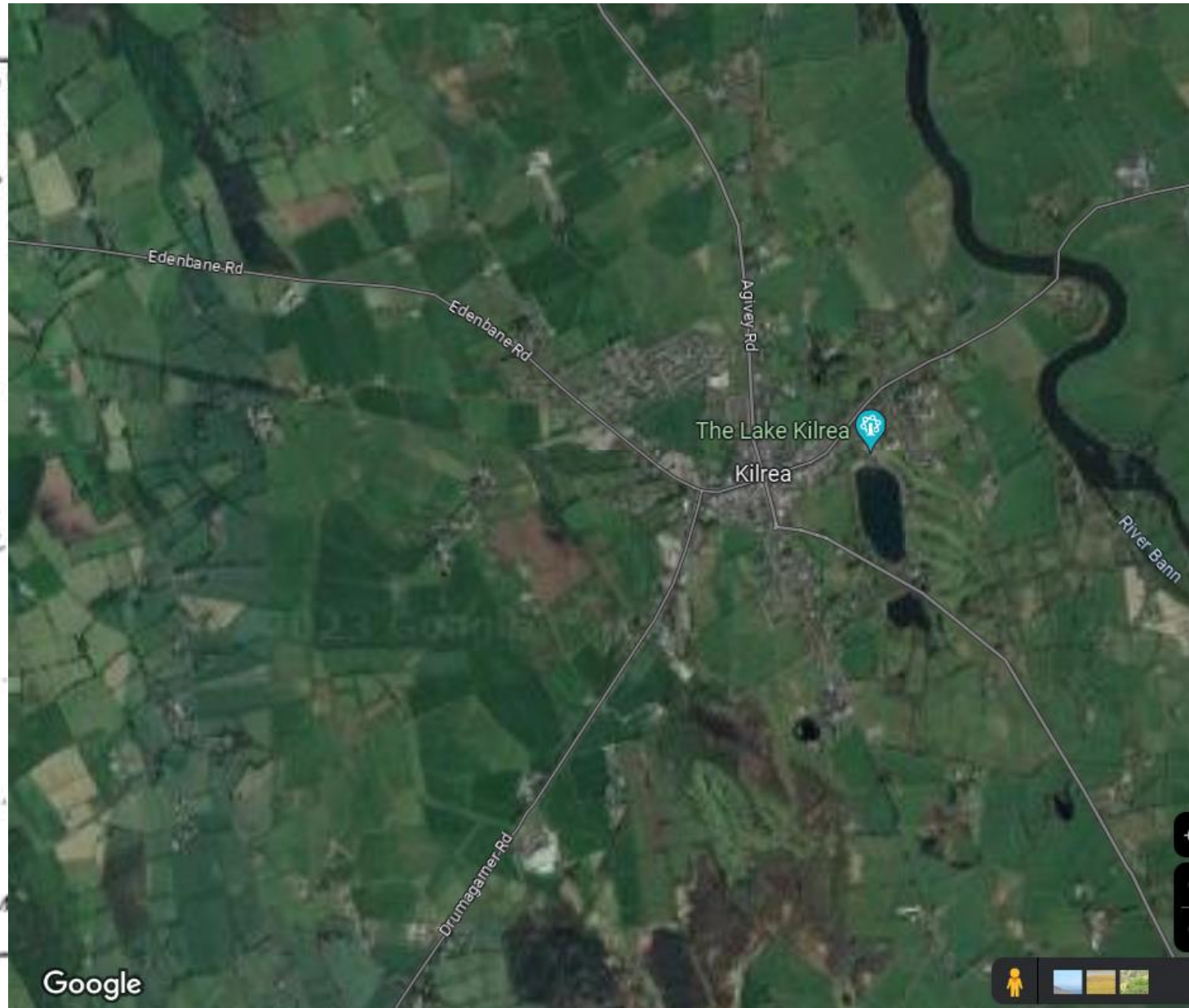
So about 3 acres of potatoes

2acres ≃ 8000m²

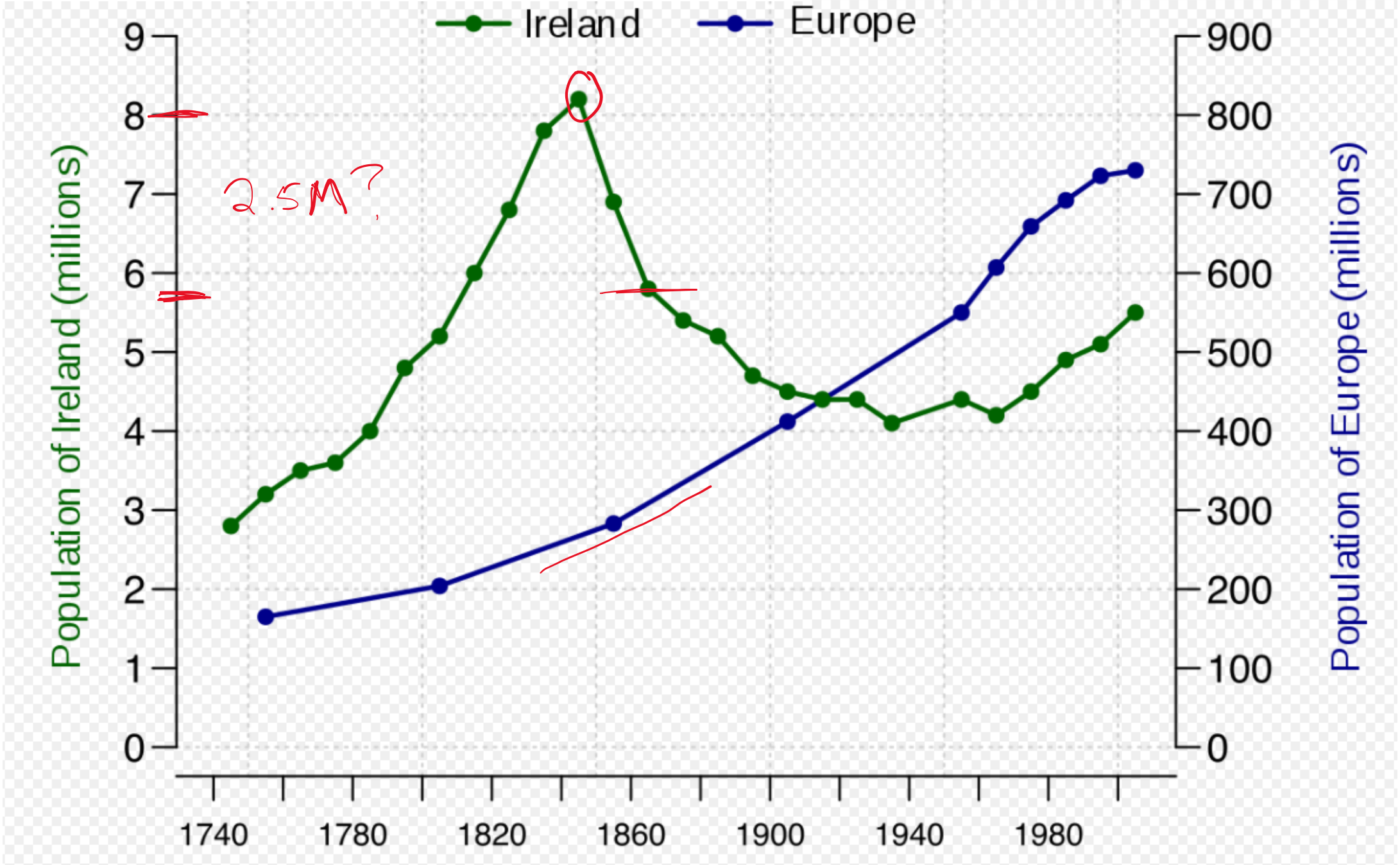
2nd Half of the talk



Can Ireland live off backyard potatoes?



The Republic of Ireland had a population of 4,761,865 at the 2016 census.



Can Ireland live off of potatoes?

~8.5M ppl in 1845 need $9.3 \times 10^{12}\ kcal$

84,000 km^2 of land, 64% arable, so 54,000km^2 can be used for ag

How much land area, sown in potatoes, would produce this food?

$$9.3 \times 10^{12} kcals / \left(1.908 \times 10^{6} \frac{kcal}{acre}\right) = 4.87 \times 10^{6} acres,$$
$$\approx 19,700 km^2.$$

How much land area, sown in oats, would produce this food?

$$9.3 \times 10^{12} kcals / \left(1.254 \times 10^{6} \frac{kcal}{acre}\right) = 7.41 \times 10^{6} acres,$$
$$\approx 30,000 km^2.$$

