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Beyond the spill: the hidden effects of crude oil pollutants on fish behaviour

Professor Keith Tierney

Beyond the spill: the hidden effects of crude oil pollutants on fish behaviour

How do pollutants like crude oil affect aquatic life, specifically fish? At the **University of Alberta** in Canada, **Professor Keith Tierney** is exploring how exposure to pollutants can lead to long-term behavioural changes in aquatic vertebrates. His research in ecotoxicology reveals the profound impacts of these chemicals, pushing the boundaries of what we consider toxic.

Professor Keith Tierney

Tierney Lab, Department of Biological Sciences, Faculty of Science, University of Alberta, Canada

PROFILE

Fields of research
Biological sciences, ecotoxicology, aquatic toxicology and physiology

Research project
Investigating the impact of toxic pollutants on aquatic life

Funder
Natural Sciences and Engineering Research Council of Canada (NSERC)

Website
grad.biology.ualberta.ca/tierney

Talk like an ...

ecotoxicologist

Crude oil — a natural, unrefined petroleum product composed of a complex mixture of hydrocarbons, nitrogen and sulfur

Ecosystem — a community of living organisms (plants, animals, microorganisms, etc.) interacting with each other and their physical environment

Ecotoxicology — the branch of science that studies the effects of toxic substances (e.g., pollutants) on living organisms and ecosystems

Effluent — liquid waste

Hydrocarbons — organic compounds consisting entirely of hydrogen and carbon

Personality changes — long-term alterations in the typical behaviour or traits of an animal

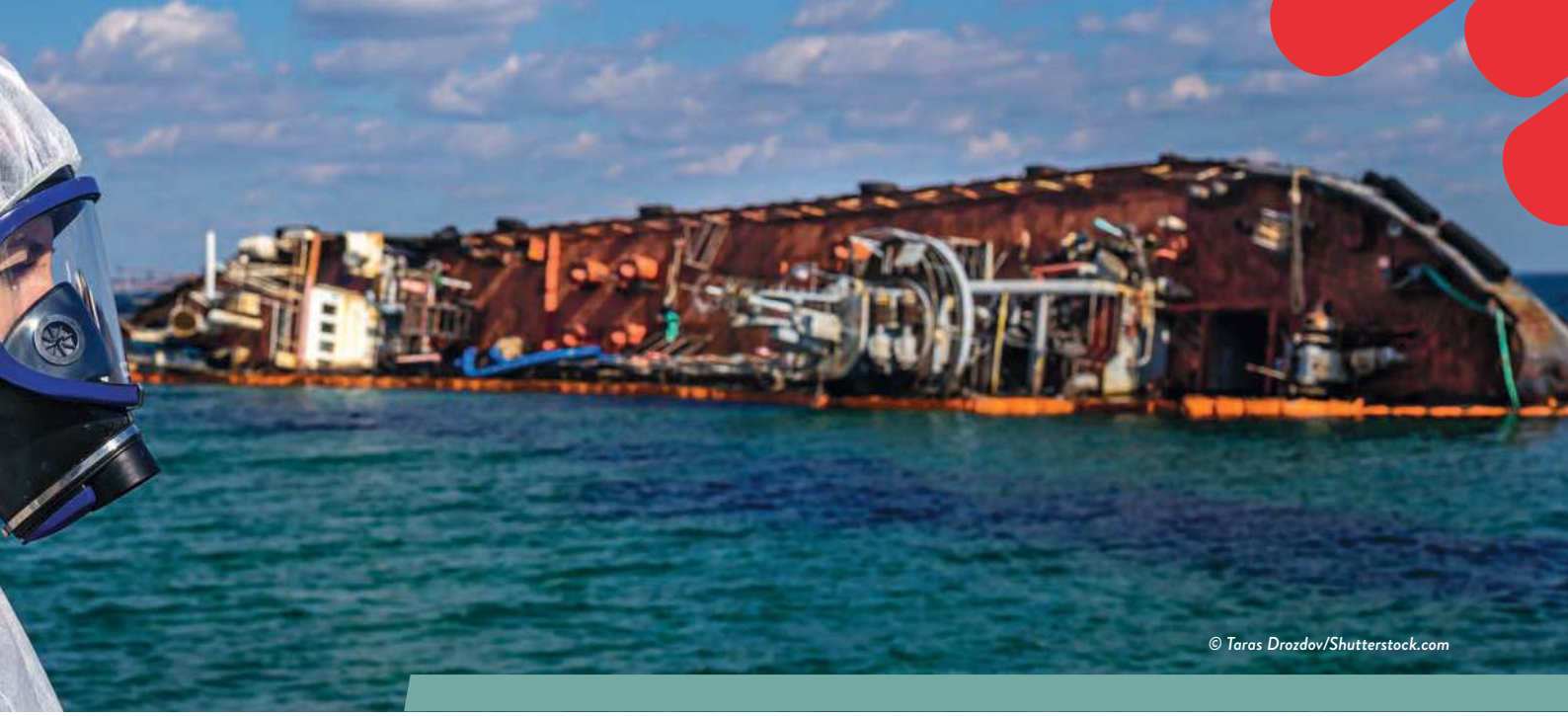
When we think of the effects of pollution, we often focus on the physical damage it causes to the environment. But what about the more subtle effects that may not be immediately obvious, such as changes in animal behaviour? While the image of oil-soaked birds or lifeless fish washed ashore is a powerful reminder of the damage caused by oil spills, the hidden impacts on aquatic life can be even more concerning.

