Selenium and Mercury

Fishing for Answers

An essential element

Selenium (Se) is essential for many functions in our bodies. Selenium fosters growth and development, has powerful antioxidant and cancer prevention properties, and is essential for normal thyroid hormone homeostasis and immunity. Studies indicate selenium is especially important for the brain, heart, and immune system. Selenium is even the target of certain types of viruses that disrupt essential function by stealing the selenium from our cells.

Compromised selenium-dependent metabolic processes have been linked to congenital muscular dystrophy, autism, Alzheimer's disease, Down syndrome, brain tumors, diabetes, liver diseases, and other conditions associated with increased oxidative stress or inflammation, such as rheumatoid arthritis, pancreatitis, asthma, and even obesity.

Sources of selenium

Ocean fish are among the richest sources of nutritional selenium in the American diet. Seafood constitutes 17 of the top 25 sources of dietary selenium commonly consumed in the United States. Other good sources are foods made from grains grown in selenium-rich soils, such as breads and pasta, and beef grazed on selenium-rich grasses.

The developing story

Less than 30 years ago, scientists discovered the 21st amino acid, selenocysteine. This amino acid is unique from the other 20 amino acids in that it contains selenium and it is required as the active component of selenoproteins. Scientists now know that selenium is essential for the normal function of 20–30 very important enzymes involved in numerous biological functions. The process of selenocysteine incorporation into proteins requires a complex system which is also regulated by selenoproteins. Remarkably, selenocysteine is the only amino acid that must be degraded and reformed during each cycle of selenoprotein synthesis. Selenide is released from selenocysteine when it is degraded, making it vulnerable to binding with heavy metals such as mercury because of its high binding affinity for these elements. Once bound to mercury, selenium is no longer available for selenoprotein synthesis. Therefore, if selenium is not replenished, selenoprotein synthesis cannot be maintained, and their related functions will be compromised.

R*x*

Our bodies need selenium to function properly. Selenium has important roles throughout our bodies, especially in our brain and nervous system and protects against oxidative stress.

Insufficient selenium in our diets is linked to many diseases occurring from prenatal development through old age.

Some of the best sources of selenium in our diet come from ocean fish.

The selenium–mercury connection

The affinity constant for selenocysteine's selenium and mercury is $\sim 10^{22}$, and the free selenides that form during each cycle of selenocysteine synthesis have an exceptionally high affinity constant for mercury: 10^{45}. Mercury selenide precipitates have extremely low solubility, ranging from 10^{-58} to 10^{-65}; thus they are thought to be metabolically inert. Therefore, once a mercury atom binds to a selenium atom, the selenium atom becomes unavailable to participate in selenoprotein formation.

Selenium is highly regulated and conserved in the brain and endocrine system. The importance of selenium in these tissues is emphasized by the fact that mechanisms of tissue redistribution have evolved to maintain normal concentrations of selenium in the brain and endocrine tissues, even during severe dietary selenium deficiency. Consequently, any substance that can surpass the protective blood–brain barrier and disrupt selenoprotein synthesis in the brain and endocrine tissues will accomplish what multigenerational selenium deficiency cannot. Mercury not only has the ability to cross the placental and blood–brain barrier, but its extremely high affinity for selenium enables it specifically to sequester the brain's selenium by forming insoluble mercury selenides, thereby diminishing selenoprotein synthesis in these otherwise protected tissues.

In addition to stealing available selenium from selenoprotein synthesis, methylmercury can also bind to the selenium of the selenocysteine in the selenoprotein. Mercury is, therefore, biochemically defined as a "highly specific, irreversible selenoenzyme inhibitor." Based on evidence such as this, scientists are recasting the concept of mercury toxicity in terms of its effect on selenium physiology.

Methylmercury is a highly specific, irreversible inhibitor of selenium-dependent enzymes.

Rx

Mercury can combine with selenium, preventing selenium from doing its job.

Selenium is the key to understanding mercury exposure risks. Scientists discovered that if a body has sufficient selenium to maintain proper function, the risks from mercury are mitigated.