Food products.	Calories per acre.
Food crops:	
Corn	3,124,240
Sweet potatoes	2,851,200
Irish potatoes	1,908,000
Rye	1,807,200
Wheat	1,788,000
Rice, unpolished	1,684,840
Rice, polished	1,581,216
Soy beans	1,534,000
Peanuts	1,265,018
Oats	1,254,400
Beans	1,123,080
Cowpeas	852,600

https://arxiv.org/abs/2301.06637

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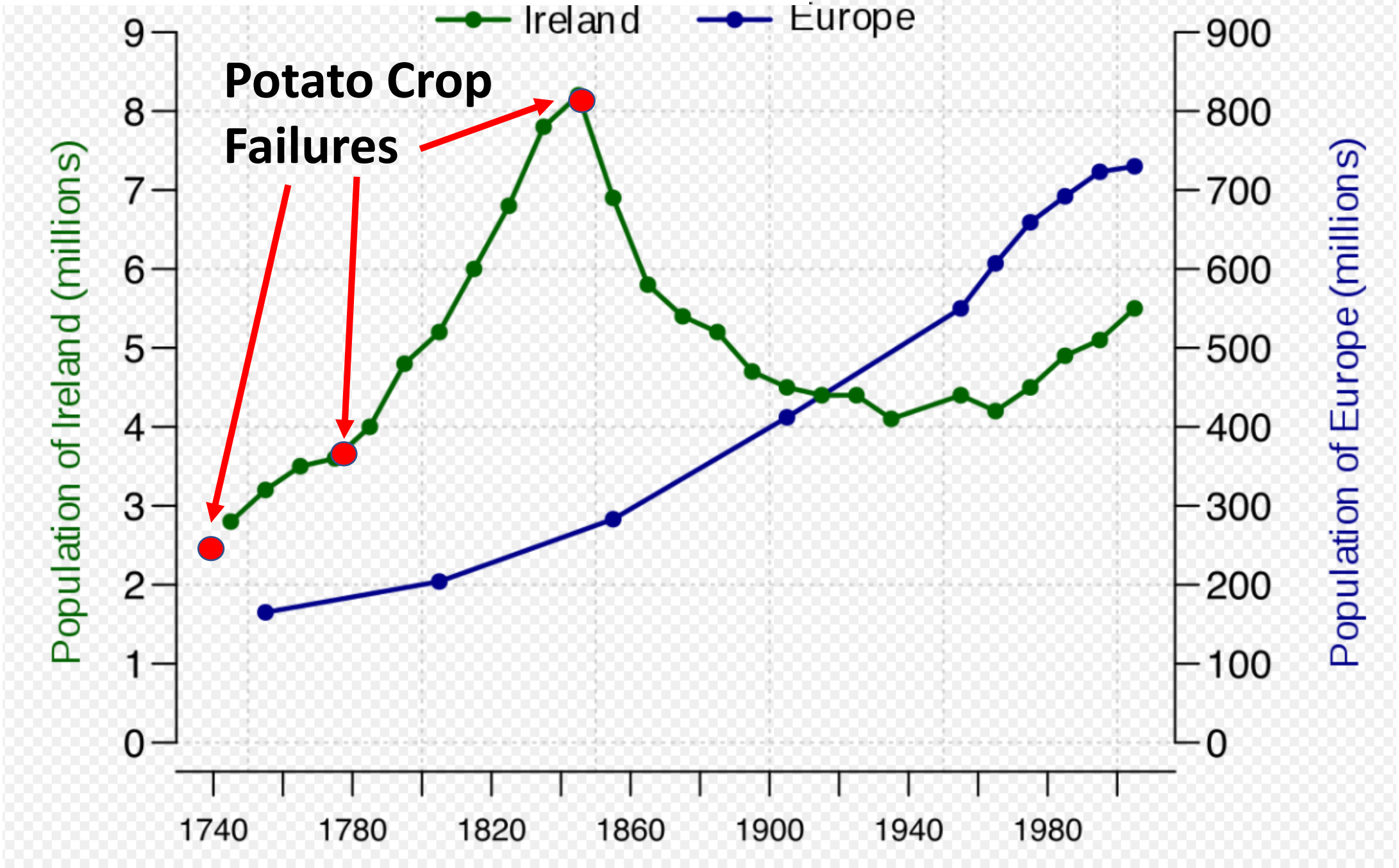

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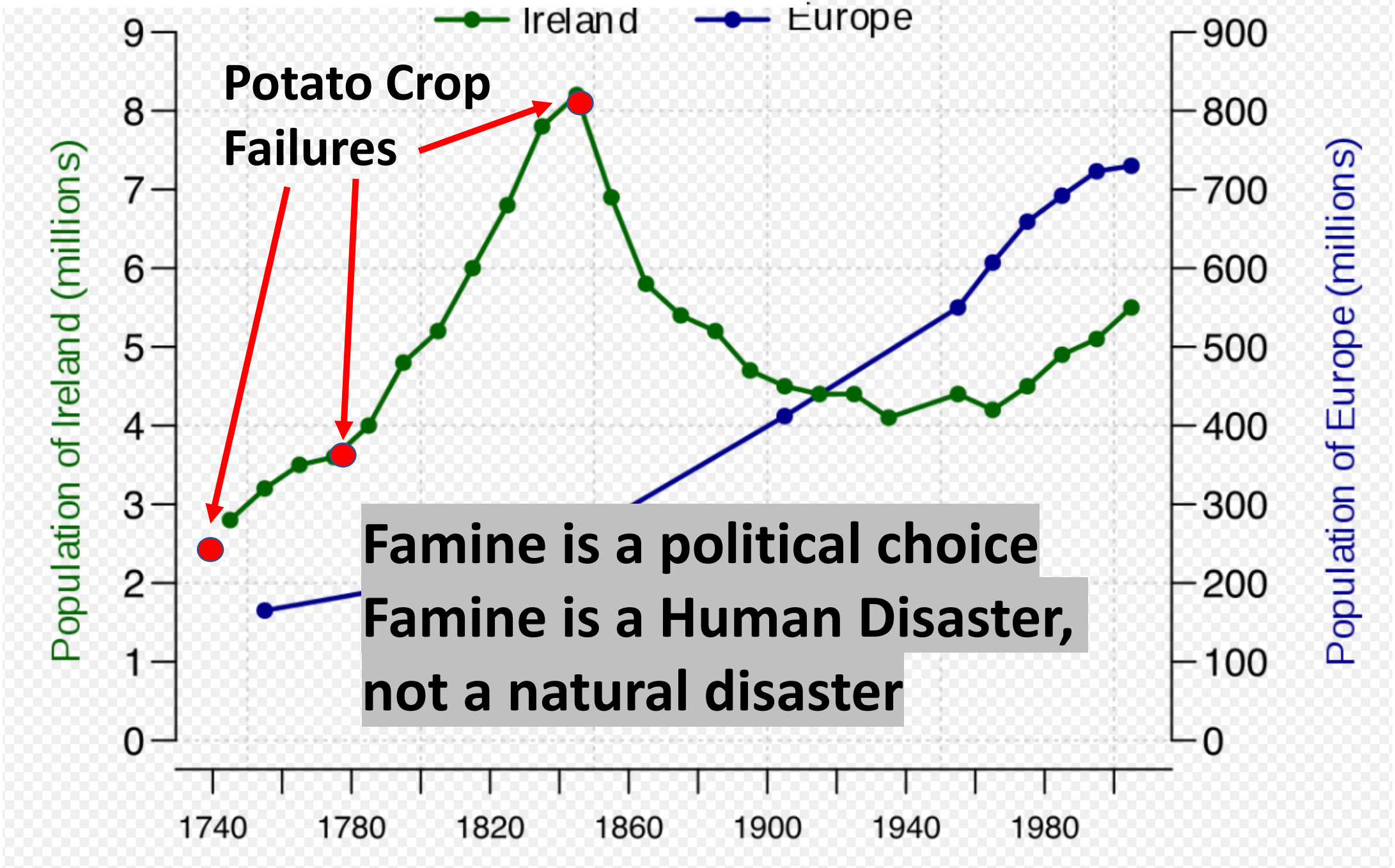


Third Horseman of the Apocalypse: Famine

Not scarcity, but allocation

Black Horse [edit source]

