A One Health Perspective on Food Security

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www.webbertraining.com January 23, 2020

Food Security Challenges in the 21st Century

- What impact will climate change have on food production?
- What policies can governments implement to maximize food security? (And food safety?)
- Governments have an incentive to ensure food security to minimize risk of civil unrest or possibly even revolution.
- How can everyone be fed without destroying the planet's biosphere (global sum of all ecosystems)?

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Threats to Agriculture and Food Security

- Climate Change
- Crop Threats
  - Diseases and Pests
- Pollinator Threats
- Food Animal Threats
  - Diseases
  - Antimicrobial Resistance

3

Domestication of Plants and Animals

- Agriculture began about 10,000 years ago.
- Agriculture is foundation of civilization.
- Towns, cities, and nations flourished with secure food supplies..

http://www.nature.com/nature/journal/v447/n7142/full/nature05775.html

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Climate Change

https://climate.nasa.gov/effects/

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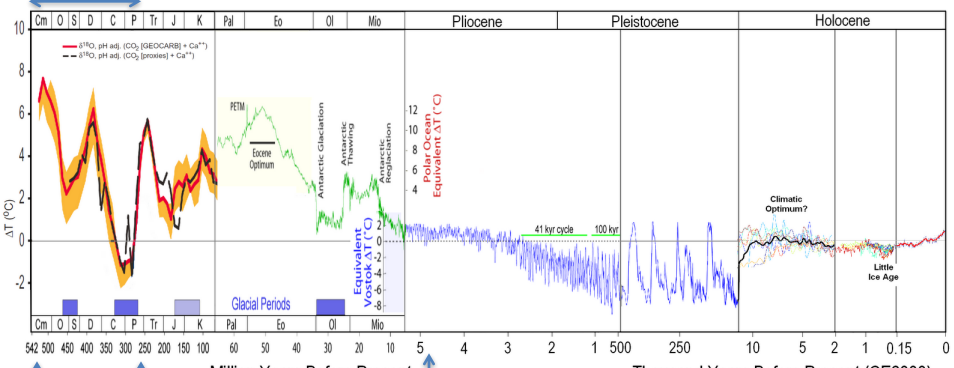
Time of Complex Life on Earth

Paleozoic Era

Temperature of Planet Earth



Permian-Triassic Extinction

Early hominids

Cambrian Explosion: Thriving life in seas but barren land

Earth is 4.5 Billion Years Old

https://commons.wikimedia.org/wiki/File:All_palaeotemps.png
http://gergs.net/2015/06/updating-the-geological-temperature-plot/all_palaeotemps/

6

Little Ice Age from 1300 to 1850

The Frozen Thames, Britain, 1677
Frost fairs lasted from 1607 to 1814

Ice skating on main canal of Pompenburg, Rotterdam, 1825.

The hunters in the snow, Pieter Brueghel the Elder, 1565

Little Ice Age noted for crop failures, bread riots, famine, wars.

Details outlined in "Global Crisis," by Geoffrey Parker and "Nature's Mutiny" by Philipp Blom.

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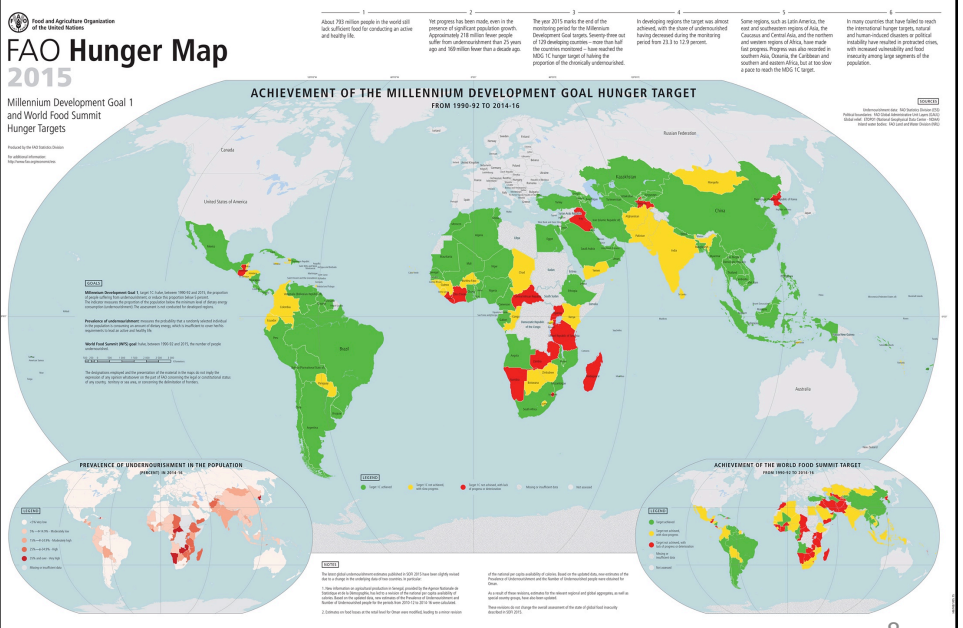
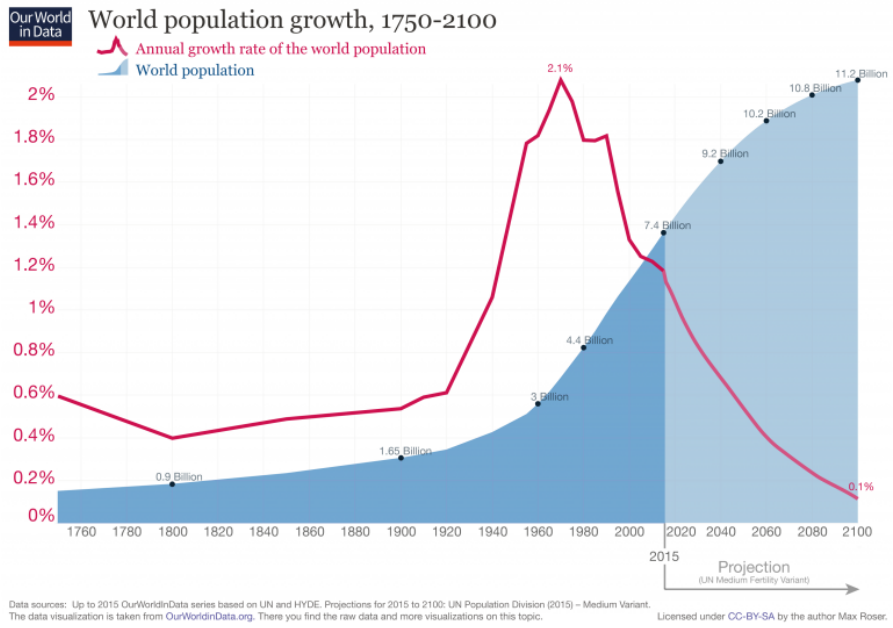


