One Health: Connecting Human, Animal, and Environmental Health

The One Health Triad

Healthy People  Healthy Environments  Healthy Animals

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The One Health concept: human, animal, and environmental/ecosystem health are linked.

This concept provides a useful framework for analyzing and addressing complex issues such as antimicrobial resistance.

One Health seeks to increase communication and collaboration between human, animal, environmental health professionals.

• www.onehealthinitiative.com
Indigenous Peoples Intuitively Understood One Health
“Conquering” Nature Ultimately Harms Ourselves
Hippocrates (ca. 460 BCE--ca. 370 BCE)

Recognized the link between human health and the environment.

Malaria = “mal” + “aria.”
Middle Ages (14\textsuperscript{th} Century): Black Death

Bacteria: \textit{Yersinia pestis}

Spread by fleas carried by rats
Vaccination Against Smallpox

"Vacca" is Latin word for cow.

Dr. Edward Jenner vaccinating 8 yr old boy
Opposition to Vaccination
Germ Theory of Disease

- Louis Pasteur, French chemist studied chicken cholera and discovered germs cause disease, concept of immunity, and how vaccines work.
- Robert Koch, German physician studied anthrax (zoonotic disease) and developed Koch’s postulates.

Dr. Louis Pasteur (1822-1895)
Recognizing Zoonotic Diseases

- German physician and "father of pathology."
- "Between animal and human medicine there are no dividing lines--nor should there be."
- Coined term "zoonosis"
- Advocated for meat inspections.

*Trichinella spiralis*

Dr. Rudolf Virchow (1821-1902)
Arthropods transmit disease

- Theobald Smith, MD (pictured) and F.L. Kilbourne, DVM discovered the cause of cattle fever.
- *Babesia bigemina* transmitted by the cattle tick.
- Set the stage for Walter Reed and colleagues’ discovery that mosquitoes transmit yellow fever.

Dr. Theobald Smith (1859-1934)

[Cattle Fever Ticks](https://entomology.tamu.edu/extension/cattle-fever-tick-information/)
20th Century Developments

• Scientific knowledge exploded
• Medicine became increasingly specialized
• Medicine and veterinary medicine diverged
• But the emergence of new infectious diseases and antimicrobial resistance has forced a rethinking of the status quo...
Examining Antimicrobial Resistance Using A One Health Approach
Unexpected Findings

• The rise of one microbe, vancomycin-resistant *Enterococcus faecium* (VRE) drove policy in the European Union.

• Avoparcin, a growth promoting antibiotic used in livestock production, belonging to the same chemical class as vancomycin, was assumed to be the cause of VRE.

• The EU banned avoparcin in 1997.

• The ban had no effect on VRE rates in EU hospitals.
VRE in the United States

• The U.S. never approved avoparcin.

• But VRE has been a huge problem in hospitals.

• Surveillance data of pork, chicken meat, chickens, and pigs show zero evidence of VRE in the years tested.

• VRE didn’t come from the livestock.

• So what’s been going on?
VRE precursors (AREF CC17) genetically related to VRE CC17 in hospitals have been isolated in dogs in 2 Danish studies

Understanding Our Microbial Bodies and World

http://www.theatlantic.com/health/archive/2013/06/healthy-soil-microbes-healthy-people/276710/
Metagenomics has shed light on 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)

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.

How are humans adversely impacting the Global Resistome?

- Poor sanitation
- Indiscriminate antibiotic use
- Untreated human and animal waste
- Land and water contamination
- Wildlife spread resistant microbes and resistant genes far and wide
Humans and domesticated livestock constitute approximately 96 to 98% of global terrestrial mammalian biomass.

Broiler chickens are a signal of a human reconfigured biosphere

Broiler chickens combined mass now exceeds all other birds on Earth. Standing population of 22.7 billion.

FIGURE 4: Per capita meat consumption worldwide by type
2025 vs. base period 2013-15

Source: OECD/FAO Agricultural Outlook 2016-25
Human Open Defecation, 2012

https://riceinstitute.org/blog/new-maps-which-country-has-the-most-open-defecation-in-the-world/
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.

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.
Country-level estimates of fecal matter, 2014

Highest levels:
China (19%)
India (11%)
Brazil (7.2%)
USA (6.1%)
Pakistan (3.3%)
Country-levels with highest animal: human feces ratios, 2014

Ratios highest in Western Pacific (26) and the Americas (11) compared to other regions.

Flood waters partially submerged 14 manure lagoons. The waters carried large amounts of animal waste downstream and out to sea. What is the public and environmental health risk?

Study noted moderately high levels of antibiotic consumption per person in Australia and New Zealand.

Largest total antibiotic consumers were India, China, and USA.

Countries with highest increasing rates were BRICS countries: Brazil, Russia, India, China, and South Africa.