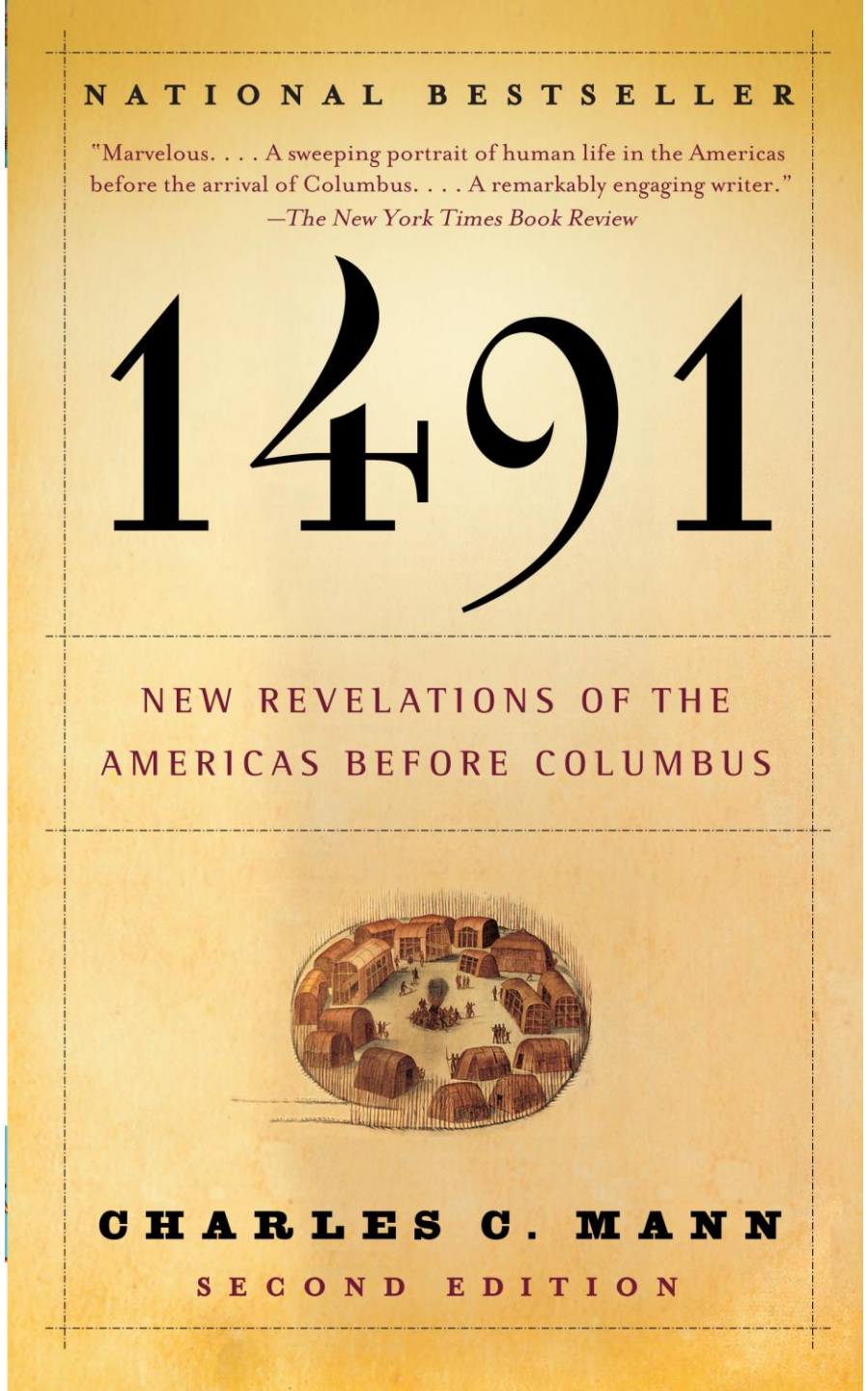
> When He broke the third seal, I heard the third living creature saying, "Come." I looked, and behold, a black horse; and he who sat on it had a pair of scales in his hand. And I heard something like a voice in the center of the four living creatures saying, "A quart of wheat for a denarius, and three quarts of barley for a denarius; but do not damage the oil and the wine."
>
> —Revelation 6:5–6 NASB[40]

The third Horseman, Famine on the Black Horse as depicted in the Angers Apocalypse Tapestry (1372–82)

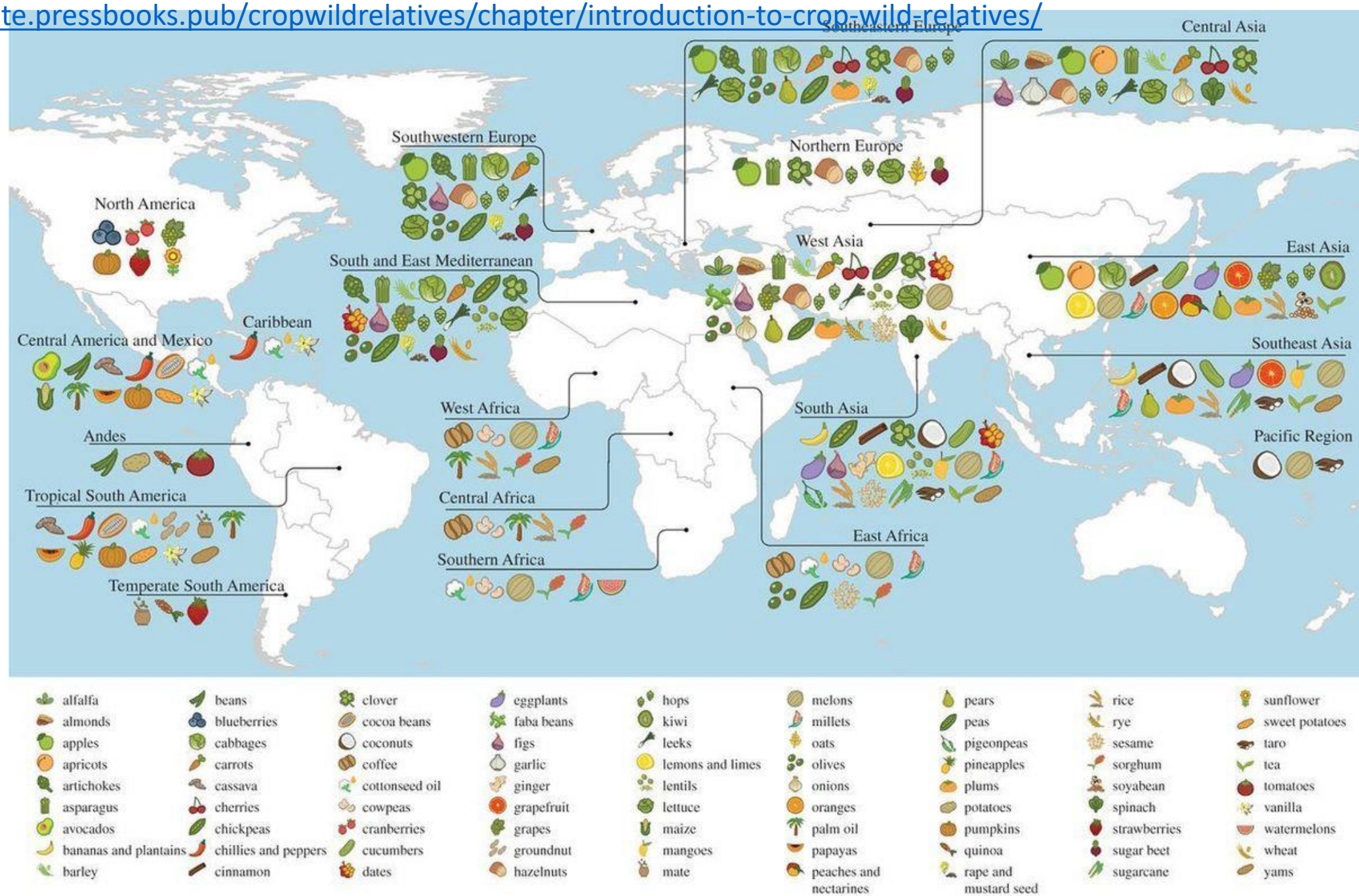
The third Horseman rides a black horse and is popularly understood to be Famine, as the Horseman carries a pair of balances or weighing scales (Greek ζυγὸν, *zygon*), indicating the way that bread would have been weighed during a famine.[5][35] Other authors interpret the third Horseman as the "Lord as a Law-Giver," holding Scales of Justice.[41] In the passage, it is read that the indicated price of grain is about ten times normal (thus the famine interpretation popularity), with an entire day's wages (a denarius) buying enough wheat for only one person (one *choenix*, about 1.1 litres), or enough of the less nutritious barley for three, so that workers would struggle to feed their families.[5] In the Gospels, the denarius is repeatedly mentioned as a monetary unit; for example, the denarius was the pay of a soldier for one day, and the day labor of a seasonal worker in the harvesting of grapes is also valued at one denarius (Matthew 20:2). Thus, it is probably a fact that with the approach of the Apocalypse, the most necessary food will rise in price greatly and the wages earned per day will be enough only for the minimum subsistence for the same day and nothing more.

Of the Four Horsemen, the black horse and its rider are the only ones whose appearance is accompanied by vocalization. John hears a voice, unidentified but coming from among the four living creatures, that speaks of the prices of wheat and barley, saying, "and see thou hurt not the oil and the wine". This suggests that the black horse's famine is to drive up the price of grain but leave oil and wine supplies unaffected (though out of reach of the ordinary worker). One explanation is that grain crops would have

3rd Half of the talk



https://www.npr.org/sections/thesalt/2016/06/13/481586649/a-map-of-where-your-food-originated-may-surprise-you
https://colostate.pressbooks.pub/cropwildrelatives/chapter/introduction-to-crop-wild-relatives/