http://www.fao.org/hunger/en/

8



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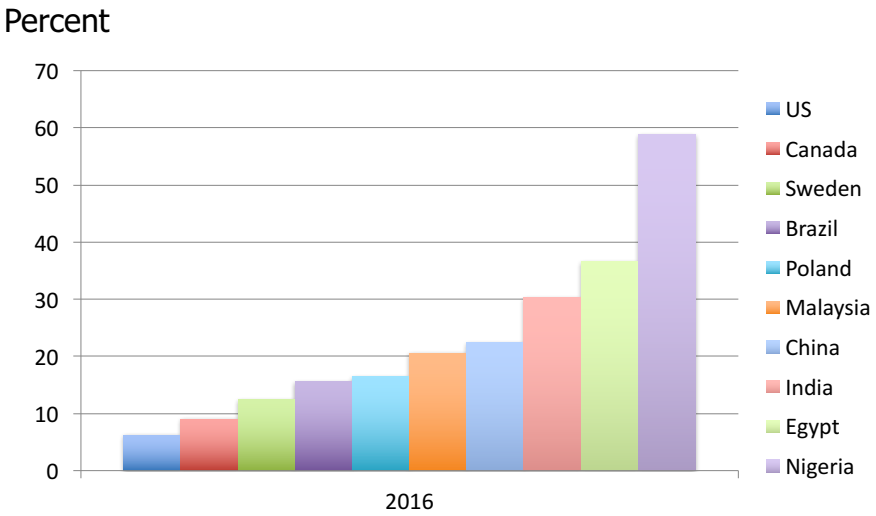
https://ourworldindata.org/world-population-growth

USDA: Percent of consumer expenditures spent on food consumed at home by selected countries, 2016



Our entire consumer economy depends on relatively inexpensive food

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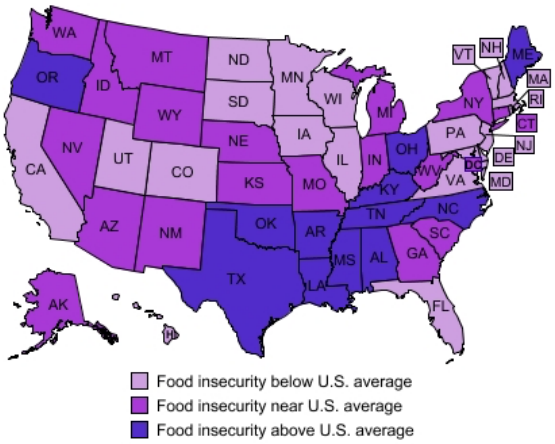
http://www.ers.usda.gov/data-products/food-expenditures.aspx

Prevalence of food insecurity, average 2013-15



Source: Calculated by ERS, USDA, using data from the December 2013, 2014, and 2015 Current Population Survey Food Security Supplements.

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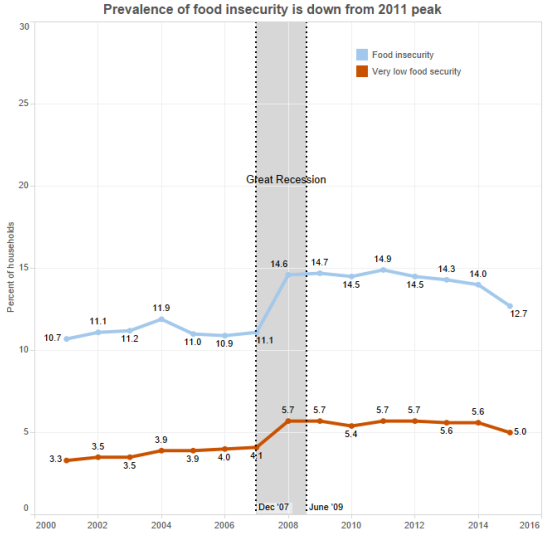
Characteristics of the food insecure in the U.S.

Food insecurity, 2001-15	Food insecurity before, during, and after the Recession	Very low food security before, during, and after the Recession	Changes in food insecurity, 2001-15	Changes in very low food security, 2001-15

Prevalence of food insecurity is down from 2011 peak



Source: Calculated by USDA, Economic Research Service, using Current Population Survey Food Security Supplement data
http://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us.aspx

Food insecure: Reduced food quality. Little reduction of food intake.

Very low food security: Disrupted eating patterns. Reduced food intake.

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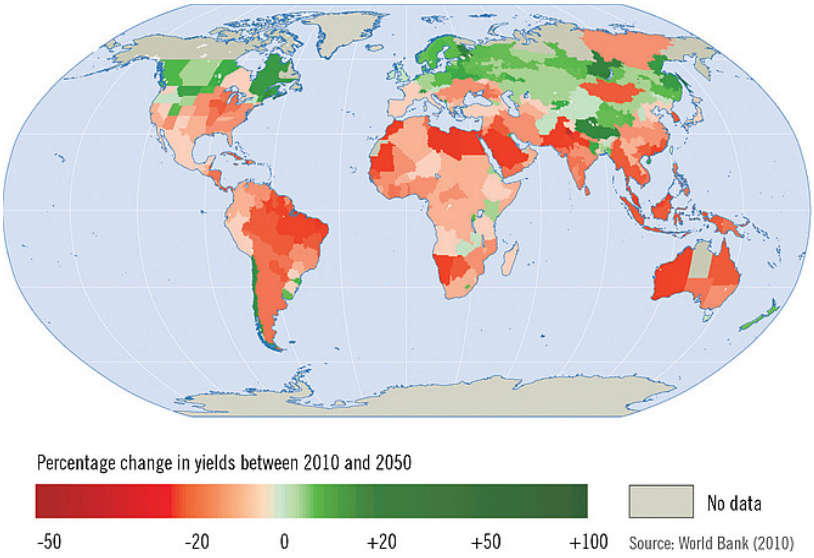
Estimated agricultural yields in 2050 due to climate change effects, assuming current agricultural practices and crop varieties.