Is there a relationship between environmental fecal contamination and antibiotic consumption?
We Need to Work With Nature Not Against It

Antibiotics have saved countless lives but they kill indiscriminately the good bacteria along with the bad.

We need to target the pathogens but spare the microbes needed for our health.

Bacteriophages are the natural foes against bacteria.
Bacteriophages ("Phages")

- 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 bacterial contamination on farms and other settings with high microbial burdens.
- A number of issues with them have been identified that need to be addressed.
- A One Health forum addressing phage use in human, animal, and microbial ecosystem health should be considered.

https://www.nature.com/articles/s41396-017-0042-4
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 baumannii* infection cured with phage therapy.

UC San Diego is now establishing a Center for Innovative Phage Applications and Therapeutics

Climactic conditions, such as storms, affect microbial ecosystems

Lake Gulshan, Dhaka, Bangladesh

John Mekalanos and colleagues studied the relationship between *Vibrio cholerae* (i.e. cholera outbreaks) and vibrio phages in Dhaka, Bangladesh
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.

Electron micrograph of vibriophages isolated from environmental waters in Bangladesh.
Challenges of the 21st century

• Require a new One Health paradigm:
  • Water Quality and Sanitation
  • Antimicrobial Use and Resistance
  • Food Safety and Security
  • Infectious Diseases
  • Air Quality
  • Cancers
  • Cardiovascular Diseases
  • Metabolic Diseases
  • Neurological Diseases
  • Mental Health
  • And others...
Humans and Animals Get the Same Diseases: New Therapeutic Discoveries Can Benefit All Species
Many faulty canine genes have human counterparts

- Autoimmune diseases, including lupus in Nova Scotia duck-trolling retrievers.
- Copper toxicosis (metabolism disorder) in Bedlington terriers
- Epilepsy affects 5% of dogs reported in many breeds.
- Icthyosis (skin disorder) in Norfolk terriers
- Narcolepsy in Doberman pinschers
- Morris Animal Foundation Golden Retriever Lifetime study
  - Aims to identify environmental, genetic, and dietary risk factors for diseases such as cancer

https://caninelifetimehealth.org/
Fecal Transplants Used in Veterinary Medicine for 100 years

Now being used in medicine

The Power of Pets

• American Pet Products Association Owners Survey:
  • 68% of U.S. households own a pet
  • Approx. 84.6 million homes
  • 60.2 million households own a dog
  • 47.1 million households own a cat
  • In 2017, almost $70 billion spent on pets in U.S.

https://www.americanpetproducts.org/press_industrytrends.asp
Physical Health Benefits of Pets

• Lower high blood pressure
• Decrease cholesterol levels
• Decrease triglyceride levels
• Reduce risk of allergies in children
• Increase exercise motivation

https://www.cdc.gov/healthypets/health-benefits/index.html
Dog Walking
Mental Health Benefits

• Human-animal bond:
  • Lower feelings of loneliness
  • Reduces depression
  • 32% of dog owners take their pets with them when gone for 2 or more nights.
• Animal-assisted therapy

Hurricane Katrina 2005
Social Health Benefits

- Animals teach responsibility and caring
- Animals give people a sense of purpose and self esteem
- Animals provide unconditional love

Puppies for Prisoners
Social Health Benefits

• For elderly or people living alone, a pet might be only family member.
• Increases social interactions.
• Increases sense of well-being.
Risks of Pet Ownership: Microbes are shared
New York Times, September 21, 2009

Dr. Elizabeth A. Scott et al. swabbed household surfaces at 35 randomly selected addresses. Nearly half of homes had MRSA on surfaces.

Cat owners were 8 times more likely than others to have MRSA at home.

“Tie to pets has germ jumping to and fro” Methicillin Resistant Staph aureus (MRSA) is infecting both humans and animals.

Zoonotic Diseases of Companion Animals

- Dogs—Campylobacter, Dog Tapeworm, Hookworm, Roundworm, Rabies
- Cats—Cat-scratch Disease, Cryptosporidium, Echinococcus, Giardia, Hookworm, Pasteurella, Plague, Ringworm, Rabies, Roundworm, Salmonella, Toxoplasmosis
- Reptiles—Salmonella, Aeromonas, Mycobacteriosis
- Birds—Cryptococcus, Histoplasmosis, Avian Tuberculosis, Parrot Fever (Psittacosis)

http://www.cdc.gov/healthypets/pets/dogs.html
http://www.cdc.gov/healthypets/pets/birds.html
http://www.cdc.gov/healthypets/pets/cats.html
http://www.cdc.gov/healthypets/pets/reptiles.html
People, pets, and disease risks

• Some people are at greater risk:
  • Chronically immunosuppressed
    • HIV/AIDS
    • Organ transplant recipients
    • People with autoimmune diseases
  • Pregnant women
  • Infants and very young children

https://www.cdc.gov/onehealth/basics/zoonotic-diseases.html
Risks of Reptile Pets

• Reptiles carry *Salmonella* in their guts.
• In U.S., exposure to these animals leads to 100,000 cases of reptile-associated salmonellosis each year.
• Reptiles are popular pets: In 2001, estimated households with reptiles— 1.7 million
  [http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5249a3.htm](http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5249a3.htm)
Don’t Kiss Your Chickens!