Fish exposed to pollutants like crude oil do not just suffer immediate harm; their behaviour can also be altered in ways that disrupt their entire lifecycle. These changes can make it harder for fish to find food, avoid predators and reproduce, with negative effects that extend throughout the ecosystem. Over time, these behavioural shifts can weaken fish populations and threaten the balance of marine environments, revealing a side of pollution that is not as visible, but equally destructive.

Professor Keith Tierney, an ecotoxicologist at the University of Alberta, is studying how pollutants, particularly those from crude oil, impact the behaviour of aquatic vertebrates such as fish.

How do pollutants affect fish behaviour?

Pollutants like crude oil can significantly affect how fish behave, disrupting the natural instincts they rely on for survival. “Fish behave as most animals do,” says Keith. “They get scared of things that might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kill them, seek out food sources and explore novel environments and items."

Oil-related effluents may include a complex mix of harmful substances, including hydrocarbons, metals and salts, that can affect a fish's behaviour. For example, exposure to these chemicals can dull a fish's senses, making it harder for them to detect predators or find food, which increases their vulnerability in the wild. "In some cases, pollutants can even cause fish to behave in ways that are harmful to them, like seeking out polluted areas instead of avoiding them," explains Keith. These changes do not only affect individual fish but can also disrupt entire ecosystems, making it essential for researchers like Keith to understand and address these hidden impacts to protect aquatic life.

What does a typical day in the lab look like?

Studying how pollutants affect fish behaviour is a complex process that requires a combination of technology, teamwork and creativity. At Keith's lab, the research is largely driven by technicians, undergraduate students and graduate students who work closely together to investigate these behavioural changes.

Video analysis is a key method that Keith's team uses in its research. Keith and his team set up video cameras to observe fish in controlled environments, where they carefully regulate the amounts of pollutants the fish are exposed to. These video recordings enable the team to capture how the fish move, hunt and interact with their surroundings. For instance, they might record how quickly a fish captures its prey or how it responds to a new environment. These videos are then processed using advanced computer software that tracks the fish's movements and analyses various behavioural metrics, such as reaction time and movement patterns. This data is crucial for understanding how pollutants, like those found in crude oil, alter normal fish behaviour.

> "*In some cases, pollutants can even cause fish to behave in ways that are harmful to them...*"

What has the team discovered so far?

Keith's research has already provided some valuable insights into how pollutants impact animal behaviour. More specifically, the team has discovered that exposure to certain pollutants can cause permanent changes in the personality of fish, especially when they are exposed at a young age. This is not just a temporary effect; it can fundamentally alter how these animals behave for the rest of their lives.

