The Science of Chemical Safety
Essential Toxicology - 1

General Considerations

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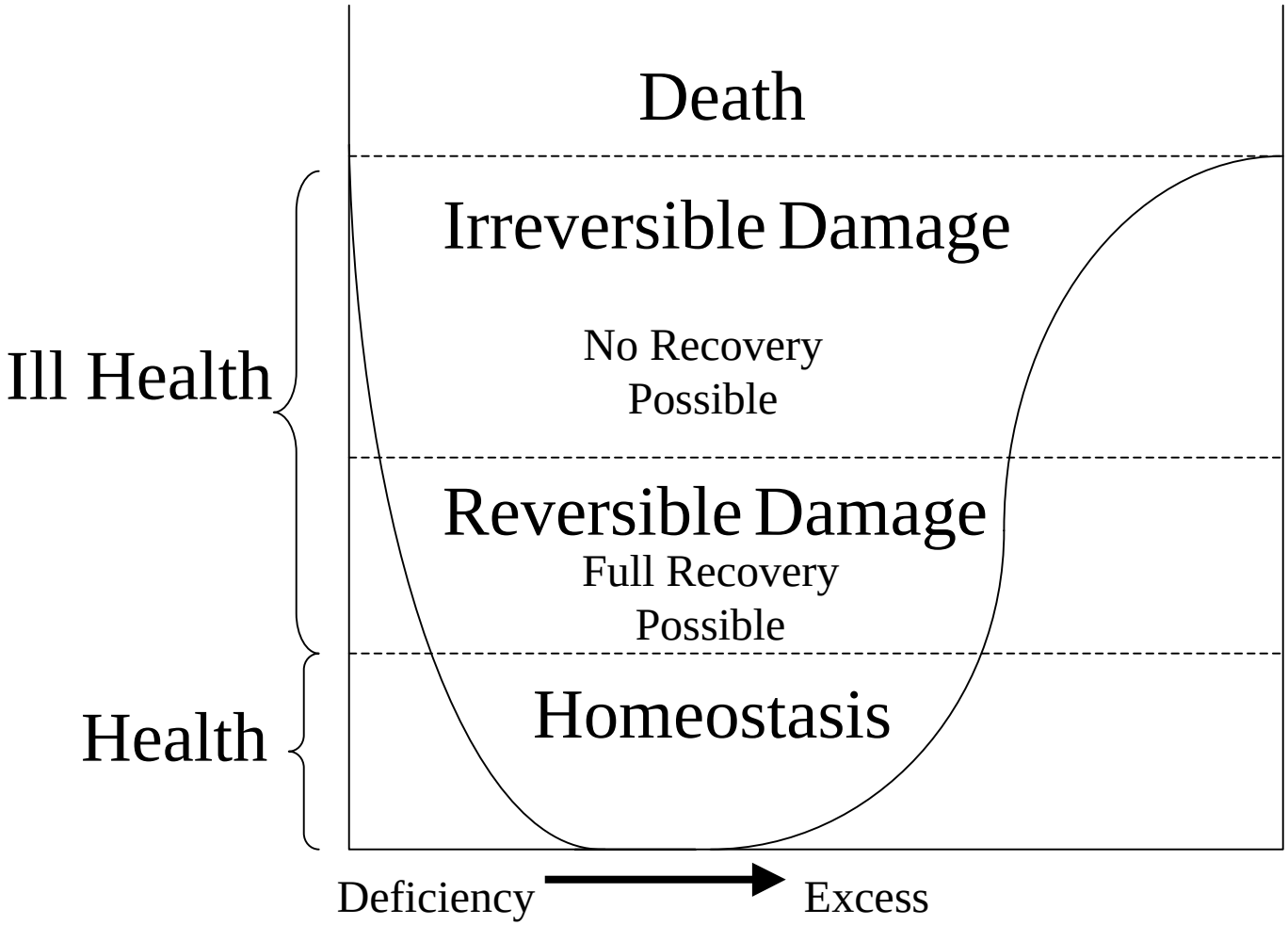
IUPAC Educators' Resource Material