https://siteresources.worldbank.org/INTWDR2010/Resources/5287678-1255547194560/WDR2010_BG_Note_Mueller.pdf
http://www.wri.org/sites/default/files/wri13_report_4c_wrr_online.pdf
https://openknowledge.worldbank.org/handle/10986/4387

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Crop Vulnerabilities

- According to FAO, 3 grains provide 60% of the world's food: rice, maize, and wheat.
- Almost half of humanity relies on rice as a food staple.
- Roots and tubers (e.g. potatoes and cassava) feed over 1 billion people in developing nations.
- Crops feed food animals as well.
- Naturally-occurring or bioengineered disease pathogens could devastate the world's food supply.

FAO. Dimensions of Need. An Atlas of Food and Agriculture. http://www.fao.org/docrep/U8480E/U8480E01.htm#Contents 14

Disease Threats to Crops

Rice blast caused by fungus *Magnaporthe oryzae*

Cassava brown streak virus transmitted likely by a whitefly species.

Best strategy is developing disease and drought resistant crops.

The problem?

They are labeled GMO.

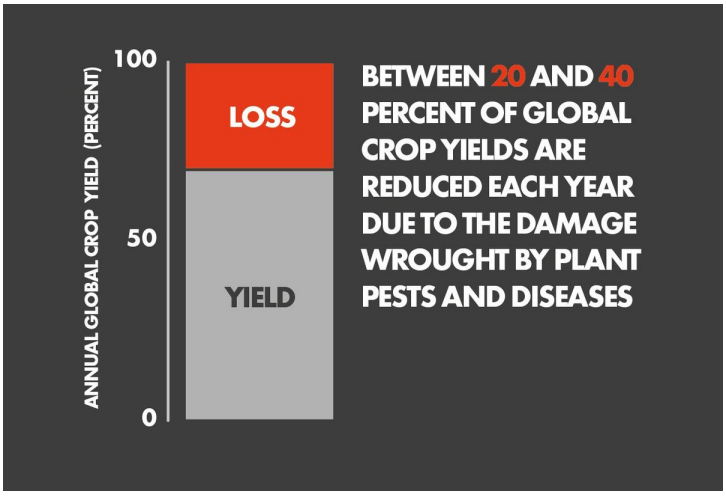
Wheat rust caused by fungus genus Puccinia, three different species.

African cassava mosaic virus transmitted by whiteflies.

https://www.agric.wa.gov.au/rice/rice-blast-disease
http://news.cornell.edu/stories/2008/04/gates-foundation-awards-268m-cu-fight-deadly-wheat-plague

15

FAO Estimates



http://www.fao.org/coag/en/

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Let's turn to insects: the good, the bad, and the ugly



https://www.mybeeline.co/en/p/how-the-honey-bees-navigate
http://www.pan-uk.org/about_neonicotinoids/
http://wlrn.org/post/mosquitoes-battling-zika-released-south-miami-neighborhood

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Insect Threats to Crops

Swarms of millions of locusts can consume over 100,000 tons of crops per day, enough to supply food to tens of thousands of people for a year.

http://www.fao.org/english/newsroom/field/locust_photo_gallery/locust1.htm
http://www.fao.org/emergencies/emergency-types/plant-pests-and-diseases/en/

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Pests and Pesticides

- Farmers have been battling pests (insects, fungi, weeds) since the dawn of agriculture.
- 4500 years ago, Sumerians used sulphur compounds to control pests.
- Pyrethrum, botanically derived from the dried flowers of *Chrysanthemum cinerariaefolium,* used as an insecticide for over 2000 years, deteriorated in sunlight.
- Naturally-derived inorganic (e.g. copper sulfate, lime sulfur, lead arsenate) and organic (i.e. pyrethrins, nicotine, rotenone) compounds were used until 1940's.
- Development of synthetic pesticides began during WW II.

https://agrochemicals.iupac.org/index.php?option=com_sobi2&sobi2Task=sobi2Details&catid=3&sobi2Id=31
Matthews, Graham. Pesticides: Health, Safety and the Environment. John Waley & Sons, Inc. 2016.

19

DDT's deleterious effects in the environment

https://pops-science30.weebly.com/history-of-pops.html

20

Neonicotinoids

- Neonicotinoids are a class of neuroactive insecticides chemically similar to nicotine. Less toxic than the organophosphate pesticides but have been implicated in Colony Collapse Disorder that has been devastating bee populations essential for pollination services.
- EU banned 3 of them in 2018.

https://www.epa.gov/ingredients-used-pesticide-products/chlorpyrifos
https://www.nytimes.com/interactive/2017/10/21/us/document-EPA-Chlorpyrifos-FOIA-Emails-to-NYT.html

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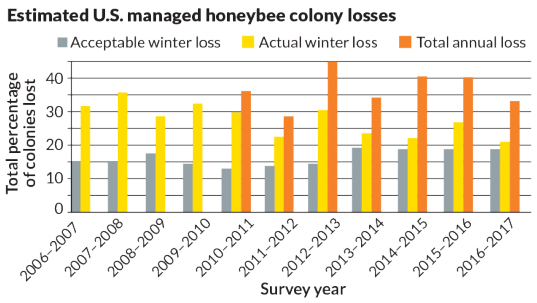
Honeybee Health

Colony Collapse Disorder:
A seemingly healthy bee colony loses most of its workforce.
Theories: stressors such as poor nutrition and pesticide exposure made bees vulnerable to diseases.



Honey bee colony losses are higher than acceptable.
Poor nutrition, pesticides, pathogens, and parasites continue to threaten bees, increase pollination costs, and affect food prices.
What impact will a hotter, drier climate have on bees?

