Jerry B. Miller
Water Quality Scientists- Aquatic Ecologists of the Colorado River Basin for 5 decades
Interactions of Trace Elements in Fish Toxicology; and Selenium and Mercury in Human Consumption Advisories - A personal 5 decade review featuring my home: The Colorado River Basin.
My perspective- farming on Mancos Shale, coal mining, fishing, cowboy, aquatic ecologist, geologist, geochemist, limnologist, water quality sciences, personal health, nutrition, retirement, and Living all of my Life!
Your perspective?

- Fish Biologist
- Aquatic Toxicologist
- Other
Who are all the others

- Medical Doctors
- Biomolecular Chemists
- Epidemiologist
- Toxicologist
- Animal Husbandry Nutritionist
- Veterinarians
- Agencies
Who Else? A cast of thousands!

- State Department of Health
- State Environmental Agencies
- EPA
- FDA
- U.S Fish and Wildlife Service
- State Game Fish or Departments of Natural Resources
- Department of Interior
- Department of Agriculture
- EPA
- Splitting of the Atom entities
- Locals governments
- Education
- People
Oxidation

> The fire within or the engine of life

A. Many physiological processes are mediated by oxygen and nitrogen free radicals and pathophysiological disorders may be the consequence not only of overproduction but also the insufficient formation of free radicals.

B. Essential trace elements and vitamins with important functions in the free radical processes include:
   > Iron, manganese, magnesium, calcium, zinc, copper
   > Selenium, vitamins E & C,

C. Other elements function largely as free radical toxicants:
   > Mercury, cadmium, lead, and arsenic.

The key to health is balance in essential metabolic functions, and control of metabolic contaminants.
Philosophy Ancient Cultures

- Balance
  - Wood (fuel of fire)
  - Fire (heat and energy)
  - Water (necessary to control cool fire)
  - Earth (elements of life)
  - Metal
  - Live all of our life- Jerry’s wisdom from a 93 year old great uncle
Life’s work: Water Quality and Aquatic Ecology of the Colorado River

- Reduced salinity of the Colorado River by over 50% from early 1970’s
- Even during this historic drought
- Sulfate Salinity Geochemistry controls the water quality of the Colorado River
Personal Perspective Colored by need for Health

- Elevator fell 10 stories in 1975
- Medical Doctors wanted no part of putting me back together- potential lawsuit.
- Gave no help when they did try.
- Left to my chemistry background to figure out liver, kidney, thyroid, bladder, urinary tract, blood sugar disorders; orthopedic issues.
- Biomolecular Chemists work saved my life
Published in 1978

Dr. Pfeifer’s books on minerals and micro-nutrients in physiology and mental health were utilized in most human physiology text books for Pre-med majors as basic reference for essential trace element, mineral, and vitamin biochemistry or molecular biochemistry- meaning Biochemistry at the cellular level.
Chapter 5 of Dr. Pfeiffer’s Book

Selenium:
Stepchild of Sulfur

Deficiencies of Selenium related to:

Nutritional muscular dystrophy, growth, exudative diathesis (spontaneous swelling and hemorrhages), pancreatic atrophy, liver necrosis, and infertility, several forms of cancer.

Jerry Added- T4 >T3 Thyroid Conversion
Wisdom of a Grandfather

As a child fly fishing with Grandfather
I learned many lessons of aquatic Ecology-Fly tying

Practice

Move to Moab, aquarium of Colorado River fish!
Irrigation Drainwaters negative impact on reproduction of Colorado River endangered fish

Selenium Aquatic Toxicity Major Focus

1982 Jerry said can not study selenium and leave out metals!
Aquatic Toxicologist

- Many selenium proteins mistaken
  Replacements of sulfur- dysfunctional
  amino acids causing toxicity and mutation

Selenium narrowest ranges between beneficial and toxic
Conflict of two worlds

> Many- 50 + selenium proteins in the body are related all the deficiency diseases act beneficially;
> Organisms process selenium and sulfur very specifically, very differently
Emphasis research find all good things Se
Quote Dr. Pfeiffer “Selenium does not substitute for sulfur in the human body, but has entirely unique biochemical functions”.
EPA

- Establishing water quality standards
- The very long fight to remove Lead from gasoline and paint
- Established new committees for Selenium and Mercury
- Human Consumption of Fish?
Mercury in Fish
Mercury in Amalgam Fillings

- Several countries banned amalgam filling
- Research strongly suggested major medical expenses, greater than cost of the governments paying 90% of cost of removing all amalgam fillings
- Swedish Scientist considered fish a small mercury source in humans compared to fillings (personal communication->Jerry)
Dr. Pfeiffer (1978) said that neurotoxins – specifically mercury, lead, cadmium, and other contaminants caused mental health illnesses:

Specifically Autism, ADD, ADHD, mental retardation in children; while zinc, iron, copper, lithium, selenium all have unique roles in physical and mental health.

He also said that selenium reduced the toxicity of Mercury in 1978.