States with Salmonella outbreaks from backyard chickens
10 outbreaks involving 790 cases as of July 7, 2017

https://www.npr.org/sections/goatsandsoda/2015/07/16/423204177/chicken-owners-brood-over-cdc-advice-not-to-kiss-cuddle-birds
http://www.aappublications.org/news/2017/08/24/MMWR082417
Grant and Olsen Study, *EID*, February 1999

- Grant and Olsen, “Preventing zoonotic diseases in immunocompromised persons.”
- Surveyed MDs and DVMs in Wisconsin
- MDs generally not comfortable discussing role of animals in zoonotic disease transmission.
- DVMs typically didn’t know pet owner’s health status.
- Found nearly a complete lack of communication between MDs and DVMs.
- Result: Zoonotic disease risk communication to patients falls through the cracks.

Grant and Olsen Study, *EID*, February 1999

• MDs and DVMs asked to rank animals posing greatest risk to immunocompromised patients.

• DVMS: ranked reptiles (*Salmonella*) and puppies (*Campylobacter*)

• MDs: ranked cats and kittens

• Both groups ranked *Salmonella* and *Toxoplasma gondii* as microbes of greatest risk.

https://wwwnc.cdc.gov/eid/article/5/1/99-0121_article
Zoonotic Diseases of Urban Wildlife

- Rabies
- Hanta virus
- Hendra virus
- Lyme Disease
- Ehrlichioses
- Leptospirosis
- Salmonella
- Brucellosis
- Anthrax

https://wwwnc.cdc.gov/eid/article/10/12/pdfs/04-0707.pdf
Risks of Exotic Pet Ownership
Monkeypox Outbreak 2003

• Orthopoxvirus group: Includes smallpox, cowpox, and other pox viruses.
• Viral disease found mostly in rainforest countries of Central and West Africa.
• Called “monkeypox” because first identified in lab monkeys in 1958.
• Natural host may be African squirrel
• Shipment of rodents from Africa to U.S. set off Midwest outbreak requiring smallpox vaccinations to stop it.
Root Cause of Outbreak: People buying wild exotic animals as pets

- Giant Gambian Rat
- Dormice
- Striped Mice
- Brushtail Porcupines
- Tree Squirrel

April 9, 2003: Shipment of 800 small mammals from Ghana (including 762 African rodents) arrived in Texas.
Some animals simply shouldn’t be pets

More tigers are now kept as pets in the U.S. than living in the wild.

15,000 big cats and 15,000 primates in private hands in U.S. according to Humane Society of US.

400 tigers left in Sumatra.

Only 18 states have outright bans on exotic animals as pets. NYTimes Jan. 10, 2012.
Benefits of a Green Environment

Which scene would you rather look at?

Plants and animals help mental health and help people heal
We Have One Home

Healthy Environment = Healthy People and Animals
How Can You Engage in One Health?

• All health professionals should promote and advocate for One Health.
• Human, animal, and environmental health professionals have much to learn and benefit from each other.
• Hold more inter-disciplinary symposiums and conferences.
• Develop collegial relationships with health professionals of other disciplines.
• Educate policy makers and the public about the importance of One Health.
• Ask your patients if they own pets or are around animals.
• Environmental health assessments should be done routinely. People don’t develop symptoms in a vacuum.
Take Home Messages

• Human, animal, and environmental/ecosystem health are linked.
• One Health concept provides an important framework to analyze and address complex health issues such as antimicrobial resistance.
• Companion animals might be playing a larger role than we realize in spreading antimicrobial resistant microbes.
• Whole genome sequencing is essential in AMR surveillance.
• Animals suffer from many of the same diseases as people; new therapies would benefit all species.
• Animals (and plants) improve people’s physical, mental, social, and environmental health.
• Zoonotic disease risks can be minimized through preventive efforts.
• A healthy environment benefits everybody. We need regulations to protect it!
• Human health professionals should work with animal health professionals to prevent zoonotic disease transmission, especially in high risk groups, that rely on pets for mental and social well-being.
The One Health Umbrella
• One Health Initiative *pro bono* team:
  • Bruce Kaplan, DVM
  • Tom Monath, MD
  • Lisa Conti, DVM, MPH

http://www.onehealthinitiative.com
Thank you!