General Considerations

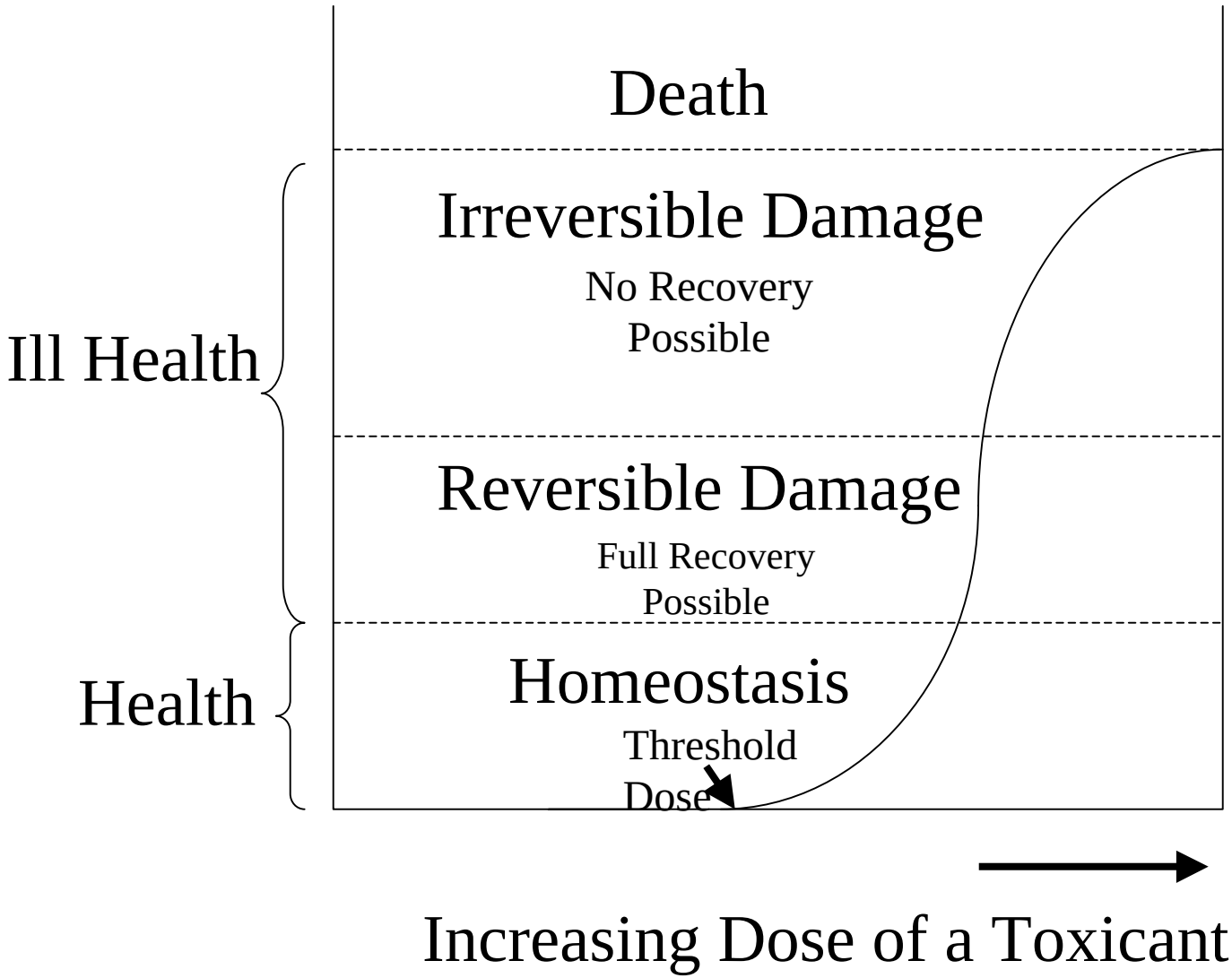
- Toxicology is the science which lets us know how substances can harm life by physico-chemical reactions with living cells
- All substances, whether synthetic or natural, can cause harm to people, animals, plants, micro-organisms, and their environment
- There are naturally occurring substances which are at least as poisonous as the most toxic synthetic chemicals

Toxicity and Dose

- The toxicity (poisonous nature) of any substance is inversely related to the amount (dose) required to cause harm
  - The more that is required, the lower the toxicity
- Substances which can cause harm following exposure to very small amounts, sometimes no more than a few molecules, are said to be extremely toxic
- Substances which require exposure to many grammes before harm results are said to have low toxicity
- Even essential nutrients become toxic if the amount ingested is above a certain acceptable dose



Increasing Dose of An Essential Nutrient



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Nutrients, Drugs and Poisons 1