"Such changes can have significant long-term implications, and this is exactly the crux of the issue," explains Keith. "What does it mean to change the diverse personalities of animals in a population?" To grasp the full impact of these behavioural changes, the team is collaborating with mathematicians to create models that predict the ecological consequences. These models show that shifts in animal behaviour can throw ecosystems out of balance, potentially causing declines, or even collapses, in animal populations. When these behavioural changes are combined with other environmental problems, such as habitat loss and climate change, the effects can be even more severe.

What does the future hold?

The research conducted by Keith and his team is important because it helps us understand how pollutants, especially from oil spills, affect wildlife in ways that are not always obvious. "Our work has been used by regulators and risk assessors for issues around oil and its transport," explains Keith. "I would like to see our work go towards setting a new standard for what we consider 'toxic', and by that, I mean pollutants that cause subtle adverse effects in animals. Our work on personality changes, for example, provides insights into this." Recognising these hidden impacts can lead to improved standards for environmental protection and more effective strategies for managing and reducing pollution. This approach promises better preservation of ecosystems and a healthier environment for all living beings.

About *ecotoxicology*

Ecotoxicology explores the effects of toxic chemicals on the environment, particularly on ecosystems and living organisms. Unlike traditional toxicology, which often focuses on the impact of chemicals on human health, ecotoxicology broadens this scope to include all forms of life, from microorganisms to plants and animals. This field is essential for understanding how pollutants – ranging from pesticides and heavy metals to more complex substances like crude oil – affect ecosystems, often in ways that are not immediately visible.

The importance of ecotoxicology has grown alongside increased industrialisation and chemical use. As new chemicals are developed and released into the environment, understanding their potential harm becomes even more important. Ecotoxicologists study how these substances move through the environment, accumulate in organisms, and disrupt natural processes. "As humanity is a big fan of chemicals, the issue of chemicals and their toxicity to wildlife is just not going to go away, maybe ever," explains Keith. "Predicting the effects of the next generation of potentially toxic chemicals will be a big area of research. New concerns for chemicals we actively use crop up all the time; it is a continuous game of catch-up. Nanomaterials (which are new materials created at the incredibly small nanoscale), for example, are being produced faster than we can provide safety regulations for them."

Although ecotoxicology can be a very challenging field, one of the most rewarding aspects is the opportunity it offers to make a tangible impact on real-world problems. "The ability to work on issues that affect our lives and the health of ecosystems has me constantly motivated," says Keith. "It is a dream and a privilege to work in this area, especially in the context of a training environment for young people."

Pathway from school to *ecotoxicology*

A career in ecotoxicology requires a strong foundation in biology and chemistry as they provide the basic knowledge needed to understand how pollutants interact with living organisms and ecosystems.

At university level, students typically start with a degree in biology, environmental science or chemistry. Courses in ecology, toxicology and environmental chemistry will be especially relevant.

"A wonderful feature of ecotoxicology is that it is multidisciplinary," explains Keith. "We work with engineers, mathematicians and social scientists." You might also benefit from taking courses in engineering, statistics and social sciences, which can help you understand the broader implications of your work.

Many universities, including the University of Alberta, offer specialised programmes that provide practical experience in environmental research. For example, UAlberta's I-STEAM Pathways programme (**isteam-pathways.ualberta.ca**) offers internships in environmental research for Indigenous students, while the WISEST programme (**ualberta.ca/en/women-in-scholarship-engineering-science-technology/index.html**) provides summer research opportunities for women in science and engineering.

Explore careers in *ecotoxicology*

Ecotoxicology offers various career opportunities, from research and academia to roles in government, industry and environmental consulting. Because the field is research-intensive, it is important to choose educational programmes that align with your specific interests. "Pick a college or university with people who work on the specific problems you are interested in," says Keith. "For example, if you are interested in metals, such as mercury, there are outstanding researchers that do that work. My advice is to focus on the institution or researcher you wish to train with and go from there."

It is also worth exploring organisations and resources that can offer guidance and opportunities. The Society of Environmental Toxicology and Chemistry (**setac.org**) is an international organisation that provides educational resources, conferences and networking opportunities for professionals in this field.

According to Salary Expert, the average annual salary for an ecotoxicologist in Canada is $43,600.