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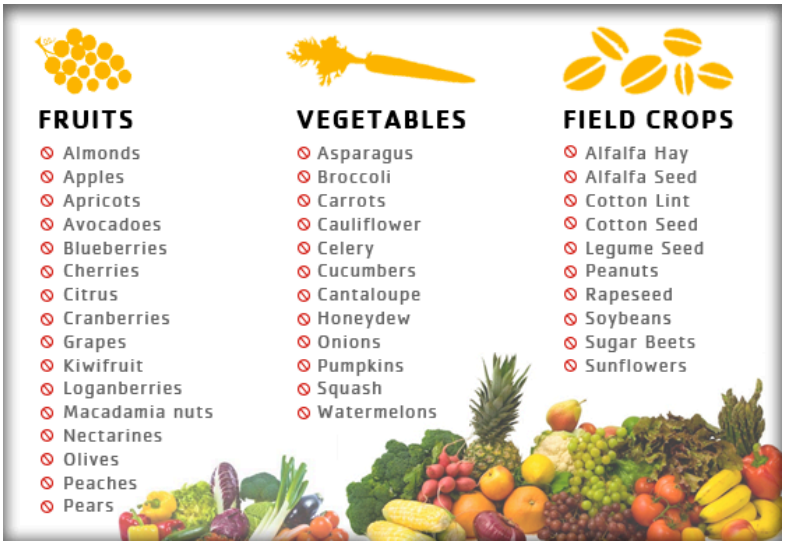
https://www.sciencenews.org/article/mystery-vanishing-honeybees-still-not-definitively-solved

Foods Dependent on Bees' Pollination Services



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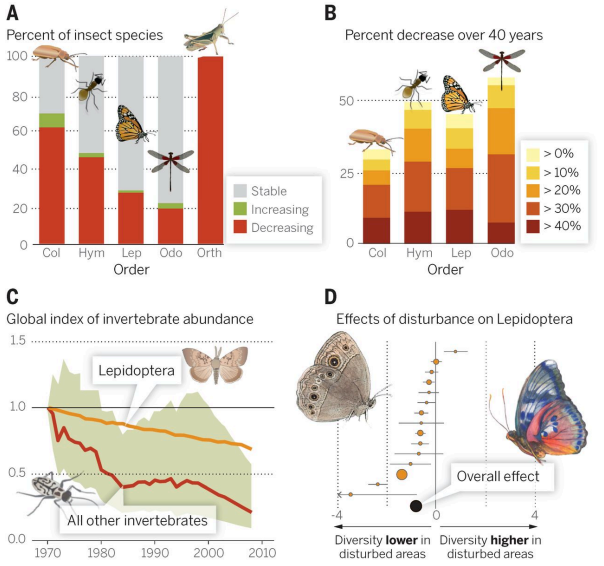
https://nohoneymoproblems.wordpress.com/why-should-we-care/

Fig. 1 Evidence of declines in invertebrate abundance.



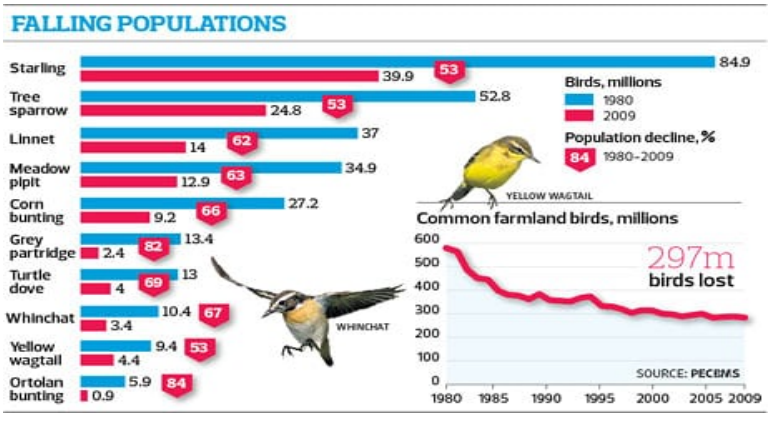
Science AAAS

Rodolfo Dirzo et al. Science 2014;345:401-406

Published by AAAS

25

Farming policies in Europe over 30 past years has led to decline of bird populations



Widespread pesticide use and destruction of ecosystems.

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https://www.theguardian.com/environment/2012/may/26/eu-farming-policies-bird-population

Sustainability of Pesticide Use

- Pesticides are analogous to antibiotics—they kill off the good bugs along with the bad bugs.
- Pesticides harm ecosystem and environmental health.
- We need to work with Nature, not against it, when growing crops.
- Harnessing the natural foes of pests should be a priority.

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Food Animal Vulnerabilities

- Severe **livestock diseases** could severely affect the world's food supply and economies, particularly in developing countries where farmers rely on livestock for food and livelihoods.
- In 2011, **Rinderpest** was 2nd disease (after smallpox) to be eradicated. A member of the *Paramyxoviridae* family, the virus causes disease in cloven-hoofed animals. Historically, outbreaks of it devastated the food supply. What would happen if it were re-introduced?
- **Foot and Mouth Disease (FMD)** is a severe, highly-infectious disease of livestock. US eradicated it in 1929. FMD remains a major problem in many countries. Moving National Bio and Agro-Defense Facility from Plum Island, New York to Manhattan, Kansas raises concerns about lab accidents/breaches in the middle of livestock country.
- **Arthropod-borne animal diseases**—The midge (Culicoides imicola and other culicoids) transmits Bluetongue disease & Epizootic hemorrhagic disease; Culex tritaeniorhynchus and Aedes vexans mosquitoes transmit Rift Valley fever virus. How will climate change affect the spread of these diseases?

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http://www.oie.int/fileadmin/Home/eng/Media_Center/docs/pdf/Disease_cards/RINDERPEST-EN.pdf

Vaccines, Medications, and Genetically Diverse and Robust Food Animals That Tolerate Heat and Drought Will Be Essential for Food Security in the 21st Century

MERS Vaccine needed for camels & for people who work with camels

http://www.nationalhogfarmer.com/animal-health/each-farm-needs-right-vaccination-program-pigs-and-profits
https://www.fda.gov/ForConsumers/ConsumerUpdates/ucm378100.htm
http://www.pnas.org/content/113/13/3410
https://www.timeoutabudhabi.com/restaurants/features/42057-camel-milk-in-abu-dhabi

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Public Opposition to Science

- Widespread mistrust of science, vaccines, and genetically modified organisms will hinder the ability to feed people in the 21st century.
- Vaccines have been a victim of their own success. People have forgotten the severity of the diseases that vaccines prevent.
- The affluent have the luxury to refuse food they deem "unacceptable."
- Opposition is not necessarily a matter of education (or the lack thereof).
- Market research, public outreach, and communication will be important strategies to counter public mistrust and misperceptions.