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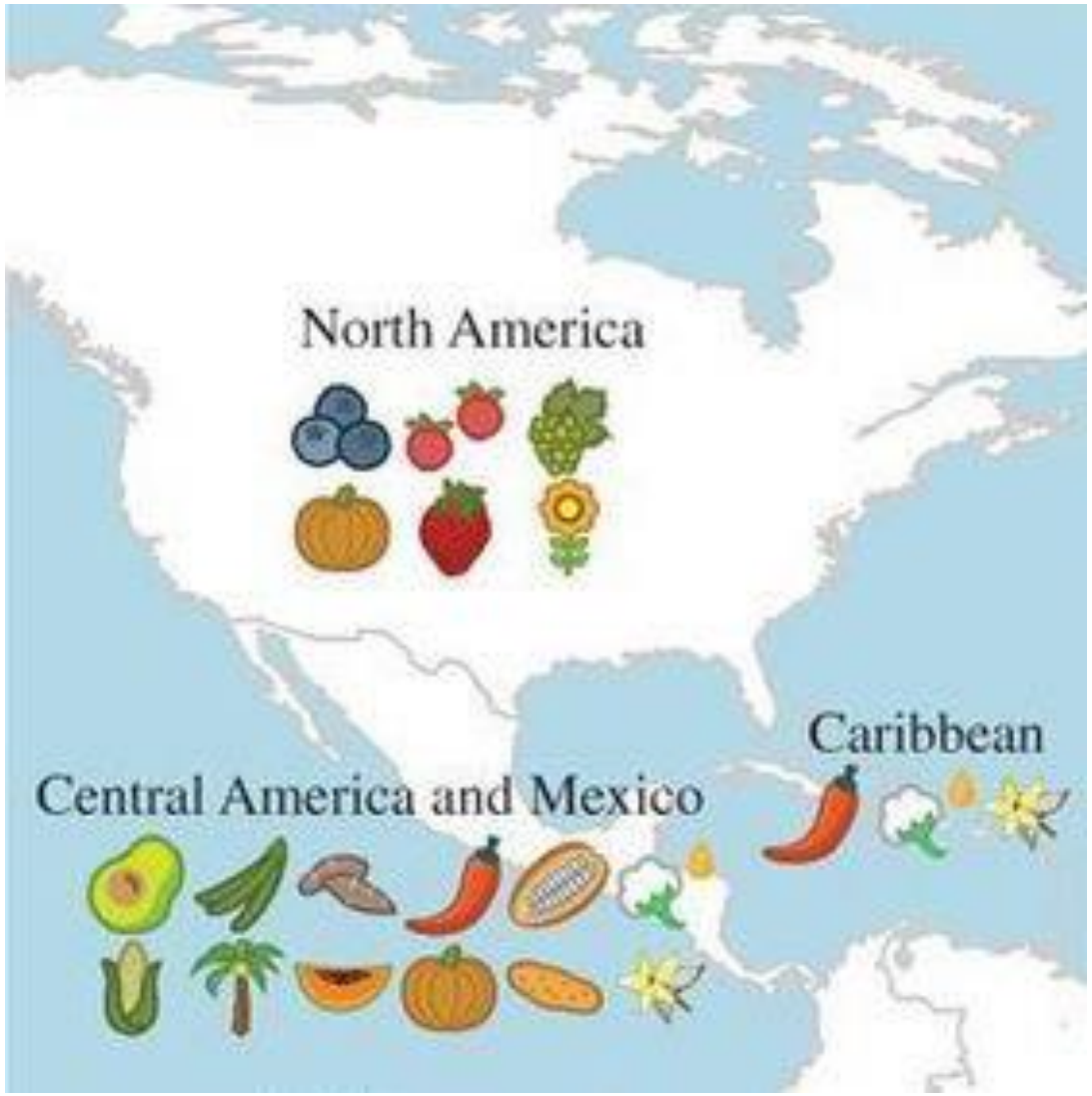
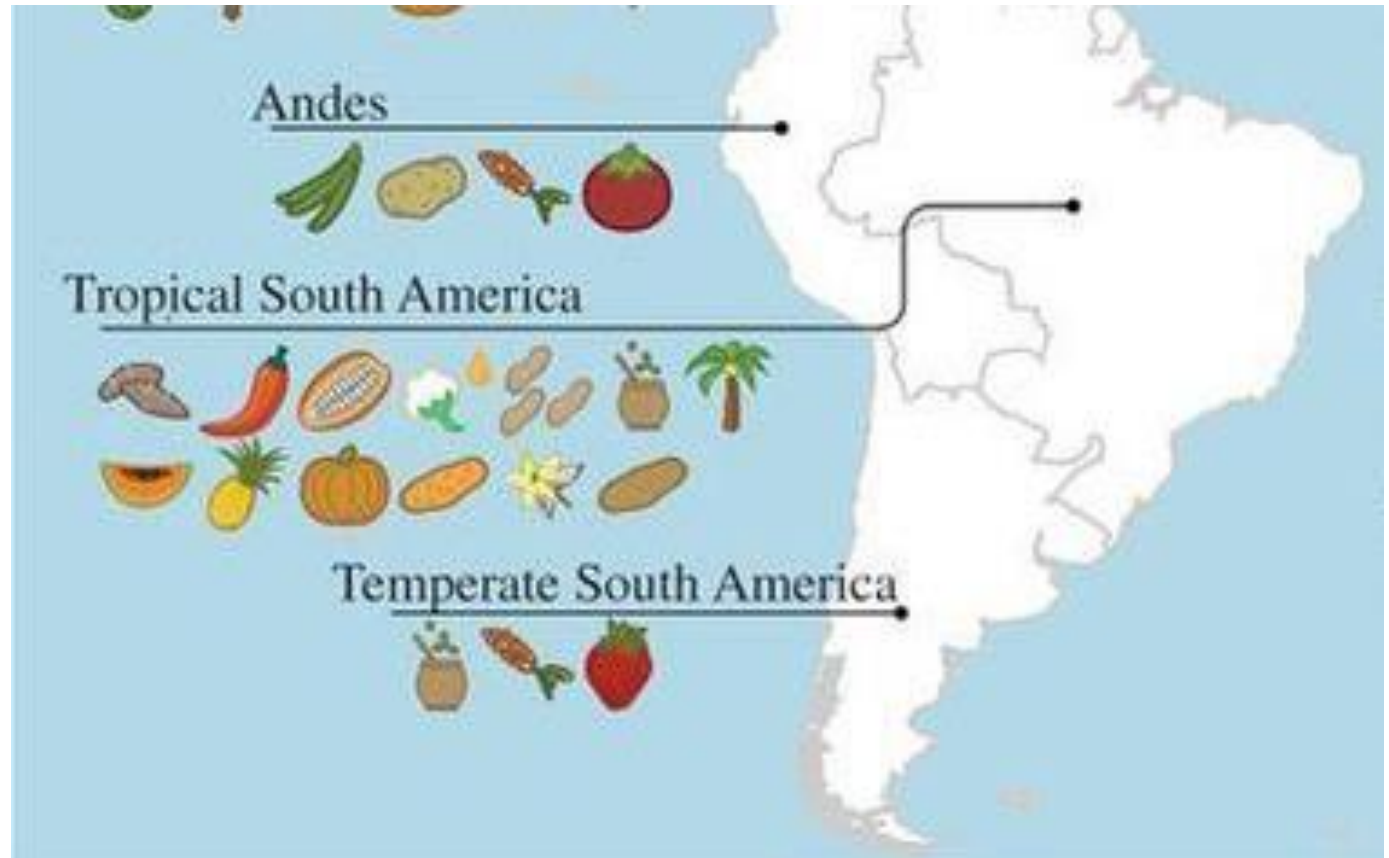




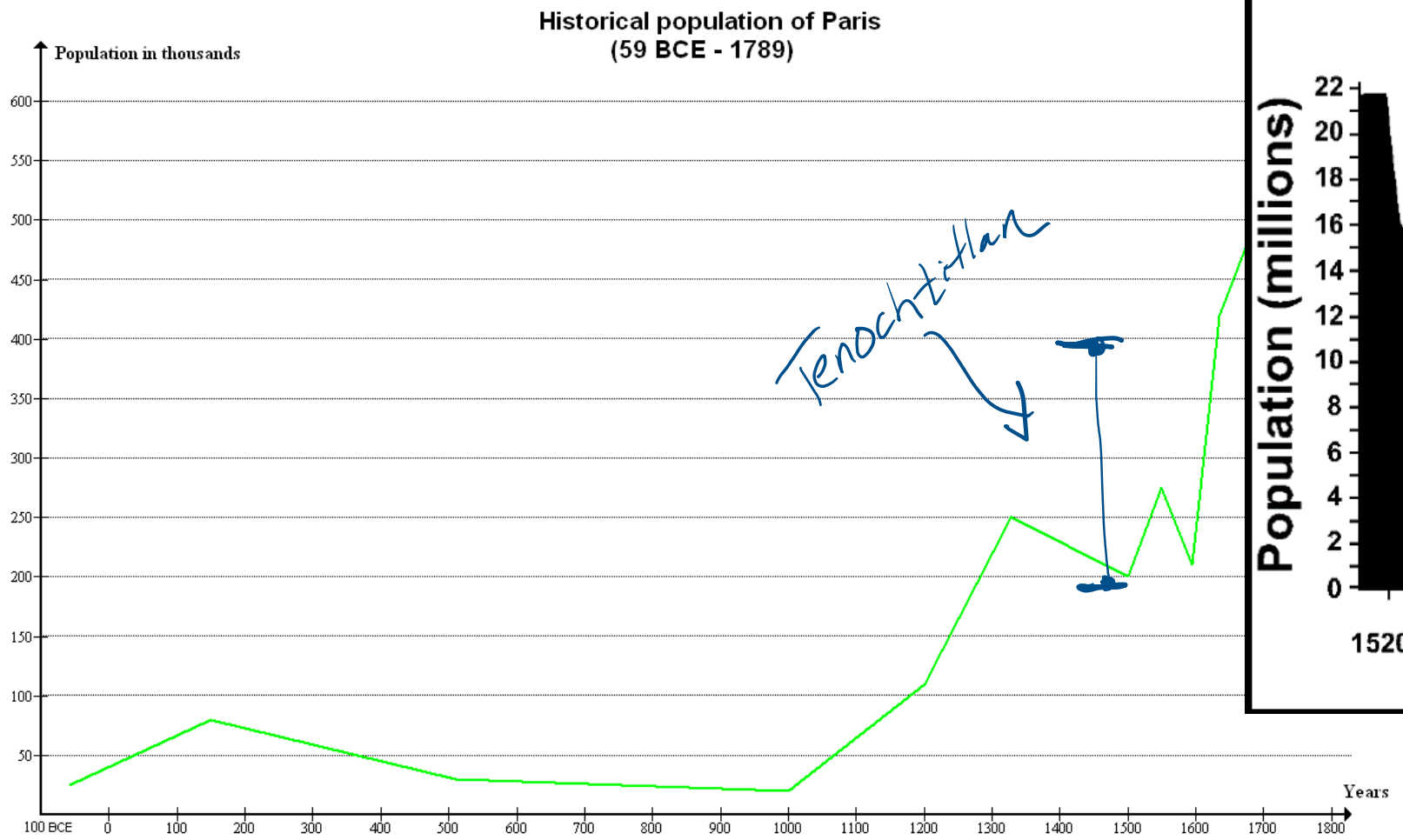
How does the world get their kcals today?