Meet *Keith*

In my third year of university, I took a course in ecotoxicology. It changed my life. I learnt that incredibly small amounts of the chemicals that we produce and release into the environment can have tremendous effects on life. I was absolutely hooked on this field, even though it can be morbid! I was very lucky to find a mentor who was willing to work with me over many years, one who had faith in me even when I was going through the foibles of graduate school, which can be considerable. That person was Professor Christopher Kennedy at Simon Fraser University.

It is the difficult things that seem to evoke the most change. Graduate school is not easy, and it is not for everyone. It can bring extremely difficult times where you think nothing will work out. Finding determination on a daily basis, in spite of your research not 'behaving', and knowing your supervisor will support you through these times are key. I have also found that learning to take criticism can be the most difficult thing for people, and it sure was for me. I can think of several experiences along the way of my advisors telling me things I just didn't want to hear. Eventually, over the years, I learnt to listen.

I think my best work is in front of me, and I think that is extremely exciting. Having said that, the things that have brought me the most joy in recent years come from students inviting me to give lectures at their events. This is humbling in a way I cannot describe. In 2022, I was asked to give a commencement speech to the new Golden Key International Honor Society. It was wonderful. I talked about the importance of the student-mentor relationship.

I will continue to do the science that the world pushes me towards. My personal goal is to stay relevant to my field. The work that my students are doing on methane toxicity to aquatic life, on the toxicity of perfumes, and on the ramifications of 'green' protein sources on animal health are super exciting. I want to see this work released to the public where it might stand a chance of making a difference.

Keith's *top tips*

1. If you have a passion for science, follow it.
2. Nothing beats hard work and dedication.

Meet *Zhanika*

Zhanika Gimeno, master's student, Tierney Lab, University of Alberta

During my undergraduate studies, I enrolled in an environmental chemistry course, expecting it to be a 'typical' chemistry class. However, it opened my eyes to the multidisciplinary approach needed to care for the environment. This realisation led me to Dr Tierney's lab, where the focus on toxicology and behaviour was a perfect fit for my passion for studying the side-effects of pollution.

As one of three research-based master's students in the Tierney Lab, I'm investigating the impact of synthetic fragrances, which are released into aquatic ecosystems from wastewater treatment plants, on organisms that aren't typically considered in the production of these chemicals. I've observed some intriguing results regarding their toxicity and aim to contribute further research to help resolve a debate in the scientific community.

Research often involves trial and error, along with a good dose of creativity to overcome challenges. The satisfaction of finally resolving an issue is incredible! It is also thrilling to analyse the data and see the fruits of all that hard work in the final results.

I was awarded a scholarship from the Natural Sciences and Engineering Research Council of Canada for my research, which I had the opportunity to present at several conferences, including those at an international level. This experience enabled me to connect with fellow researchers in the field and expanded my perspective on the potential impact of my work.