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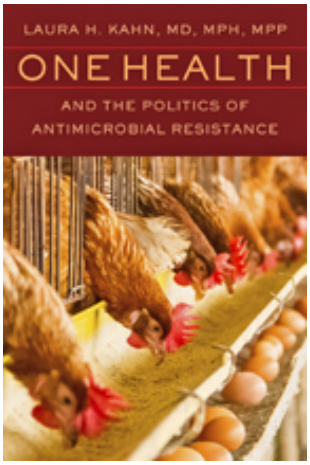
Antimicrobial resistance threatens veterinary medicine and agriculture



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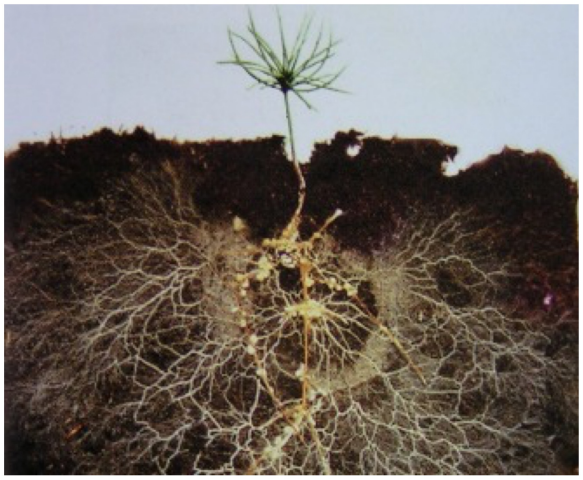
https://jhupbooks.press.jhu.edu/content/one-health-and-politics-antimicrobial-resistance

Microbial Ecology
We need to understand our microbial world better



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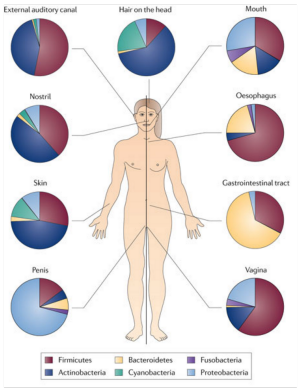
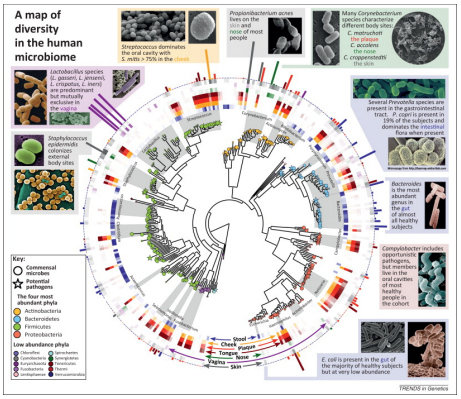
http://www.theatlantic.com/health/archive/2013/06/healthy-soil-microbes-healthy-people/276710/

Our bodies are microbial ecosystems





http://fullspectrumbiology.blogspot.com/2013/06/a-healthy-microbiome-is-healthy-you.html
https://www.sciencedirect.com/science/article/pii/S016895251200145X

33

Animals have microbial ecosystems too.

http://journal.frontiersin.org/article/10.3389/fmicb.2013.00087/full
https://www.nature.com/articles/496400c
http://blogs.plos.org/everyone/2015/03/30/let-microbes-paw-print-doggy-skin-bacteria/
https://www.progressivedairy.com/topics/feed-nutrition/don-t-upset-the-digestive-microbiome-utilize-direct-fed-microbials

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Metagenomics has shed light on microbial ecosystems in the environment

- DNA extracted directly from environment.
- Low doses of antibiotics in environment seem to serve as signaling agents for bacteria.
- Induce them to change behavior such as increase movement, produce biofilms, or synthesize chemicals.
- Antibiotic resistance genes are *everywhere* including places with no anthropogenic antibiotic exposure.

Linares J.F., Gustafsson I, Baquero F. et al. Antibiotics as intermicrobial signaling agents instead of weapons. PNAS 2006; 103: 19484-19489 (http://www.pnas.org/content/103/51/19484.full)

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The Global Resistome

- Evidence suggests that antibiotic resistance genes are ancient and predate the selective pressures of modern antibiotic use.
- DNA sequences from Alaskan permafrost dating back to Late Pleistocene were highly diverse and showed resistance to tetracycline, penicillin, vancomycin, and other antibiotics.
- But not clear if microbes in permafrost have been dormant or metabolically active—potentially influencing when they evolved and acquired resistance genes.

D'Costa V.M., King C.E., Kalan L., et al. Antibiotic resistance is ancient. Nature. 2011; 477: 457-461.
Steven B, Leveille R, Pollard W.H. et al. Microbial ecology and biodiversity in permafrost. Extremophiles. 2006; 10: 259-267.

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How are humans adversely impacting the Global Resistome?

- Poor sanitation
- Indiscriminate antibiotic use
- Widespread human and animal waste applications
- Land and water contamination
- Wildlife spread resistant microbes and resistant genes far and wide

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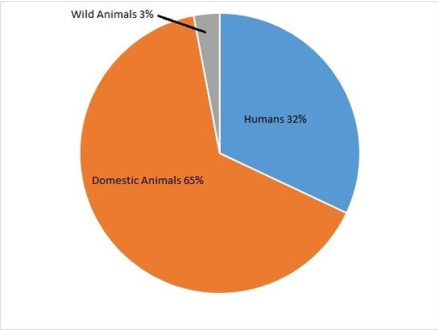
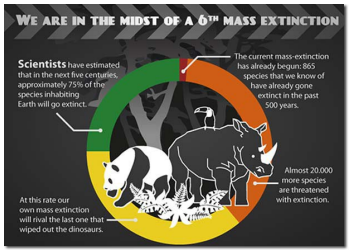
Humans and Domesticated Animals Make Up Approximately 97% of Total Mammalian Zoomass on Earth.