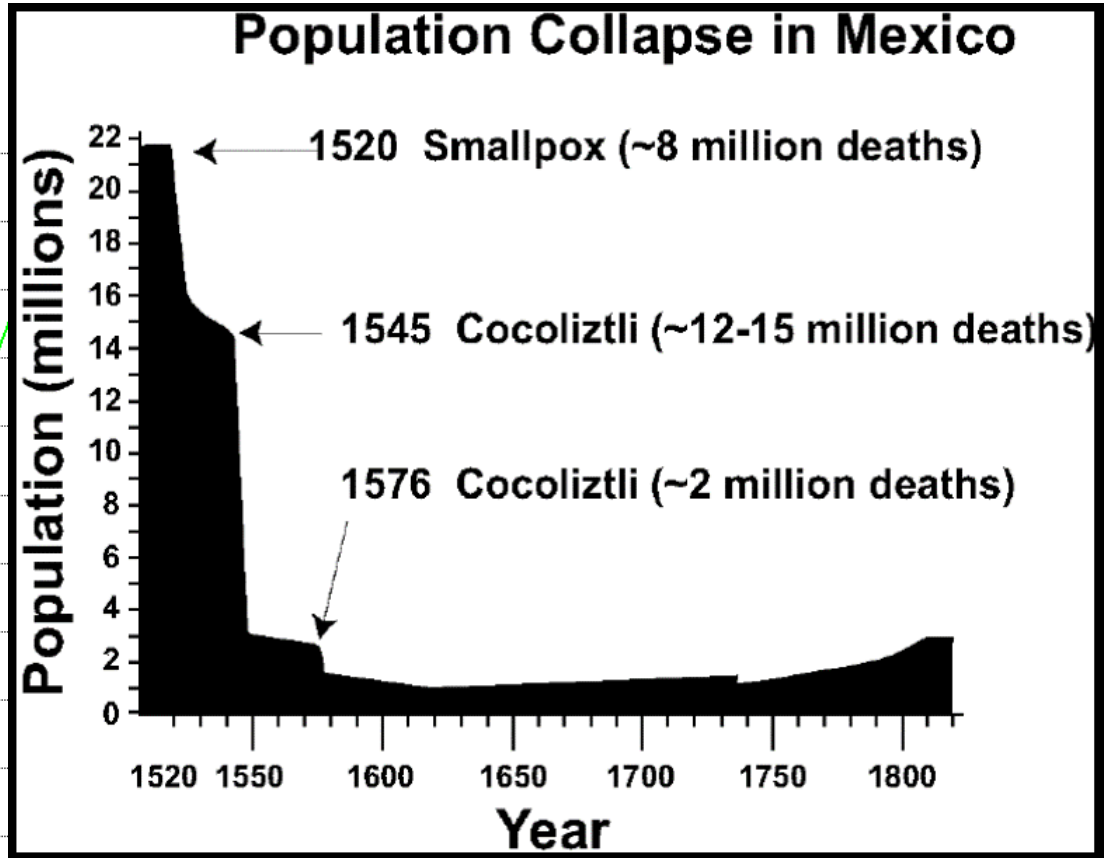
Ten staple foods of global importance (ranked by annual production)[12]

		World production, 2012[13]	Average world yield, 2010	World's most productive countries,[14] 2012[15]		World's largest producing countries, 2013[16]	
Rank	Crop	(metric tons)	(tons per hectare)	(tons per hectare)	Country	(metric tons)	Country
1	Maize (Corn)	**873 million**	5.1	11.1[17]	United States	**354 million**	United States
2	Rice	738 million	4.3	9.5	Egypt	204 million	China
3	Wheat	671 million	3.1	8.9	New Zealand	122 million	China
4	Potatoes	365 million	**17.2**	**45.4**	Netherlands	96 million	China
5	Cassava	269 million	12.5	34.8	Indonesia	47 million	Nigeria
6	Soybeans	241 million	2.4	4.4	Egypt	91 million	United States
7	Sweet potatoes	108 million	13.5	33.3	Senegal	71 million	China
8	Yams	59.5 million	10.5	28.3	Colombia	36 million	Nigeria
9	Sorghum	57.0 million	1.5	4.5	United States	10 million	United States
10	Plantain	37.2 million	6.3	31.1	El Salvador	9 million	Uganda

How did the Americas get their kcals in 1491?

In 1491 there were ~50M people in N. America and ~70M people in Europe. The Americans were a primarily agricultural society. What did they eat? (for 7 centuries!!!)



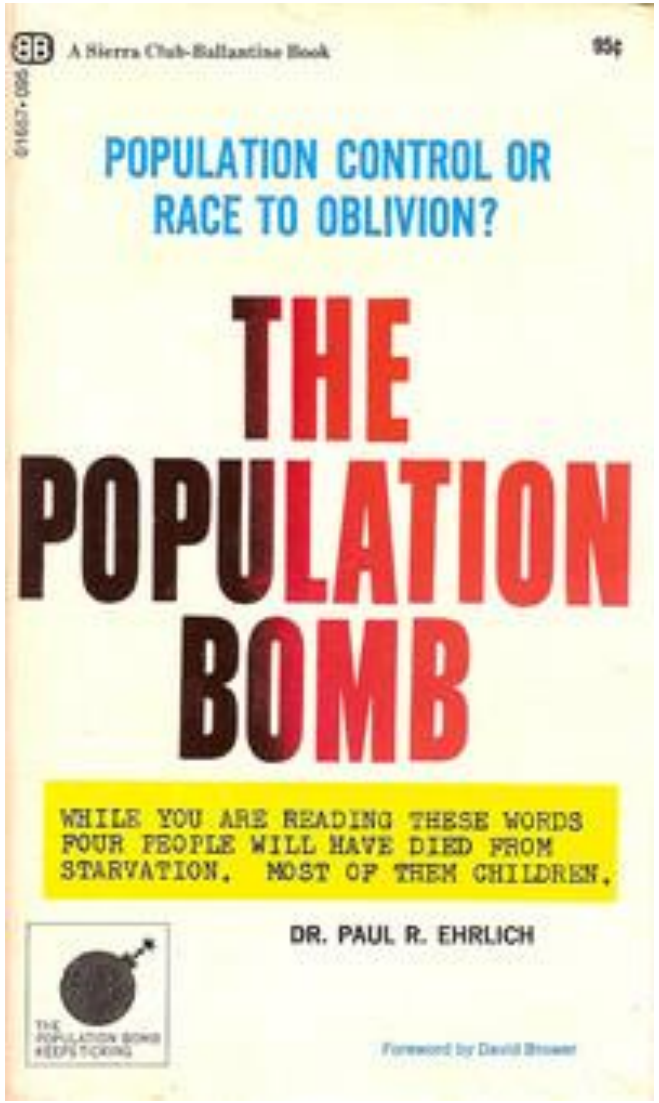


Tenochtitlan was 200-400k people in 1491!

In 1491, the Aztecs:

1. Were a HUGE society (50M people!)
2. Tenochtitlan was ~= Minneapolis !
3. Had NO draft animals
4. Had NO farm animals
5. Had NO large animals (eg bison) to hunt
6. Had NO large-scale whaling
7. Produced lots of art depicting human sacrifice and cannibalism.

1970's Zeitgeist



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So… Cannibalism was a response to protein deficiency during famine years?

A scene depicting ritualistic Aztec cannibalism being practiced in the Codex Magliabechiano, folio 73r.

The Ecological Basis for Aztec Sacrifice

Author(s): Michael Harner

Source: *American Ethnologist*, Feb., 1977, Vol. 4, No. 1, Human Ecology (Feb., 1977), pp. 117-135

Published by: Wiley on behalf of the American Anthropological Association

Stable URL: https://www.jstor.org/stable/643526

Or, calm down and run the numbers…

Gross!

An opportunity for Claim-Evidence-Reasoning?

12 May 1978, Volume 200, Number 4342 SCIENCE

Aztec Cannibalism: An Ecological Necessity?

The Aztec diet was adequate in protein and cannibalism would not have contributed greatly.

Bernard R. Ortiz de Montellano

In a recent article Harner proposed that the Aztecs conducted sacrifices in order to supplement their diet through cannibalism (*1*). The parts of his argument with which I am concerned are:

1) The Aztecs lacked domesticable herbivores and therefore lacked a good source of protein.

2) Corn and beans could satisfy protein needs but must be eaten together to be useful.

becoming a part of the privileged nobility and thereby partaking of the extra food.