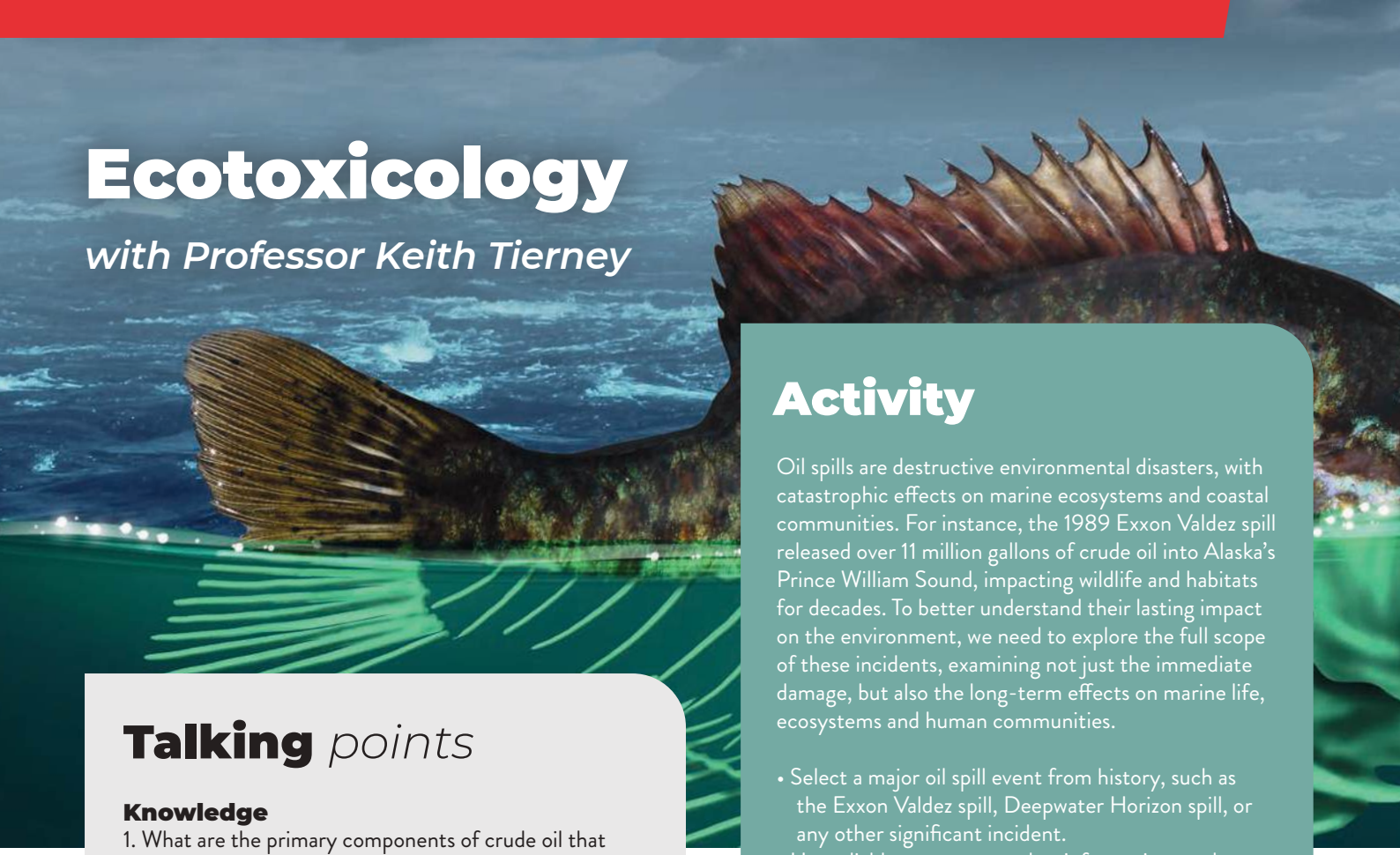
I'm still exploring my options for the future, but I know I want to continue working in the areas of environmental, animal or human health. My degree has already exceeded my expectations in terms of what I've learnt, and I hope to keep growing in this field.

Zhanika's *top tips*

1. Take that first step, even if something feels intimidating or beyond your level.
2. Bad days will happen, so just keep moving forward.

Ecotoxicology

with Professor Keith Tierney



Talking *points*

Knowledge

1. What are the primary components of crude oil that can harm aquatic life?
2. What are the methods used by Keith's lab to study fish behaviour?

Comprehension

3. How can exposure to crude oil pollutants disrupt the natural instincts of fish?
4. What are the long-term behavioural effects that pollutants can have on fish, particularly when exposed at a young age?

Application

5. How might the findings of Keith's research influence the way oil spills are managed or prevented in the future?
6. Consider a fish population in a polluted environment: how would these behavioural changes impact their ability to survive and reproduce?

Analysis

7. Discuss the potential negative effects that changes in fish behaviour could have on a marine ecosystem.
8. How might Keith's research help in predicting and mitigating the ecological consequences of pollution?

Evaluation

9. How do you think other environmental stressors, such as habitat loss or climate change, could exacerbate the impacts of pollution-driven behavioural change?
10. What are the potential long-term consequences of ignoring subtle behavioural changes in fish when creating environmental policies?
11. How important is interdisciplinary collaboration, such as between ecotoxicologists and mathematicians, in understanding and predicting the ecological impact of pollutants, and why?