Together, they make a lot of manure, contaminating food and the environment, and increasing antibiotic use.





https://www.ecowatch.com/earth-is-facing-most-severe-extinction-crisis-in-65-million-years-1882085041.html
https://howwegettonext.com/pandemic-proofing-the-world-98222a38782#.fwwutac03
https://www.theodysseyonline.com/quick-facts-sixth-mass-extinction

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Is large scale animal agriculture ecologically sustainable?

https://en.wikipedia.org/wiki/Intensive_animal_farming
http://www.stoptac.org/index.php?mact=News,cntnt01,detail,0&cntnt01articleid=273&cntnt01origid=93&cntnt01returnid=93
http://www.fis.com/fis/techno/printable.asp?id=55672&l=e&ndb=1&print=yes

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Estimation of global recoverable human and animal fecal biomass

- In 2014, global population of humans (7.2 billion) and livestock animals (29.7 billion) produced an estimated 3.9 trillion kilograms of fecal matter.
- Animal fecal matter made up almost 80% of the total fecal biomass.
- Chickens, cattle, and sheep constituted the largest animal populations and produced the most fecal matter.
- Since 2003, total fecal matter production has been increasing by over 52 billion kilograms per year.
- By 2030, total fecal mass is estimated to be 4.6 trillion kilograms per year.

Berendes DM, Yang PJ, Lai A, et al. *Nature Sustainability* 2018; 1: 679-685.

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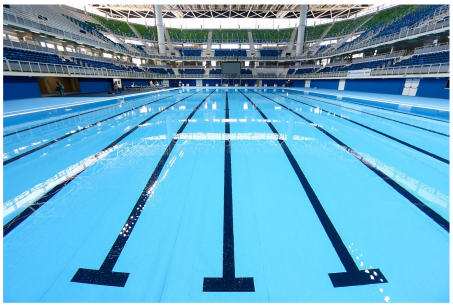
Total fecal matter produced by humans and livestock in 2014 would fill…



over 1.6 million Olympic-sized swimming pools,
and by 2030, over 1.8 million Olympic-sized swimming pools.

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Flooded Manure Lagoon After Hurricane Matthew, 2016

Flood waters partially submerged 14 manure lagoons. The waters carried large amounts of animal waste downstream and out to sea putting waterways and public health at risk.

Hurricane Florence's impact in North Carolina?

42

https://www.npr.org/sections/thesalt/2016/11/04/500701098/manure-happens-especially-when-hog-farms-flood

Manure's role in spread of disease and antibiotic resistance genes

- Application of manure to soil as fertilizer is widespread in many countries.
- In US, large concentrated animal feeding operations (CAFOs) produce massive amounts of manure.
- CAFOs alter microbial ecosystems and promote transfer to resistant genes through manure, air-borne drift of contaminated dust, animal waste run-off into water systems leading to water contamination.

GAO. Concentrated Animal Feeding Operations.
EPA Needs More Information and a Clearly Defined Strategy to Protect Air and Water Quality from Pollutants of Concern.
September 2008. GAO-08-944. Page 5. (http://www.gao.gov/assets/290/280229.pdf)

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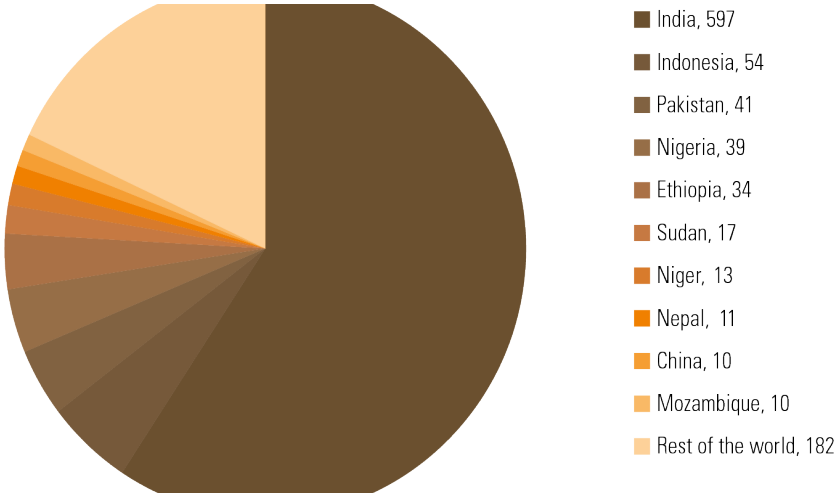
1 Billion People (14% World's Population) Openly Defecate



Source: Unicef data http://data.unicef.org/water-sanitation/sanitation

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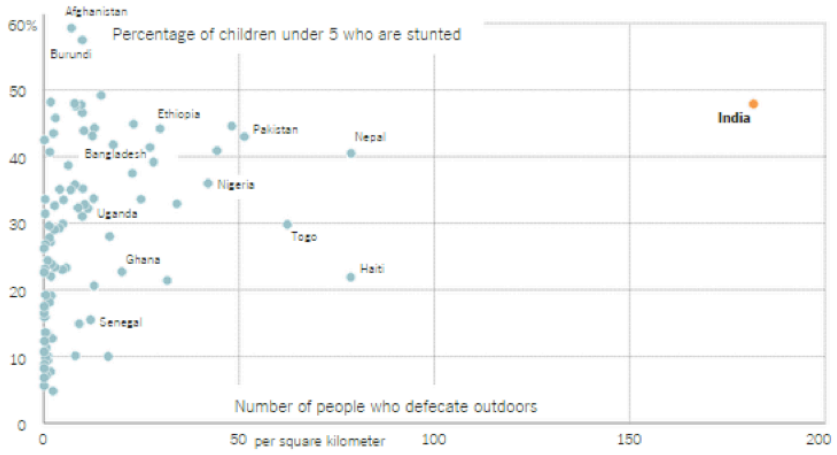
Open Defecation and Childhood Stunting



Harris G. Poor Sanitation in India May Afflict Well-Fed Children with Malnutrition. *New York Times*. July 13, 2014. http://www.nytimes.com/2014/07/15/world/asia/poor-sanitation-in-india-may-afflict-well-fed-children-with-malnutrition.html

45

Why is Open Defecation linked to antibiotic resistance?