5) Unpublished figures (Woodrow Borah, cited in Harner) place the population of Central Mexico at 25 million, with 250,000 sacrificed yearly, and that of Tenochtitlan at 300,000, with 15,000 sacrificed annually.

6) The evidence of widespread cannibalism is clearly shown in Spanish

protein deficiency, then human meat should make a significant dietary contribution. In this article I show that it did not suffice as a protein source, even for the privileged 25 percent. If the meat was really needed for dietary reasons, the other 75 percent of the population was in even greater need since its diet was sparser than that of the nobility. It is not satisfactory to say that the commoners strived for future rewards, since protein consumption cannot be delayed for the time span (several years until reaching adulthood) proposed by Harner.

The principle of parsimony seems to dictate that, rather than beginning with an abnormal response, such as cannibalism, to dietary deficiency, responses which have occurred frequently in the past with other cultures should be investigated. Such responses to population pressures are improvement in agriculture and expansionist conquests.

With respect to motivations, it is relevant to examine those of the Spanish chroniclers of the conquest as well as those of present-day Mexicans and anthropologists.

Most of the data I present deals with Tenochtitlan, both because there is more information available for this city and be-

Table 1. Sample diets derived solely from grains received in tribute by the Aztecs and which meet dietary requirements of the Food and Agriculture Organization–World Health Organization (FAO-WHO). The data from (*52*).

Item	Energy (kcal)	Protein (g)	Fat (g)	Calcium (mg)	Phosphorus (mg)	Vitamin A (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic acid (mg)
					Diet 1					
Corn (400 g)	1432	33.6	18	44	484	0.6	1.52	0.4	7.6	–
Beans (100 g)	343	22.7	1.6	1.3	415	0.008	0.47	0.40	2.1	1
Chia (100 g)	463	15.6	22.7	518	518	0.01	0.38	0.13	3.74	–
Huauhtli (100 g)	53*	6.2*	0.6	468*	91	2.74	0.09	0.29	1.5*	75
Total	2291	78.1	42.9	976	1508	3.36	2.86	0.97	15.0	76
					Diet 2					
Corn (300 g)	1074	25.2	13.5	33	363	0.45	1.44	0.3	5.7	
Beans (200 g)	686	45.4	3.2	2.6	830	0.016	0.94	0.3	4.2	
Chia (200 g)	926	31.2	45.4	1036	1036	0.02	0.76	0.26	7.48	
Huauhtli (100 g)	53*	6.2*	0.6	468*	91	2.74	0.09	0.29	1.5*	
Total	2739	108	62.7	1540	2320	3.23	3.23	1.15	18.9	
FAO-WHO	2200	45		800	800	1	1.2	1.8	20	

*Data taken from Oliveira and Carvalho (9) corrected to net rather than dry weight. These values are probably low since they are for amaranth leaves, and th also ate the seeds of the amaranth.

Aztec Cannibalism: An Ecological Necessity?

The Aztec diet was adequate in protein and cannibalism would not have contributed greatly.

Bernard R. Ortiz de Montellano

Amaranth

Amaranthus tricolor

History [edit]

The native range of the genus is cosmopolitan.[8] In pre-Hispanic times, amaranth was cultivated by the Aztec and their tributary communities in a quantity very similar to maize.[37] Known to the Aztecs as ***huāuhtli***,[38] amaranth is thought to have represented up to 80% of their energy consumption before the Spanish conquest. Another important use of amaranth throughout Mesoamerica was in ritual drinks and foods. To this day, amaranth grains are toasted much like popcorn and mixed with honey, molasses, or chocolate to make a treat called *alegría*, meaning "joy" in Spanish.

Are you normally starving to death during the holidays or the harvest?

Aztec Cannibalism: An Ecological Necessity?

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Table 4. Comparison of the agricultural cycle with Aztec ritual ceremonies.

Aztec month	Christian* calendar	Agricultural† cycle	Ritual ceremonies‡
	Dry season		
1 Atlcualo	02/14 to 03/05		Children sacrificed to Tlaloc
2 Tlacaxipehualiztli	03/06 to 03/25		Big kill, children to Tlaloc
3 Tozozoztontli	03/26 to 04/14		Children to Tlaloc
4 Hueytozoztli	04/15 to 05/04		
	Rainy season		
5 Toxcatl	05/05 to 05/24	Planting of corn	Eating of victims possible but not mentioned
6 Etzalcualiztli	05/25 to 06/13	Planting of corn	
7 Tecuilhuitontli	06/14 to 07/03		
8 Hueytecuilhuitl	07/04 to 07/23		Time of scarcity
9 Miccailhuitl	07/24 to 08/12		
10 Xocotlhuetzi	08/13 to 09/01		No killing, no victims eaten
11 Ochpaniztli	09/02 to 09/21	Fruit harvest	Harvest feast
12 Teotleco	09/22 to 10/11		
13 Tepeilhuitl	10/12 to 10/31	Corn harvest	Big kill and eating
14 Quecholli	11/01 to 11/20	Corn harvest	
	Dry season		
15 Panquetzaliztli	11/21 to 12/10	Corn harvest	Biggest kill and eating
16 Atemoztli	12/11 to 12/30	Corn harvest	No killing, no victims eaten
17 Tititl	12/31 to 01/19		Eating of victims possible but not mentioned
18 Izcalli	01/20 to 02/08		No killing, no victims eaten

*Correlation of Gregorian and Aztec calendars according to Caso (57). †Agricultural cycle correlation (58). ‡Characteristics of ritual ceremonies particularly involving sacrifices and cannibalism taken from a survey of (*13; 38; 51*, p. 432).

Per capita meat consumption in the United States in 2022 and 2031, by type

(in pounds)

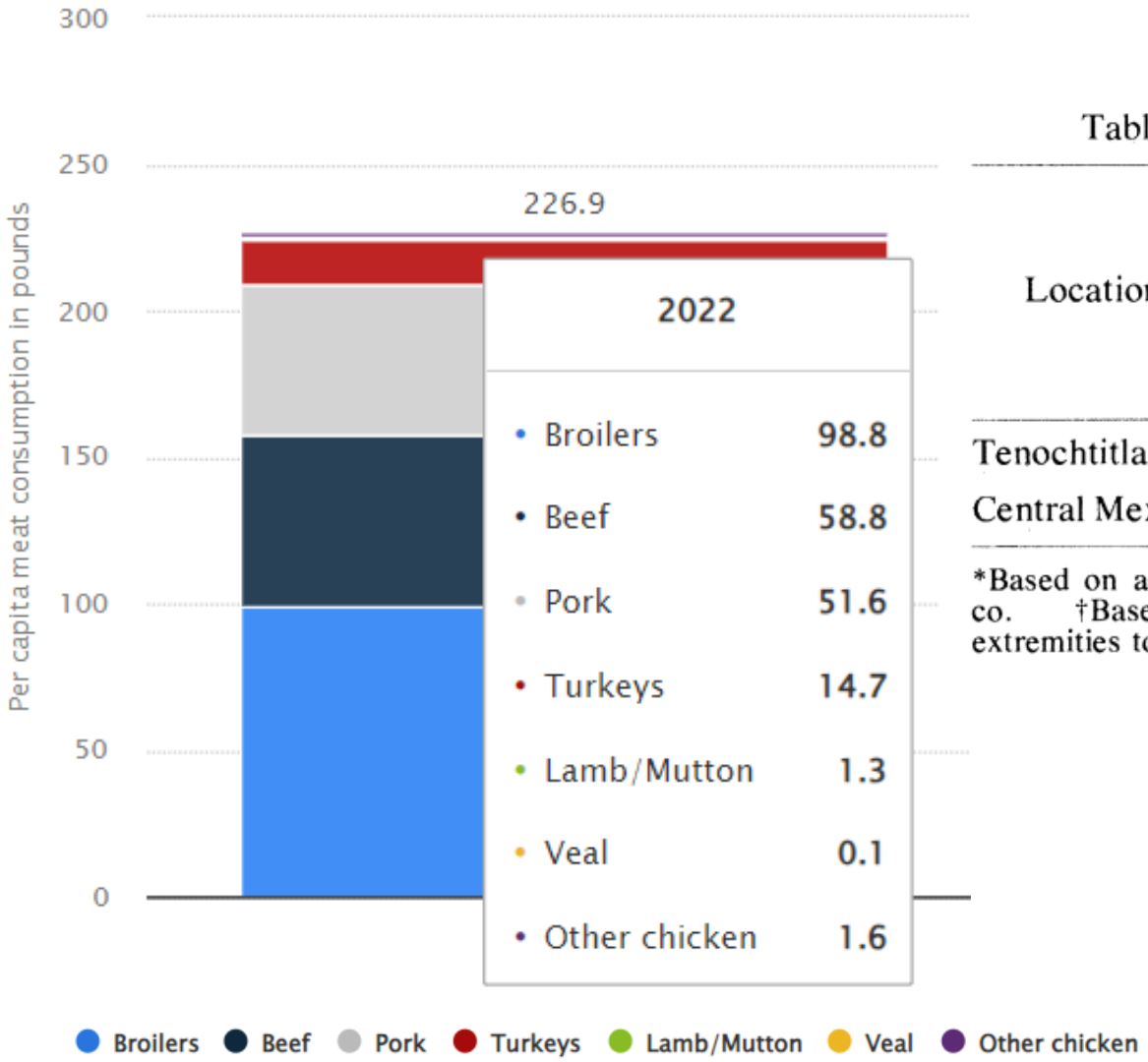


Table 3. Potential protein contribution of cannibalism to the diet of the Aztecs.