Neurotoxicity from all forms is additive!
American Dental Association
Suspended a Dentist license for publishing
Science on the dangers of mercury in
Amalgam filling;

Threatened to suspend license of any dentist
who told a patient mercury in filling might be
dangerous

This according the biomolecular chemists
without a schintilla of evidence that mercury
In fillings is SAFE!
Sources:
- Mitochondria
  - (respiratory chain)
  - P450 reductase system
- Xanthine oxidase
- NADPH oxidase
  - (phagocytic cells)
- Semiquinones

Defences:
- $O_2$
- $H_2O$
- Catalase
- GSH peroxidase
- Se
- GSSG
- Vitamin E

Sources:
- $O_2$
- SOD
- Flavin oxidases
- $H_2O_2$
- Quinones
- Fe, Cu
- ‘OH

SOD
- NO'
- Peroxynitrite
- Ionizing radiation

Damage:
- DNA damage
- Lipid peroxidation
- Protein oxidation
Fish and marine mammal tissues contain inorganic metals.

I proposed the geochemical solution—metal selenides.

Today the formation of solid metal selenides is considered a physiological mechanism for the storage of essential trace elements in low solubility forms to meet future needs.

Toxic metals detoxified several ways, one is metal selenides. High concentrations of mercury selenide found as inorganic streaks in fish and marine mammals.

Marine Mammals organ concentrations of mercury and selenium can exceed 30 ppm.
Modification of Methylmercury Toxicity and Metabolism by Selenium and Vitamin E: Possible Mechanisms

by Howard E. Ganther*

Selenium and vitamin E exert powerful effects in reducing acute or chronic methylmercury toxicity. Levels of selenium normally found in foods (below 1 ppm) delay the onset of toxic signs caused by much higher levels of methylmercury. Tissue levels of mercury in selenium-supplemented animals equal or exceed those found in animals given methylmercury alone. Selenium does not appear to act by simply modifying intake, absorption, excretion, or distribution of methylmercury, and direct effects of both selenium and vitamin E have been observed in vitro when methylmercury was added to cultured nervous tissue cells. The only established functions for selenium and vitamin E in animals are related to the prevention of oxidative damage in tissues. To encompass the protective effects of selenium and vitamin E
Mercury induces mitochondrial dysfunction with reduction in adenosine triphosphate, depletion of glutathione, and increased lipid peroxidation. Increased oxidative stress and reduced oxidative defense are common.

Selenium and fish containing omega-3 fatty acids antagonize mercury toxicity.

The overall vascular effects of mercury include increased oxidative stress and inflammation, reduced oxidative defense, thrombosis, vascular smooth muscle dysfunction, endothelial dysfunction, dyslipidemia, and immune and mitochondrial dysfunction. The clinical consequences of mercury toxicity include hypertension, coronary heart disease, myocardial infarction.
Decreasing the Damage of Free Radicals By Eliminating Heavy Metals?
Normal Cell → Cell Attacked by Free Radicals → Cell with Oxidative Stress
**Nomination and Main Histology**

**Initial lesion**
- histologically "normal"
- macrophage infiltration
- isolated foam cells

**Fatty streak**
mainly intracellular lipid accumulation

**Intermediate lesion**
- intracellular lipid accumulation
- small extracellular lipid pools

**Atheroma**
- intracellular lipid accumulation
- core of extracellular lipid

**Fibroatheroma**
- single or multiple lipid cores
- fibrotic/calcific layers

**Complicated lesion**
- surface defect
- hematoma-hemorrhage
- thrombosis

**Sequences in Progression of Atherosclerosis**

<table>
<thead>
<tr>
<th>EARLIEST ONSET</th>
<th>MAIN GROWTH MECHANISM</th>
<th>CLINICAL COLLEGERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>from first decade</td>
<td>growth mainly by lipid addition</td>
<td>clinically silent</td>
</tr>
<tr>
<td>from third decade</td>
<td></td>
<td></td>
</tr>
<tr>
<td>from fourth decade</td>
<td>increased smooth muscle and collagen increase</td>
<td>clinically silent or overt</td>
</tr>
<tr>
<td></td>
<td>thrombosis and/or hematoma</td>
<td></td>
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</tbody>
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**Endothelial Dysfunction**
Sulfide minerals are economically important as metal ores. The sulfide class also includes the selenides, the tellurides, the arsenides, and the sulfosalts.

Common or important examples Sulfides:

- **Acanthite** Ag\(_2\)S
- **Chalcocite** Cu\(_2\)S
- **Bornite** Cu\(_5\)FeS\(_4\)
- **Galena** PbS
- **Sphalerite** ZnS
- **Chalcopyrite** CuFeS\(_2\)
- **Pyrrhotite** Fe\(_{1-x}\)S
- **Millerite** NiS
- **Pentlandite** (Fe,Ni)\(_9\)S\(_8\)
- **Covellite** CuS
- **Cinnabar** HgS
- **Realgar** AsS
- **Orpiment** As\(_2\)S\(_3\)
- **Stibnite** Sb\(_2\)S\(_3\)
- **Pyrite** FeS\(_2\)
- **Marcasite** FeS\(_2\)
- **Molybdenite** MoS\(_2\)

Gypsum (Ca/Mg SO\(_4\)) most common form in Mancos Shale irrigation drainwater, but at any particular Mancos Shale Irrigation Drainwater locals a suite metals may be included.