- Because countries with poor sanitation rely on antibiotics to treat the high disease burden.
- According to Unicef, open defecation costs world's poorest countries $260 Billion/year.
- In India, open defecation is not a matter of poverty. Govt. has built latrines, but people prefer to defecate outside. Problem is cultural preference.

Coffey D, Gupta A, Hathi P., et al. Revealed preference for open defecation: Evidence from a new survey in rural north India. SQUAT Working Paper No. 1. Rice Institute. June 26, 2014. http://squatreport.in/wp-content/uploads/2014/06/SQUAT-research-pape

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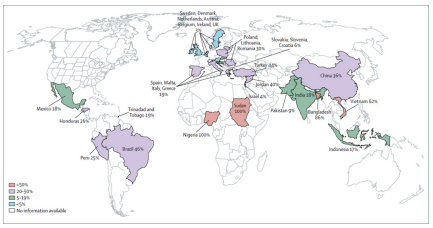
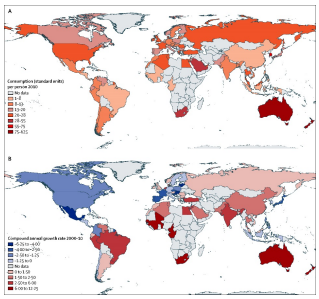
Consumption of Antibiotics in Humans



Frequency of Non-Prescription Antibiotic Use in General Population



Antibiotic Consumption per Person
Lancet Infectious Diseases 2014; 14: 742-50.

Country	Total Units	Units per Person
India	12.9 X 10^9	10.7
China	10.0 X 10^9	7.5
USA	6.8 X 10^9	22.0

Countries with high antibiotic consumption rates per person in 2010:
Australia 87 units per person and New Zealand 70 units per person.

But not all high-income countries had high consumption rates:
The Netherlands 7.89 compared to France 23.12.

Morgan DJ, Okeke IN, Laxminarayan R, et al. Non-prescription antimicrobial use worldwide: a systematic review.
Lancet Infect. Dis. Sept. 2011; 11: 692-701.
http://www.sciencedirect.com/science/article/pii/S1473309911700548

Van Boeckel T. P., Gandra S., Ashok A., et al. Global antibiotic consumption 2000 to 2010: an analysis of national pharmaceutical sales data. Lancet Infectious Diseases 2014; 14: 742-50.
http://www.thelancet.com/journals/laninf/article/PIIS1473-3099(14)70780-7/fulltext#article_upsell

47

Climactic conditions, such as storms, might be affecting microbial ecosystems

The relationship between Vibrio cholerae (i.e. cholera outbreaks) and vibrio phages in Dhaka, Bangladesh

http://weloveourbangladesh.blogspot.com/2012/08/jahaj-bari-or-boat-housechistia.html

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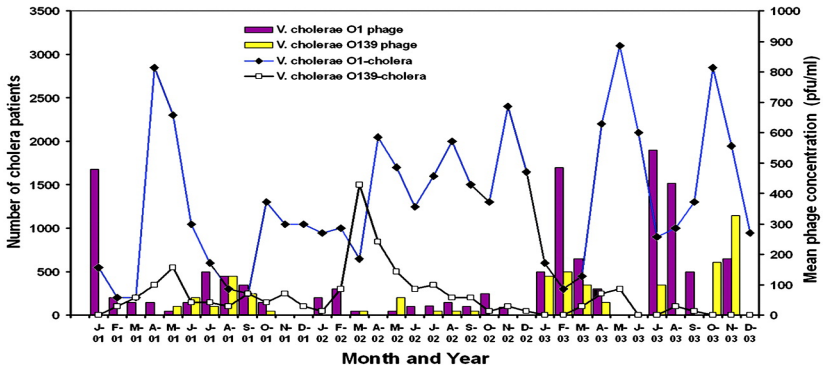
Mean concentration of lytic vibriophages in the aquatic environment of Dhaka, Bangladesh, and the estimated number of cholera cases reporting to the International Centre for Diarrhoeal Disease Research hospital in Dhaka from 2001 to 2003.



Shah M. Faruque et al. PNAS 2005;102:5:1702-1707

PNAS

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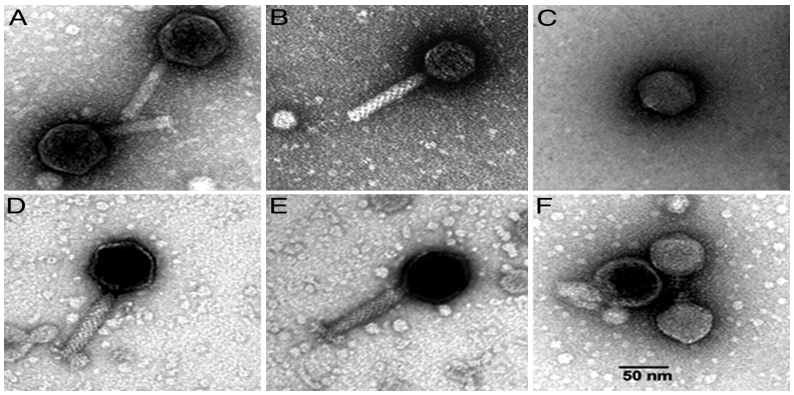
Electron micrograph of vibriophages isolated from environmental waters in Bangladesh.



Shah M. Faruque et al. PNAS 2005;102:5:1702-1707

PNAS

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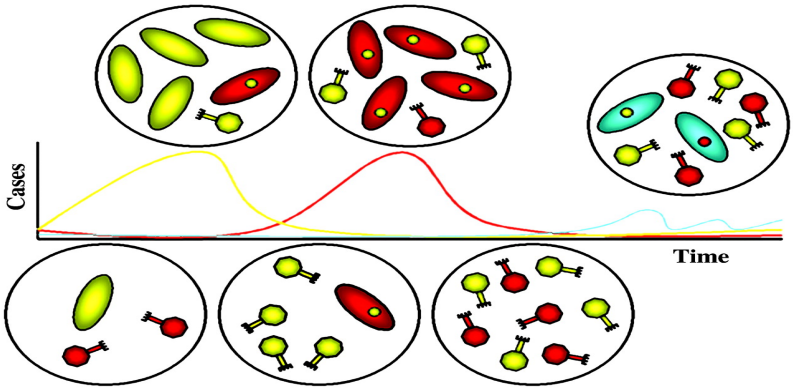
Schematic model for the influence of phage on cholera seasonality and serogroup emergence.



