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How do chemicals affect animals (and their kids)?

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Abstract

Our endocrine system is very bossy. It controls many things in our bodies, like growth or mood. Sadly, there are chemicals that interfere with this important system. Endocrine-disrupting chemicals are all around us. Their negative effects can even pass on to future generations. How does this happen? We reviewed many articles on endocrine disruptors and their effects on various animals. These chemicals have negative effects on fish, frogs, birds and mammals. Sometimes the effects pass on to many generations. However, the mechanism for this transfer is not genetic but most likely epigenetic.

Introduction

Have you ever wondered how your body controls its functions? Like how to digest food or how to grow? It's all thanks to our **endocrine system**. The endocrine system includes several **glands** in different parts of the body (Figure 1). These glands secrete (release) special chemicals, called **hormones**, into our blood. Hormones are like messengers – they tell our cells, tissues, and organs what to do. Hormones control how we grow and develop. They tell us how to get energy from the food we eat, and sometimes they even tell us how to feel. Hormones also make it possible for us to have kids. And it's not just us – all vertebrate animals have this control system, too!

A few decades ago, researchers found out there are some chemicals that mess with the endocrine system. They are called **endocrine-disrupting chemicals**, or EDCs. And that is exactly what they do – they disrupt the normal function of hormones. This can lead to serious health issues and alter development, behavior, and reproduction. EDCs include chemicals found in household items. Some drugs,

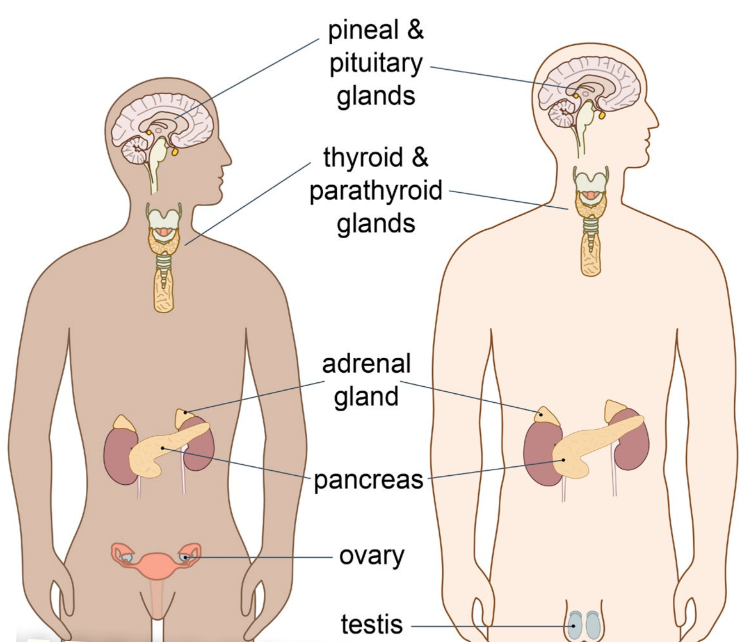

Figure 1:
The human endocrine system.
Image from OpenStax, Tomáš Kebert, & umimeto.org, **CC BY-SA 4.0**

plastic bottles, and cosmetics, for example. Using them and disposing of them every day can harm both our and the wildlife's endocrine systems.

The negative effects of endocrine-disrupting chemicals can pass on to many generations. Researchers call them multigenerational effects. Sometimes they can be seen even when a generation doesn't have direct contact with the chemicals. These are the **transgenerational** effects.

How does this happen? To find out, we compared the effects of EDCs in various species.

Methods

We reviewed hundreds of articles on endocrine-disrupting chemicals. We focused on their multi- and transgenerational effects in various species. These include fish, frogs and toads, birds, and mammals. We wanted to compare the effects among different animals, since they reproduce in different ways (Figure 2).

	FEMALE			MALE
	Endocrine disruptors affect parent fish and their germ cells. There are transgenerational effects in the second generation.	Endocrine disruptors affect parent birds and their germ cells as well as the germ cells of their offspring. There are transgenerational effects in the third generation.	Endocrine disruptors affect parent rodents and their germ cells as well as the germ cells of their offspring. There are transgenerational effects in the third generation.	Endocrine disruptors affect parent frogs and their germ cells. The transgenerational effects are in the second generation.