- 500 years ago, a physician called Paracelsus wrote the following fundamental rule of toxicology:
  - "Only the dose required makes the difference between a cure and a poison"
- For example - water is essential for life but people have died from drinking too much pure water
  - The result of drinking salt-free water is that the body loses essential salts such as sodium chloride and potassium chloride and the nerves and the muscles, which depend on the correct ionic balance, can no longer function

Nutrients, Drugs and Poisons 2

- Further examples of the Paracelsus rule are:
- Vitamin A - although this is essential for human health it is fairly easy to exceed the required dose and people have died from eating too much
  - it may also cause developmental abnormalities in babies if their mothers consume too much while carrying them during pregnancy
- Paracetamol - at the prescribed dose it relieves pain but a dose ten times higher can kill
- Carbon monoxide - produced by burning fossil fuels, at increasing doses prevents the body from using oxygen and this leads to unconsciousness and death

Natural and Synthetic Chemicals 1

- Naturally occurring substances are not inherently safer than synthetic substances and some of the most poisonous substances known are natural
- The bacterium *Clostridium botulinum* produces a toxin which is so dangerous that its industrial production as a synthetic substance would never be permitted under existing laws to protect workers and the public
- Aflatoxin, from the fungus Aspergillus flavus, is one the most potent carcinogens known, causing liver cancer in people who eat food made from contaminated cereals such as rice

Natural and Synthetic Chemicals 2

- The distinction between naturally occurring substances and synthetic substances is of little value in considering toxicity
- Pure natural vitamin C and pure synthetic vitamin C are identical molecules and equally good for people.
- Oxygen in the air and oxygen prepared industrially is exactly the same
  - Oxygen is another example of a chemical which is essential for life but which can kill in excess. Indeed, one theory of the aging process in people is that it is due to an accumulation of oxidative damage. Vitamin C helps to prevent such damage!

Homeostasis

- All life is based on chemical reactions which maintain very stable body chemistry (homeostasis) against a background of constant environmental change
- **It is <u>not</u> surprising** that large changes in our chemistry following exposure to a large dose of any substance can cause us harm
- **It is surprising** that we can keep healthy in an environment which is constantly changing over a wide range of conditions

Avoiding Poisoning - 1

- The key to our remaining healthy in a potentially toxic environment is to identify those chemical exposures which are most difficult for our bodies to deal with by normal homeostasis and to control them or to prevent them happening by appropriate regulation
- Legislation can be used effectively to control synthetic substances
  - There are many legal restrictions on the use of drugs, pesticides, solvents, and the products of burning coal, oil, petrol, and diesel fuel
- Naturally occurring toxicants will always be a problem

Avoiding Poisoning - 2

- Food poisoning is quite common but should be avoidable
- Careful handling and storage of food prevents contamination by toxins from bacteria and fungi.
- More knowledge of the lifetime nutritional requirements of people will help to ensure that we have a healthy diet
- For example, the increase in diabetes and in asthma and dermatitis, as well as in heart disease, in the developed countries has been related to changes in diet and lifestyle and may be reversible if diet is improved

Self Assessment - 1.1
True or False?

- Manmade chemicals are more poisonous than natural chemicals - see slide 2
- Substances which are very poisonous cause harm after exposure to small doses - see slide 3
- You cannot drink too much water - see slide 6
- Vitamins are always good for you - see slide 7
- You cannot have too much of a good thing - see slides 6 and 7

Self Assessment - 1.2
True or False?

- The burning of natural fossil fuels does not produce poisons - see slide 7
- Some bacteria and fungi produce powerful poisons - see slide 8
- Oxygen can damage living tissues - see slide 9
- Within limits, the human body can adjust to varying environmental conditions, including changing exposure to many chemicals, without damage to health - see slide 10

Self Assessment - 1.1 Checklist

- Manmade chemicals are more poisonous than natural chemicals - False
- Substances which are very poisonous cause harm after exposure to small doses - True
- You cannot drink too much water - False
- Vitamins are always good for you - False
- You cannot have too much of a good thing - False

Self Assessment - 1.2 Checklist

- The burning of fossil fuels does not produce poisons - False
- Some bacteria and fungi produce powerful poisons - True
- Oxygen can damage living tissues - True
- Within limits, the human body can adjust to varying environmental conditions, including changing exposure to many chemicals, without damage to health - True