Sulfarsenides:

- **Cobaltite** (Co,Fe)AsS
- **Arsenopyrite** FeAsS
- **Gersdorffite** NiAsS

Sulfosalts:

- **Pyrargyrite** Ag\(_3\)SbS\(_3\)
- **Proustite** Ag\(_3\)AsS\(_3\)
- **Tetrahedrite** Cu\(_{12}\)Sb\(_4\)S\(_{13}\)
- **Tennantite** Cu\(_{12}\)As\(_4\)S\(_{13}\)
- **Enargite** Cu\(_3\)AsS\(_4\)
- **Bournonite** PbCuSbS\(_3\)
- **Jamesonite** Pb\(_4\)FeSb\(_6\)S\(_{14}\)
- **Cylindrite** Pb\(_3\)Sn\(_4\)FeSb\(_2\)S\(_{14}\)
Acid mine drainage typical of drainages in the upper Gunnison, Dolores, and Animas Rivers in Colorado.
Brook Trout
Whole body metal

- 28 ppm lead
- Drinking water standard <5 ppb
- Health advisory question
Sulfide minerals are inorganic compounds.

The sulfide minerals are a class of minerals containing sulfide ($S^{2-}$) as the major anion. Sulfide minerals are economically important as metal ores. The sulfide class also includes the selenides, the tellurides, the arsenides, and the sulfosalts.

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- Acanthite Ag$_2$S
- Chalcocite Cu$_2$S
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- Galena PbS
- Sphalerite ZnS
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- Pyrrhotite Fe$_{1-x}$S
- Millerite NiS
- Pentlandite (Fe,Ni)$_9$S$_8$
- Covellite CuS
- Cinnabar HgS
- Realgar AsS
- Orpiment As$_2$S$_3$
- Stibnite Sb$_2$S$_3$
- Pyrite FeS$_2$
- Marcasite FeS$_2$
- Molybdenite MoS$_2$

Gypsum (Ca/Mg SO$_4$) most common form in Mancos Shale irrigation drainwater, but any particular Mancos Shale Irrigation Drainwater locals a suite metals may be included.

Sulfarsenides:
- Cobaltite (Co,Fe)AsS
- Arsenopyrite FeAsS
- Gersdorffite NiAsS
Fish and zooplankton across the Colorado River Basin often contain high concentrations of selenium, and an assortment of cations.

Selenium concentrations of 2-7 ppm in Biological tissue are common. But a high Concentration of iron, cooper, and zinc in Organs of fish is balanced by as much as a 10 X increase in selenium. Iron, cooper, and Zinc are common metallurgy in fish hooks
Biological samples from irrigation drain water or otherwise concentrated Colorado River Water may contain any combination of the sulfide mineral related cations. If cadmium or zinc are high then the larval fish with the highest concentrations of selenium lived the longest in aquatic toxicology tests. Conclusion—selenium still toxic in lowest concentrations.

Testing for selenium without full epidemiology, and full trace element analysis, and then assuming that selenium toxicity killed the organism Is a giant leap in faith that goes beyond science.

How easy is it to document histology epidemiology in dead larval fish? NOT Easy?
This is a team science, requiring multiple disciplinary groups working in harmony.

The history books will look at America’s arrogance about dental mercury as one of the terrible tragedies of medical science!

Scientists who become so cynical that they can’t see the truth when it is plainly shown to them are a one of the significant reasons it takes 40 years to ban lead, DDT, understand relationships to mental illnesses, etc.
We modeled selenium from the sources, Across the Colorado River Basin.

From the major Mancos Shale sources In the upper basin, into Lake Powell, and All the way to Lake Mead

Selenium in water was about 2.3 ppb

Final deposition- reducing environment of Salton Sea reduced to selenide deposited In the sediment, back to where it came from.
Mercury- America has issued
Fish human consumption
advisories for children and
expectant Mothers for fresh
weight concentrations ranging
from 0.1-0.5 ppm
Cardiologist- eat 2 meals of fish
per week.
Fish in Lake Powell and Lake Mead have mercury concentrations similar to marine fish.

Selenium concentrations in Lake Powell and Lake Mead exceed Marine fishes.
Americans including children still
Turn on water taps and drink the
1\textsuperscript{st} water coming out with lead concentrations over 300 ppb-
drinking water standard <5ppb.
Take children to a dentist to have
A toxic metal inserted in a tooth?
As long as science continues to present opposing ideas,

Money makes the decisions
Neurotoxins are Additive

- How many neurotoxins:
  - Mercury, Cadmium, Lead
  - PCBs
  - Anatoxin A
  - BMAA Blue-green algae
  - Child abuse
  - Drugs
  - Injury
A little Wisdom from an old Man
A true environmentalist is equally concerned with water, fish, air, and the mind of a child, the wellness of a marriage, and the ability of the Old man to LIVE ALL of HIS LIFE!
Truth- things are they really are, as they really will be, and as they have always been.

My most important stewardship-
I always though it was the Colorado River- now I know it is the MIND OF A CHILD!