Shah M. Faruque et al. PNAS 2005;102:5:1702-1707

PNAS

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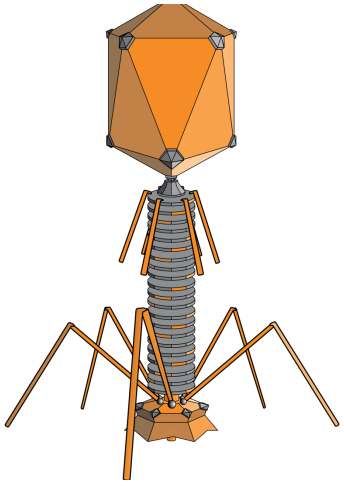
Bacteriophages ("Phages")

- Natural foes against bacteria
- Resistance is less of an issue than with antibiotics.
- CRISPR-Cas9 is bacterial immune system against phages.
- Phages evolve along with the bacteria
- Most prevalent bioform on the planet, "the Virosphere."
- They might be a viable strategy against antibiotic-resistant bacteria.
- FDA approved phage products for food safety on the market.
- A potential strategy in addressing environmental bacterial contamination on farms and other settings with high microbial burdens.



https://www.nytimes.com/2018/04/13/science/virosphere-evolution.html
https://www.nature.com/articles/s41396-017-0042-4

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TED Talk: How Sewage Saved My Husband's Life

Dr. Stephanie Strathdee and her husband Dr. Tom Patterson at UC San Diego
https://www.youtube.com/watch?v=AbAZU8FqzX4

Multidrug-resistant *Acinetobacter baumanii* infection cured with phage therapy.
UC San Diego is now establishing a Center for Innovative Phage Applications and Therapeutics

https://health.ucsd.edu/news/releases/Pages/2017-04-25-novel-phage-therapy-saves-patient-with-multidrug-resistant-bacterial-infection.aspx
https://medschool.ucsd.edu/som/medicine/divisions/infectious-diseases/research/center-innovative-phage-applications-and-therapeutics/Pages/default.aspx

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Phage Therapy Research in Food Animals

- Poultry
  - Salmonella, pathogenic E. coli, C. perfringens, C. jejuni
- Swine
  - Salmonella, pathogenic E. coli
- Cattle/ruminants
  - ETEC (carriage), S. aureus, Staphylococcus spp. (mastitis)
- Aquaculture
  - P. plecoglossicida
- Recent Reviews
  - Carvalho et al. Crit Rev Micro 2017, v. 43
  - Wernicki et al. Virology J 2017, v. 14

Slide courtesy of Jason Gill, Assist. Prof, Bacteriophage Biology & Microbiology, Texas A & M

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Food Security Challenges in the 21st Century

- Climate change will have a deleterious impact on food production around much of the world.
- Governments must implement scientifically sound policies to maximize food security—and food safety.
- We need to ensure healthy crops to feed both people and animals.
- We need to reduce losses from pests without harming the health of pollinators, other beneficial animals, ecosystems, or the environment.
- Vaccines, medications, and genetically diverse and robust food animals that can tolerate heat and drought are essential strategies for food security.
- Getting people to accept scientific advances will require market research and effective public outreach and communication to counter mistrust and misperceptions.
- Research on the role of bacteriophages in addressing antimicrobial resistance and in promoting healthy farm ecosystems should be a priority.

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We must figure out how to feed ourselves sustainably to maintain our civilization on a hotter, drier planet

We need to integrate our efforts to benefit humans, animals, and the environment (One Health) 56

One last thought...

About 2 billion people eat insects. Insects are extremely efficient at converting feed to food. High quality protein. Use minimal water. Feed on bio-waste. Less land-dependent. Can also supplement animal feed.

Major obstacle: The ick factor.

http://www.fao.org/edible-insects/en/
http://www.fao.org/docrep/018/i3264e/i3264e00.pdf

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  - Bruce Kaplan DVM, Dipl. AVES (Hon)
  - Tom Monath MD, Dipl. AVES (Hon)
  - Lisa Conti, DVM, MPH, Dip. AVES (Hon)

http://www.onehealthinitiative.com

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Thank you!

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www.webbertraining.com/schedulep1.php	
January 30, 2020	POSITIVE DEVIANCE AND HAND HYGIENE: WHAT CAN WE LEARN FROM THE BEST? Speaker: **Josiane Létourneau**, University of Montreal
February 13, 2020	MALNUTRITION RISK AND HEALTHCARE INFECTION – A *MUST* DO Speaker: **Dr. Fidelma Fitzpatrick**, Royal College of Surgeons in Ireland
February 18, 2020	*(FREE European Teleclass … Denver Russell Memorial Teleclass Lecture)* ANTIMICROBIAL RESISTANCE – A GLOBAL ONE HEALTH CHALLENGE Speaker: **Prof. Séamus Fanning**, University College Dublin, Ireland
February 19, 2020	*(South Pacific Teleclass)* DEVELOPING AND IMPLEMENTING A PERSONAL PROTECTIVE EQUIPMENT TRAINING PROGRAMME FOR HIGH-CONSEQUENCE INFECTIOUS DISEASE PREPAREDNESS Speaker: **Ruth Barratt**, University of Sydney, Faculty of Medicine
February 27, 2020	ANTIBIOTIC STEWARDSHIP IN NURSING HOMES Speaker: **Prof. Patricia Stone**, Columbia University, School of Nursing
March 3, 2020	*(European Teleclass)* THE EFFICACY OF INFECTION PREVENTION AND CONTROL COMMITTEES IN AFRICAN SETTINGS Speaker: **Eltony Mugomeri** , Africa University, Zimbabwe
	(FREE Teleclass)

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