UNIT: DNA

LESSON: ARSENIC – THE SILENT TOXIN THAT KEEPS ON GIVING

ACTIVITY 1B: *TO DRINK OR NOT TO DRINK: EVALUATING WATER QUALITY*

Not all elements in the environment are good for us. Some elements are toxic and can be fatal to humans. One such element is arsenic (***As***). In nature, arsenic is generally found attached or chemically bonded to other elements, primarily metals, forming a substance called "ores". There are different ores, such as iron ore and copper ore. Various methods are used to extract metals from ore but each method releases the other elements found in the ore, including arsenic. When arsenic is bonded to other elements, it is stable and relatively harmless. But when the bonds that attach arsenic to other elements are broken, the highly toxic arsenic is released. The freed arsenic can float in the air, settle on topsoil, or land in water where it can be carried downstream by water.

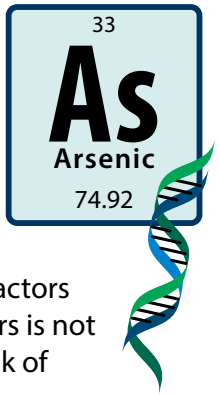
Threats of Arsenic

Arsenic can naturally be present at toxic levels in groundwater. To address this health threat, communities treat water sources, including groundwater, to remove pollutants and toxins, making the water safe to drink. But not every community has water treatment facilities. This includes indigenous people in rural communities in the western US. Without water treatment facilities, untreated water is used for drinking, cooking, and crop irrigation increasing health risks from exposure to toxins, including arsenic.

Arsenic is associated with various diseases; however, there is evidence that exposure to arsenic during pregnancy increases the risk of offspring developing metabolic diseases later in life. Metabolic diseases are defined as a disease or syndrome that disrupts normal metabolism. A metabolic disease results when abnormal chemical reactions disrupt normal metabolic processes such as converting food to energy at the cellular level. Type 2 diabetes (T2D) is an example of a ***metabolic disease*** while insulin resistance is a ***metabolic disorder***. In general, a metabolic disorder is reversable with changes in lifestyle but a metabolic disease is not.

Exposure to arsenic while in utero (when developing within the mother's uterus) does not automatically mean children will develop metabolic diseases later in life, but it does increase their risk.

Epigenetics: Connecting Arsenic and DNA



Epigenetics is the study of changes in gene expression, specifically what determines when a gene is activated or not activated. The DNA strand resembles a twisted ladder. The rungs of the ladder are made of four molecules called bases: adenine, thymine, cytosine, and guanine. When DNA is exposed to arsenic during development, a methyl group (CH_3) attaches itself to the cytosine base. The attachment of the methyl group, called DNA methylation (DNAm) does not change the DNA, but affects when genes are activated or not activated. This change in gene activation can disrupt metabolic processes and lead to the development of metabolic disease later in life. For example, when an individual with DNAm lives with environmental risk factors such as smoking or obesity, the gene which codes for specific proteins to help metabolize sugars is not activated. Without these proteins, sugar is not effectively metabolized by cells increasing the risk of insulin resistance or type 2 diabetes.

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This study seeks to assess the risk of metabolic diseases for individuals known to have been exposed to arsenic in utero. To do so, scientists consulted data from women and their grown offspring in communities with arsenic in the drinking water. The scientists compiled a list of known risk factors which contribute to type 2 diabetes. The data and risk factors are shown in the following table.

Table 1: Participant Baseline Characteristics

	SHS Mothers (n=119)	Offspring (n=226)
Aqe (years)	54.4 (49.3, 61.6)	40.4 (35.5, 47.2)
Sex (Male)	----	82 (36.2%)
Smoking Status	----	----
Never	44 (37.0%)	78 (34.4%)
Ever	32 (26.9%)	55 (24.3%)
Current	43 (36.1%)	93 (41.2%)
Waist Circumference (cm)	105.0 (98.0 116.0)	100.0(92.0 111.0)
BMI (kg/m^2)	30.9 (27.2, 35.2)	30.4 (26.8, 34.9)
Diabetes Status (diabetic)	44 (37.0%)	0 (0.0%)
Follow-up Diabetes Status	41 (41.2%)	41 (18.1%)
Fasting Glucose (ma/dl)	111.0(99.0, 168.0)	94.0 (87.0 103.0)
Follow-Up Fasting Glucose (ma/dl)	113.0 (98.0, 171.0)	94.0 (86.0, 106.3)
HOMA2-IR (optimal score 1.4)	3.7 (2.4, 5.5)	1.5 (1.0, 2.5)
Follow-up HOMA2-IR (optimal score 1.4)	3.5 (1.9, 6.0)	1.6 (0.9, 2.7)
Total Arsenic (µg/g creatinine)	7.3 (5.0, 13.8)	4.6 (3.0, 8.4)