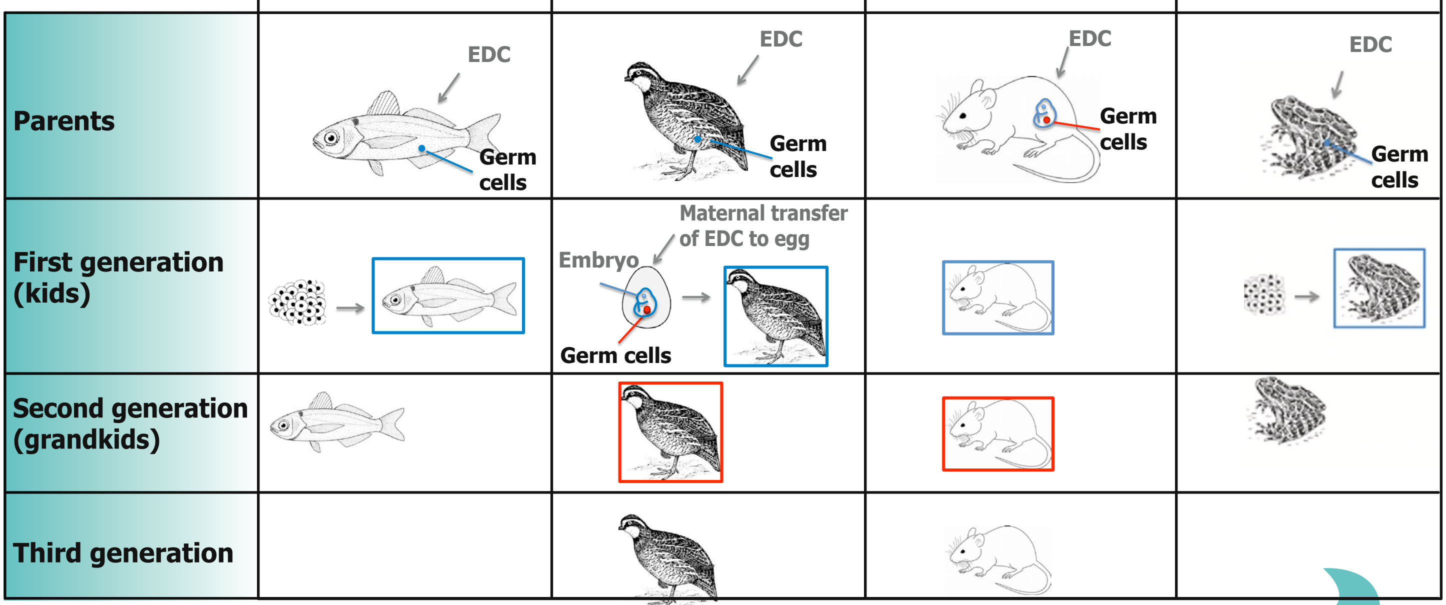

Figure 2:
Animals with different reproductive strategies are exposed to endocrine disruptors and the effects pass on to their offspring.

Why do the transgenerational effects of endocrine disruptors in birds and mammals often show up in the third generation?

Results

There are many studies on the effects of EDCs on fish. A well-known EDC is **Bisphenol A (BPA)** – a chemical used in plastic production. It causes reduced fertility in three generations of fish! Prozac, a common antidepressant, reduces responses to stress. This effect can last for four generations! Low oxygen levels can also disrupt the endocrine system. Researchers have found that it could impair fish sperm in two generations. How do these effects pass to the later generations? We believe the cause is not genetic but **epigenetic**. This means the chemicals haven't changed the **DNA code**. Instead, they have altered the way the cells read it. It's like an on/off switch for genes.

Rats and mice are common animals used for research on EDCs. Pesticides, for example, can increase the risk of tumors even in the third generation. **Plasticizers** can cause decreased body weight for many generations. Bisphenol A also causes reduced fertility in three generations of male rats. Are epigenetic mechanisms responsible here? Many studies support this theory.