Turning the tables: mercury tackles selenium

It is well established that selenium can counteract mercury toxicity. This antidotal effect has been known since the 1960s and has been noted in all investigated species of mammals, birds, and fish. Until the importance of selenium was understood, this phenomenon was speculated to be the result of selenium binding to Hg, rendering it ineffectual at creating mayhem. It is now understood that selenium's antidotal effect for counteracting methylmercury occurs by ensuring that normal selenoprotein synthesis is maintained. Therefore, this can be viewed as a matter of molar ratio: the number of selenium atoms versus mercury atoms present or consumed.

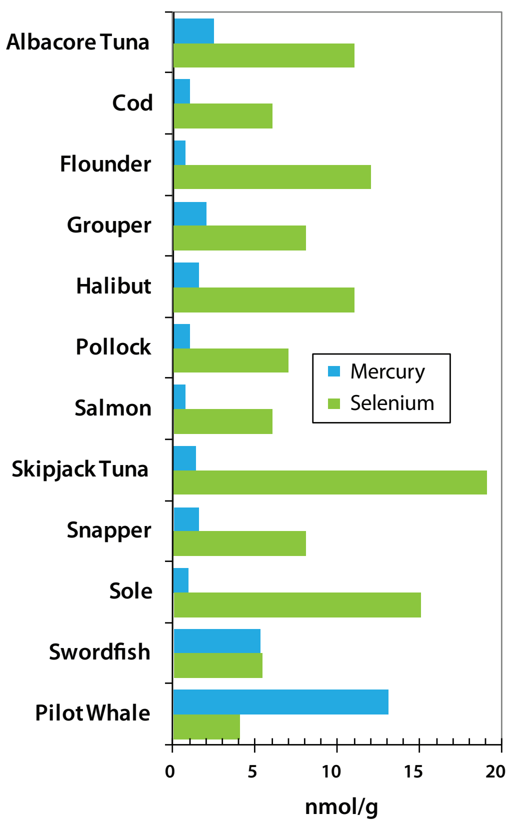
Practical applications

Mercury exposure through fish consumption

Human populations are exposed to mercury through fish consumption. Understandably, people are concerned about "eating mercury." In reality, the health risks of fish consumption vary with fish type and location. Methylmercury exposure risks vary in response to the selenium:mercury molar ratios in fish (the higher the ratio of selenium to mercury, the more likely that selenoprotein synthesis will be undisturbed) as well as individual and regional differences in selenium intake. Environmental availability of selenium is highly variable, abundant in soils of one area and dangerously low in regions only miles away. Although the overall selenium status in the United States is good, differences in relative quantities and quality of food choices can result in individual differences in selenium status.

Ocean fish

Oceans are rich in selenium. Thus most ocean fish contain more moles of selenium than of mercury (as presented below). Importantly, the detrimental effects from eating seafood were associated with maternal consumption of pilot whale, a marine mammal that contains much more mercury than selenium.



Most ocean fish contain more selenium than mercury.

Rx

Although it is a natural element in the environment, we don't usually think about mercury exposure except at the table, because the most common exposure is from eating fish.

However, fish are also packed with nutrients: omega-3s, vitamins, high-quality protein, and minerals including selenium. It is essential for our health that we understand the real risks of avoiding fish versus the potential risk of mercury exposure from eating fish.

Since ocean fish are excellent sources of selenium, they provide nutrients without repercussions from mercury exposure.

Less is known about freshwater fish, but this is an active area of research.

Freshwater fish

Although typical varieties of ocean fish are selenium-rich, the selenium in freshwater fish is more variable and may be limited in certain regions. The selenium levels in lake fish reflect the regional selenium levels in the soils. Methylmercury concentrations are higher in fish living in lakes where selenium availability is limited. Likewise, the lakes that have higher selenium availability tend to have fish with low methylmercury levels. In studies of low selenium–high methylmercury lakes, adding selenium to the lakes resulted in mercury levels in fish diminishing by more than 75%.