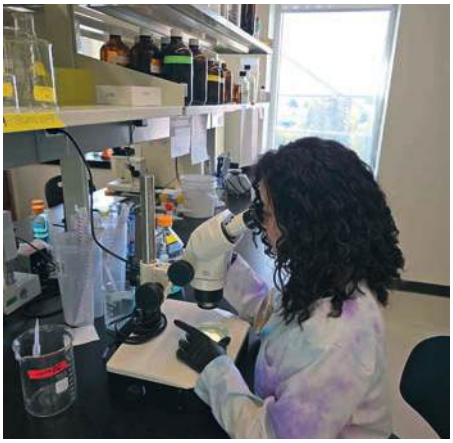
Activity

Oil spills are destructive environmental disasters, with catastrophic effects on marine ecosystems and coastal communities. For instance, the 1989 Exxon Valdez spill released over 11 million gallons of crude oil into Alaska's Prince William Sound, impacting wildlife and habitats for decades. To better understand their lasting impact on the environment, we need to explore the full scope of these incidents, examining not just the immediate damage, but also the long-term effects on marine life, ecosystems and human communities.

- Select a major oil spill event from history, such as the Exxon Valdez spill, Deepwater Horizon spill, or any other significant incident.
- Use reliable sources to gather information on the chosen oil spill, and do some research on the following aspects:
  - The timeline of the spill: how it happened, how long it lasted and what immediate actions were taken to contain it.
  - The types of pollutants involved and how they impacted the marine ecosystem, particularly focusing on fish behaviour and overall marine biodiversity.
  - The short-term and long-term environmental consequences, including the impact on wildlife, ecosystems and local communities.
  - The response from governments, environmental organisations and local communities, including cleanup efforts and policy changes.
  - Any lasting effects that are still being felt today, decades after the spill.
- Using the information you have gathered, create a visual report (e.g., poster, infographic) that summarises the key points of your research.
- Prepare a short presentation (3-5 minutes) where you explain your visual report to your class/friends.

Reflection questions

- What were the most surprising or significant findings from your research?
- How did the oil spill impact marine life in ways that were not immediately visible?
- In what ways did the spill change environmental regulations or public perceptions of oil pollution?
- How could this historical event inform future environmental disasters?



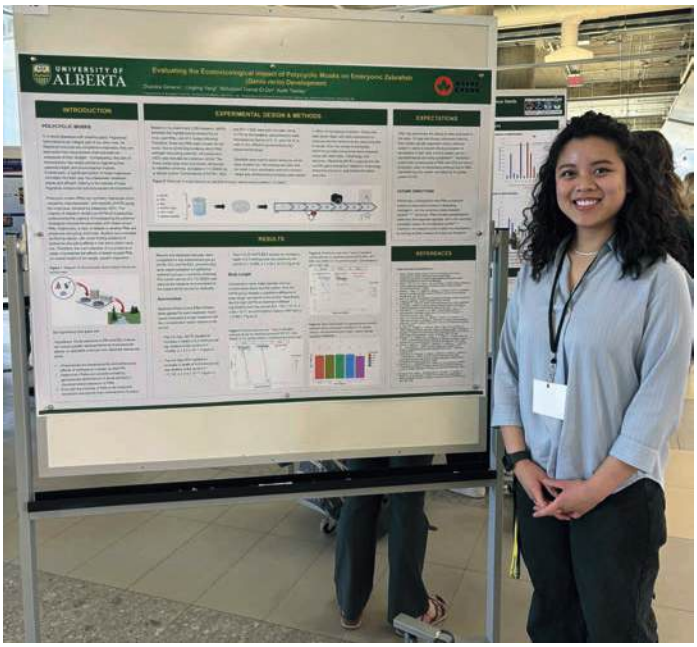


Photo *montage*

Top row: *The Tierney Lab group*

Middle row: ***Left:*** *Microscope analysis in the Tierney Lab*

Centre: *A zebrafish embryo seen under a microscope*

Right: *Tierney Lab member Christina Nykyforuk presenting on research using zebrafish models*

Bottom: *Zhanika Gimeno presenting a poster of her research*

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