EDC studies on frogs are not as common. An EDC produced while burning wood, causes delayed development in frogs' kids. The second generation (their grandkids) **metamorphoses** and matures slowly. Their eggs are not viable. One study focuses on toads that grew up in urban ponds. The researchers took the toads' kids to pristine waters. But even there, they were slow to metamorphose and matured slowly. Epigenetic mechanisms are one possible explanation for multigenerational effects. Another is how female frogs invest their resources during pregnancy. Do they gain body weight or do they leave it for the eggs? We think EDCs can make the frog choose the first option. And this is bad for their kids.

Studies on birds are also a bit scarce. But there is evidence of multi- and transgenerational effects of EDCs. Some **phytoestrogens**, for example, can cause even the third generation of birds to mature very slowly! There is not enough data to conclude if these effects pass to later generations through epigenetics.

Discussion

It is clear that endocrine-disrupting chemicals have multi- and transgenerational effects. And this is true for many different animals. There is significant evidence that epigenetic mechanisms are at play. Yet there are some things we still don't know. For many species, we don't know the exact way EDCs act. The same goes for the consequences of their effects later in life. These include both the parents and the next generations. We have a few recommendations for future studies on EDCs:

1. It is good to compare their effects on different species. They have different life cycles and reproductive systems. These differences will make it easier to understand how EDCs work.

2. When treating an animal with a chemical in the lab, it should mimic real-life situations. The dose should be the one we expect to find in the environment. How the researchers administer the chemical (through food, water, etc.) is also relevant. It should imitate the chemical exposure in the environment.

3. Further epigenetic studies are vital. But it's also important to consider social, metabolic, and environmental factors (like temperature, stress, interaction with other animals, etc.).

Conclusion

Plastics, drugs, cosmetics – we use them every day. And we throw them away every day. They end up in the environment through sewage or garbage. And they harm not only the wildlife but us as well! It makes good sense to reduce the amount of plastics and unnecessary chemicals we use. Use reusable bags and containers whenever possible and always try to recycle.

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Glossary of Key Terms

Bisphenol A (BPA) – a chemical compound used in the production of plastics.

DNA code (genetic code) – DNA code consists of "letters" (A, G, T, C). The code has instructions for the cells to make specific proteins. Sometimes the code alters – mutates – so the letters are scrambled, one letter is missing, etc.

Endocrine-disrupting chemicals (EDCs) – natural and man-made chemicals found in many household and industrial products that can interfere with the endocrine system. They have similar chemical structure to hormones. For example, your stomach might see an EDC and think it is a messenger that usually says "It's time to eat again," so you feel hungry even though you have already had enough to eat.

Endocrine system – a messaging system consisting of glands producing hormones and the hormones themselves. The endocrine system coordinates many different essential functions in the body, including growth, development, reproduction, sleep, and blood pressure.

Epigenetics – a study of how the environment and our behavior change the way our genes work. Epigenetic changes don't alter the genetic code. So, the cell doesn't produce new proteins. Instead, epigenetic changes affect which genes the cell reads and which not.

Gland – special organs in your body that make different substances. For example, some of them can produce hormones, while other glands can make sweat, tears, or juices that help your stomach digest the food you have eaten.

Hormones – chemicals that work as messengers. They move through the body in our blood and tell our organs, tissues and cells how to work. The cells have special receptors for the hormones. Each different hormone has a specific function.

Metamorphosis – the process of transformation from an immature form to a mature adult. Frogs lay eggs, tadpoles hatch from these eggs, and then they transform into adult frogs.

Phytoestrogen – a hormone that comes from the environment (plants). Animals (and humans) don't produce it, but they consume it from plants.

Plasticizer – a substance that increases a material's plasticity, or ability to change shape.

Transgenerational effects – effects that pass on to generations that haven't been in direct contact with something in the environment. For example, a pregnant mouse is exposed to an endocrine disruptor. The chemical is in direct contact with the embryo (soon to be kids) and its germ cells (future grandkids). So any effects in these two generations are multigenerational. If there are effects in the third generation, they are transgenerational because the third generation hasn't been in direct contact with the disruptor.

Check your understanding

1. What is the difference between genetic and epigenetic changes in DNA?
2. Prozac reduces responses to stress. Why can this be a bad thing?
3. Give three examples of human activity that produce endocrine-disrupting chemicals.
4. What do you know about the causes of low water oxygen levels? Discuss in a group, or with your whole class.
5. Can you think of any other ways to reduce the amount of plastic we use?

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