Location	Protein need* (10^6 kg/yr)	Available protein†		Annual need satisfied (percent)	
		Whole body (kg/yr)	Extremities‡ (kg/yr)	Whole body	Extremities
Tenochtitlan	1.2	78×10^3	27.2×10^3	6.5	2.30
Central Mexico	97.0	1.3×10^6	0.45×10^6	1.3	0.47

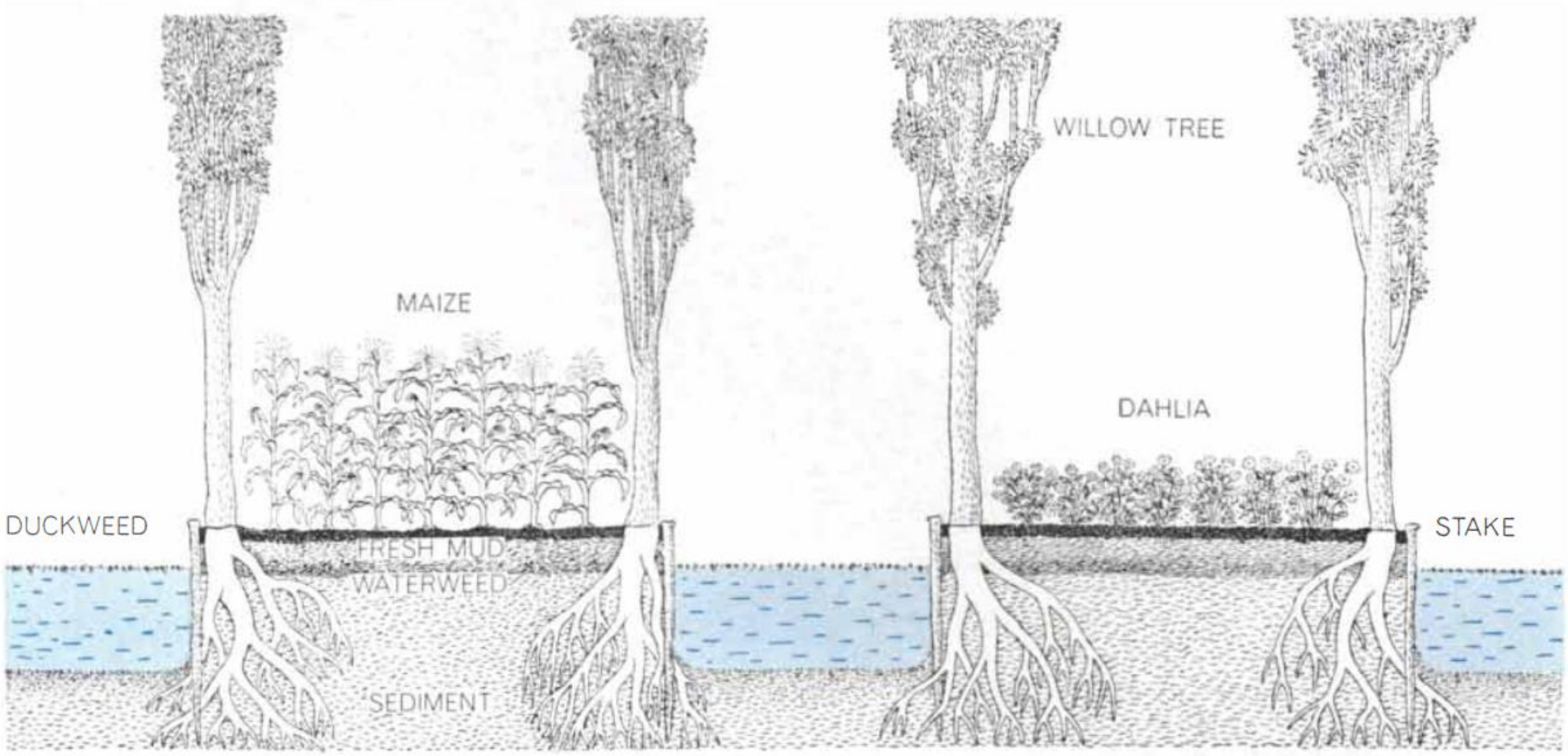
*Based on a population of 75,000 eligible consumers in Tenochtitlan and 6.25 million in Central Mexico. †Based on 15,000 annual sacrifices in Tenochtitlan and 250,000 in Central Mexico. ‡Assuming the extremities to be 35 percent of total body weight (*41*).

Reasoning: What fraction of Americans get 100% of their protein from Turkey or Lamb???

https://www.statista.com/statistics/189222/average-meat-consumption-in-the-us-by-sort/

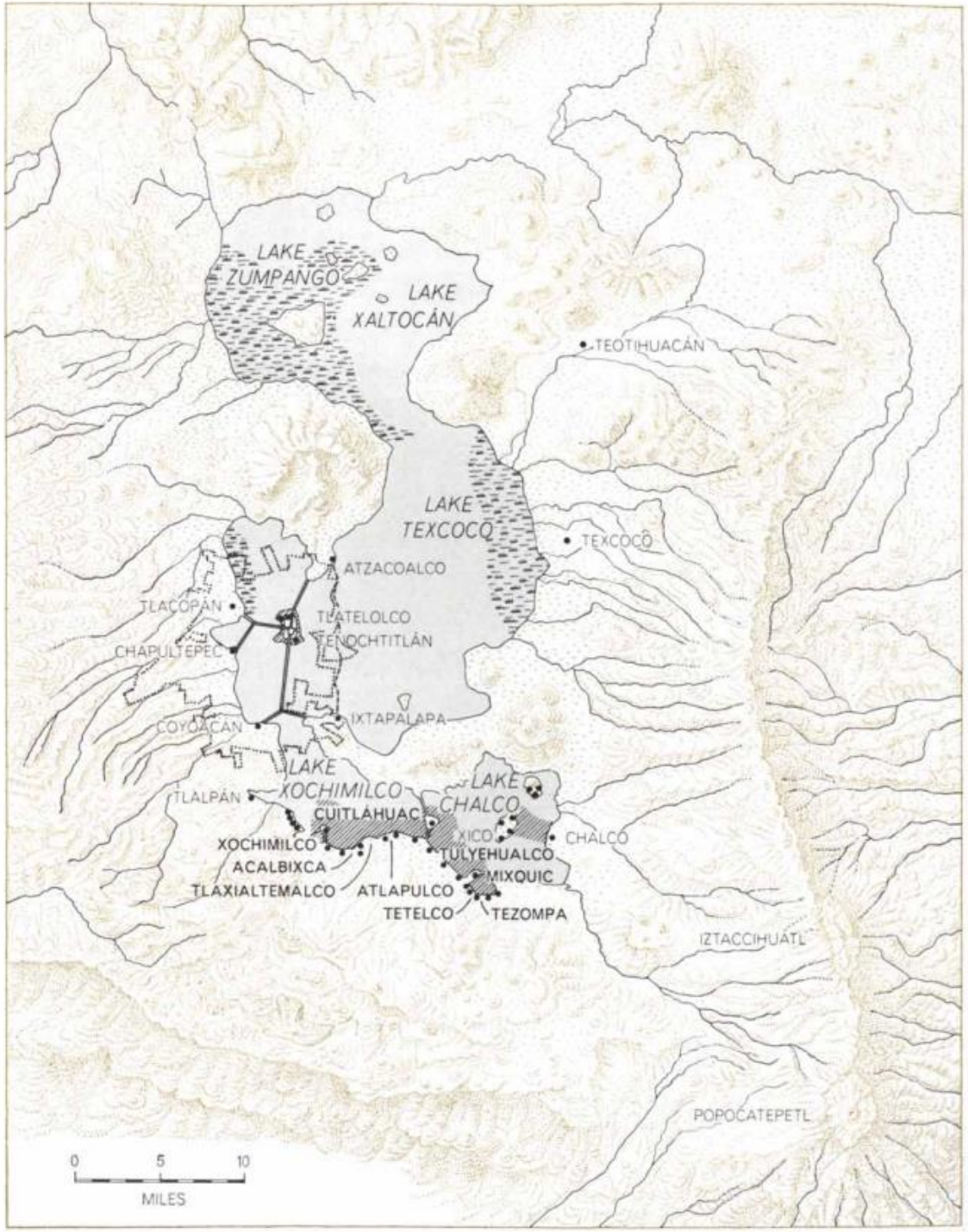
How do you grow 7 crops a year, two of them maize (corn)?

THE CHINAMPAS OF MEXICO
Author(s): Michael D. Coe
Source: *Scientific American*, Vol. 211, No. 1 (July 1964), pp. 90-99
Published by: Scientific American, a division of Nature America, Inc.
Stable URL: https://www.jstor.org/stable/10.2307/24931564



CROSS-SECTION DIAGRAM of chinampas and canals gives an idea of their construction. Fresh mud from bottom of canals and weeds for compost beneath the mud keep the chinampas fertile. Trees and stakes hold the sides of the chinampas firmly in place.

CHINAMPA GARDENS and canals that surround each of them on at least three sides form a grid pattern in this vertical air view. The grid "tilts" about 16 degrees east of north. Many of the canals that appear to be silted up are simply covered with waterweeds. Part of the town of Xochimilco, south of Mexico City, is at lower left. First canals were dug 2,000 years ago to drain swampy areas.