Therefore, the risks of consuming freshwater fish will vary, depending on their mercury and selenium levels. So while ocean fish offer nutritional benefits, the benefits of freshwater fish can be regionally specific. Although selenium levels may not be known for most lakes, local consumption advisories will inform you of the mercury levels in fish, so look to these to determine meal frequency and portion size. Freshwater advisories may change as health officials better understand the local and regional selenium:mercury levels.

The American Heart Association recommends that people eat at least 2–3 servings of fatty fish a week to maintain DHA levels.

More to fish than selenium

Omega-3 fatty acids play very important roles in our bodies, roles that can't be replaced by other fats. The long-chain polyunsaturated fats, DHA (docosahexaenoic acid) and EPA (eicosapentaenoic acid) are two especially important essential omega-3 fatty acids involved in many physiological systems. They are known to fight cardiovascular disease and promote brain function, and they are vital for neurological development during the early years of life (beginning during pregnancy). Ocean fish and seafood are the best and almost only sources of DHA and EPA in our diets! This table lists some of the seafood that are good sources of these omega-3s and have more selenium than mercury.

Seafood Type	DHA and EPA Content, mg/ 4-oz serving[1]	Selenium Content, µg/ 4-oz serving[1]
Anchovies, Herring, and Shad	2300–2400	50–75
Tuna: Bluefin and Albacore	1700	50
Oysters: Pacific	1550	170
Mackerel: Atlantic and Pacific	1350–2100	50
Salmon: Atlantic, Chinook, Coho	1200–2400	40–50
Sardines: Atlantic and Pacific	1100–1600	40–60
Tuna: White (albacore) Canned	1000	70
Salmon: Pink and Sockeye	700–900	40
Pollock: Atlantic and Walleye	600	50
Tuna: Bigeye[2]	500	100
Mahimahi[2]	400	60
Wahoo[2]	375	70
Flounder, Plaice, and Sole (flatfish)	350	35
Spearfish[2]	350	60
Crab: Blue, King, Snow, Queen, and Dungeness	200–550	45–54
Clams	200–300	60
Halibut: Atlantic and Pacific	250	60
Cod: Atlantic and Pacific	200	30–40
Tuna: Skipjack and Yellowfin	150–350	50–100
Tuna: Light Canned	150–300	90
Tilapia	150	60

[1]Except where noted, data are from the U.S. Department of Agriculture and the U.S. Department of Health and Human Services Dietary Guidelines for Americans, 2010. See more at www.cnpp.usda.gov/DGAs2010-PolicyDocument.htm and www.ars.usda.gov/ SP2UserFiles/Place/12354500/Data/SR23/reports/sr23fg15.pdf.
[2]Data are from www.hawaii-seafood.org (DHA and EPA) and from Kaneko, J.J. ; Ralston, N.V.C. Selenium and Mercury in Pelagic Fish in the Central North Pacific near Hawaii. *Biol. Trace Elem. Res.* **2007**, *119* (3), 242–254.

Should you worry about mercury?

Current mercury advisories focus only on the mercury levels in fish. They do not account for the beneficial nutrients or the selenium–mercury interactions. Regardless, the current federal advisory for fish consumption recommends that everyone eat ocean fish for the healthy nutrients fish provide.

Pregnant and Nursing Moms. The U.S. Food & Drug Administration (FDA) recommends that pregnant and nursing moms eat 12 oz of fish weekly for the health of their babies, avoiding the fish that are highest in mercury: swordfish, shark, tilefish, and king mackerel. FDA also recommends checking local advisories for fish you catch yourself.

Young Children. Because the brains of young children are still developing, the FDA recommends that young children also eat a variety of fish but, as a precaution, avoid swordfish, shark, tilefish, and king mackerel.

Everyone Else. Bon appétit! There are no recommendations to avoid any ocean fish. Dark and oily fish provide the most omega-3s, but eating a variety of ocean fish will provide balanced nutritional benefits and please your palate.

For more information on nutrition and fish, visit our Web site:

www.undeerc.org/fish

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