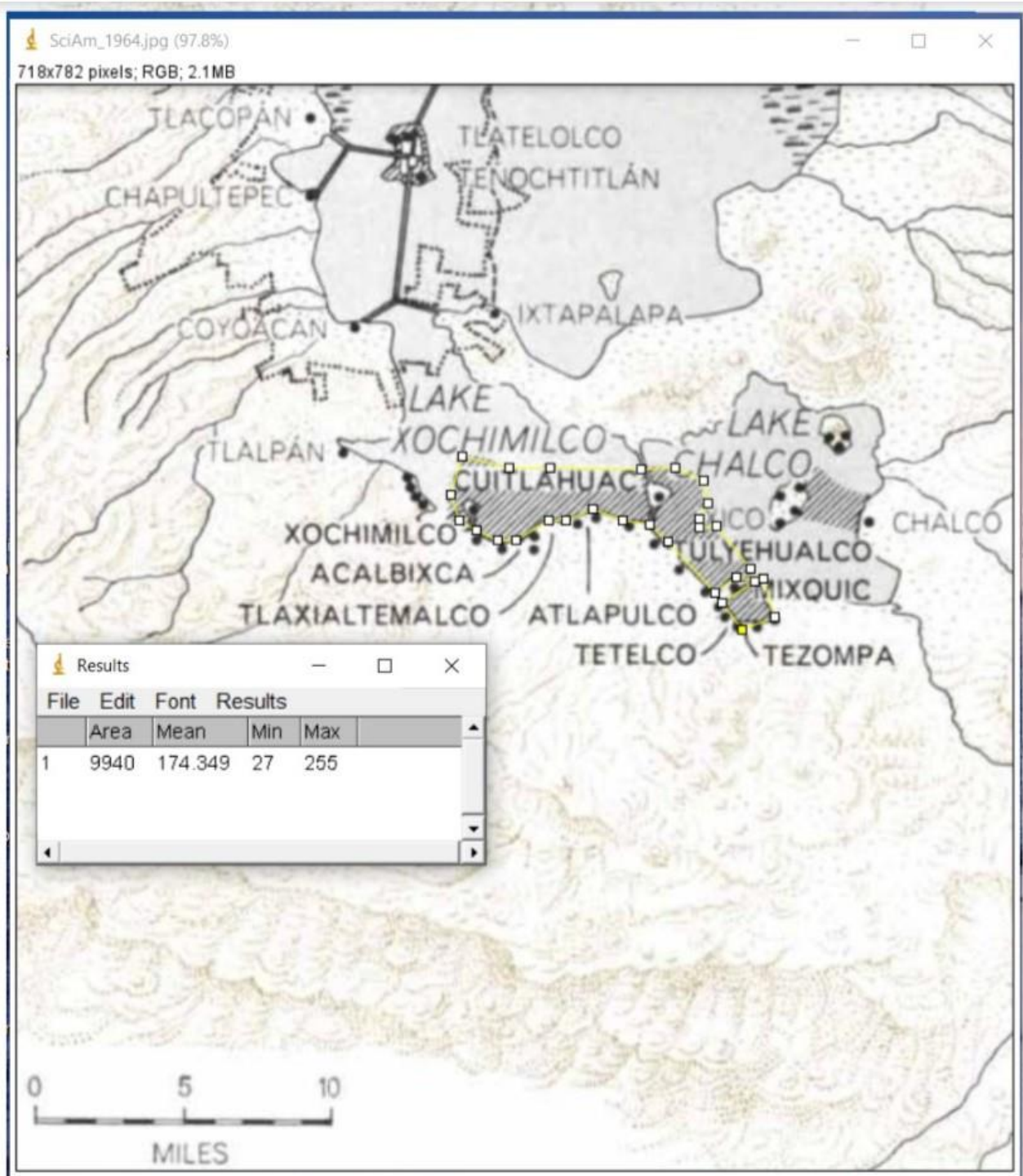
CHINAMPA AREAS (*hatched*) and the Valley of Mexico are shown as they appeared in summer at the time of the Spanish conquest in 1521. In the rainy summer season the five lakes coalesced into one large lake: the Lake of the Moon. Tenochtitlán-Tlatelolco was the Aztec capital. The dotted line marks the limits of modern Mexico City. The broken line between Atzacoalco and Ixtapalapa shows the location of the great Aztec dike that sealed off and protected the chinampas from the salty water of Lake Texcoco. Causeways and aqueducts leading to the Aztec capital are also shown. The names of the nine chinampa towns that remain today are given in heavy type. The large black dots without names are the sites of the freshwater springs that fed the chinampa zones.

TABLE I.—*A comparison of the food produced annually by an acre of land when utilized in the production of various food crops and live-stock products.*

Food products.	Yield per acre.		Calories per pound.	Pounds protein per acre (digestible).	Calories per acre.
	Bushels.	Pounds.			
Food crops:					
Corn	35	1, 960	1, 594	147. 0	3, 124, 240

https://imagej.net/ij/

ImageJ
Image Processing and Analysis in Java



Results

File Edit Font Results

	Area	Mean	Min	Max
1	9940	174.349	27	255

Results

File Edit Font Results

	Area	Mean	Min	Max	Angle	Length
1	9940	174.349	27	255	0	0
2	214	253.439	243.103	255	-0.538	213.009

0 5 10
MILES

Results

File Edit Font Results

Minimize

	Area	Mean	Min	Max	Angle	Length
1	9940	174.349	27	255	0	0
2	214	253.439	243.103	255	-0.538	213.009
3	1439	172.348	38.000	255	0.000	0.000

TABLE I.—*A comparison of the food produced annually by an acre of land when utilized in the production of various food crops and live-stock products.*

Food products.	Yield per acre.		Calories per pound.	Pounds protein per acre (digestible).	Calories per acre.
	Bushels.	Pounds.			
Food crops:					
Corn	35	1,960	1,594	147.0	3,124,240

16,000 acres @ 38bu/acre
would feed 100,000 people

16,000 acres @ 38bu/acre
would feed 100,000 people

$$Food\ production = 16,000 acres \cdot \frac{2\ corn\ crops}{year} \cdot P \frac{bu\ of\ corn}{acre}$$

$$Population\ requires = 100,000\ people \cdot \frac{3000 kcal}{person \cdot day} \cdot \frac{365 days}{year} \cdot \frac{1 lbs\ corn}{1594 kcal} \cdot \frac{1 bu}{56 lbs}$$

$$P \approx 38 \frac{bu}{acre} \tag{6}$$

https://arxiv.org/abs/2301.06637

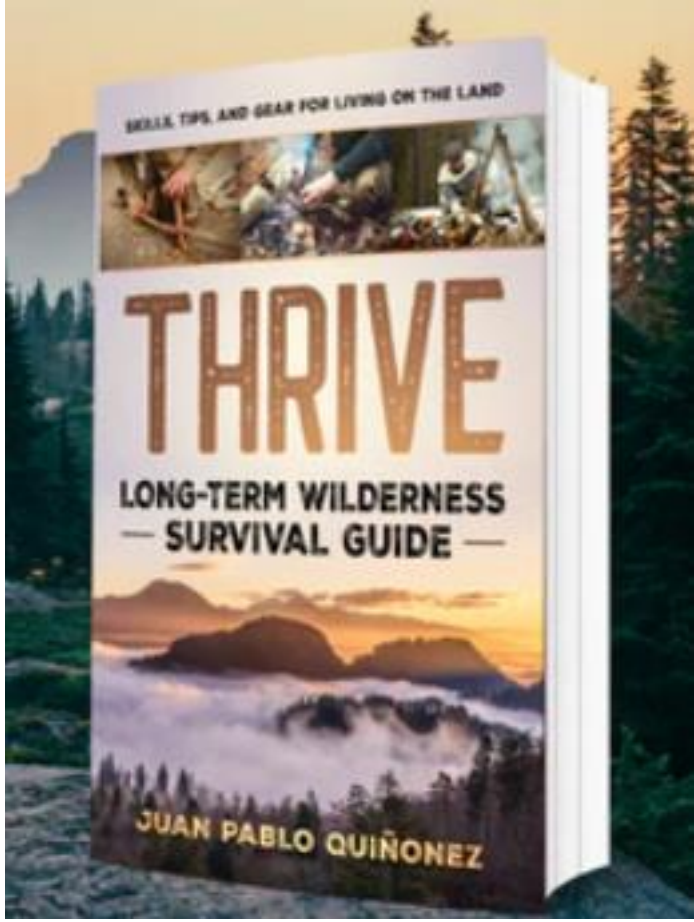
Sadly, Professor Moore is the only survivor of a plane crash in Alaska. Fortunately, the crash is adjacent a mountain stream that's filled with trout. From a map in the survival kit, he estimates that the hike downstream will take 5 days.

Should he (a) start hiking immediately,

or (b) spend a week catching and smoking trout so that he'll have food to eat while on the hike.

There are ripe wild berries along the path.

Information: 1 trout contains about 120 Calories of food energy; 1 lb of raspberries contains 240 Calories; Prof Moore is overweight at 22% body fat, or ~18kg of body fat. Human body fat contains about 3500 Calories per pound.



All businesses must be handicap accessible (per the ADA).

What if it were the law that every business must have free food available?