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LIFE'S A GAS

Pam McKinlay

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LIFE'S A GAS

Pam McKinlay

"It is the air's ubiquitous presence that becomes an absence."[1] In *The Forgetting of Air*, Luce Irigaray draws on the notion of "the ontology of breath" to ask us to focus on air as a requisite for life, thought and action. Air has been neglected in Western philosophy because "air does not show itself. As such, it escapes appearing as (a) being. It allows itself to be forgotten."[2]

Air is life. We are air-born. We can last three weeks without food, 3-4 days without water, but mere minutes without air. In Te Ao Māori, hau is the breath or wind of life. Air/breath/wind is the nebulous thing that connects all living beings. Anne Salmond, in *Tears of Rangi*, describes air as flowing in an endless cycle, nurturing, sustaining and transforming all whom it touches.[3] *Tihei Mauri Ora* – behold the breath of life!

The ninth annual Art+Science Project called for responses and collaborations on the theme of "AIR."[4] The project partners brought together their research and imaginations to explore the many interconnected notions of "air," scaling between human breathing and planetary breathing in the past, present and future. This report shares a narrative told as a call and response between the science and the emergent artworks during the process of the project.

OUR WORLD IN BREATH

We are living in our third planetary atmosphere. Our air has changed over the history of our planet. Air appears transparent to the naked eye, but we have ways of reading the changing nature of air. What we breathe and how we breathe contributes to good health outcomes and human wellbeing. A myriad of research bodies such as NIWA are tasked with daily monitoring of air quality. What is 'fresh air'? What makes up good outdoor air quality? What's in our air?

"What's in our air?" is also a question of where the air is that we are asking about. We must envisage air as having architecture. It exists in layers of density or stratification and its movement is influenced by topography (laminar flow). Analysis of air reveals the chemical composition of gases and fluctuations inside the thin blue line of our atmosphere. The air in Earth's atmosphere is made up of approximately 78 percent nitrogen and 21 percent oxygen, as well as other gases (water vapour is also present in variable and rapidly changing quantities, so these proportions are for 'standard dry air'). Into this mix we can also add natural and anthropogenic aerosols. Carbon dioxide makes up only a small part of the atmosphere. It is an important atmospheric gas that helps absorb heat that radiates from the planet, but excessive concentrations from burning are changing our current atmosphere. Indoors, there are different issues when we cannot trust our air – no less so than right now, with pathogens like SARS-CoV-2/COVID-19 travelling the airstreams and leaving havoc in their wake.

NIWA scientist Gustavo Olivares partnered with Pam McKinlay in a Curious Minds Participatory Science Platform Project. The data from this citizen science project was used in a sculptural visualisation in the exhibition, alongside a collaborative citizen art provocation.

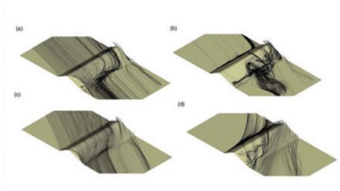
Stella Lange worked with an epidemiology team led by Dr Michael Baker on past, current and future preventative measures directed at Covid-19 and the importance of correct mask use.

Jackie Herkt's pick-up woven panel was inspired by the "Scan in" Poster issued by the Ministry of Health during the 2020 Covid-19 pandemic lockdown.

Sofia Kalogeropoulou's choreography explored the social impacts of air and isolation using social distancing and Perspex barriers in a dance performance.

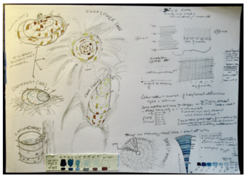
IN THE PRESENCE OF BUTTERFLIES

We generally can't see air, but we can feel its presence. Wind is moving air, caused by pressure differences in the atmosphere. Those air pressure differences are what drive a lot of our weather. Robert FitzRoy (captain of HMS *Beagle* and former Governor General of New Zealand) is credited as the inventor of the weather forecast as we know it[5] – but, as we also know, weather forecasts are never as accurate as we would like them to be. Advances in scientific understanding reveal the complex systems underlying our weather. Driven by water vapour, constantly changing from gas to liquid and sometimes to a solid state, the weather system is activated by shifts in latent heat. The constant changes in temperature cause changes in pressure zones which we call high- and low-pressure fronts, whose shifting behaviour makes it difficult to predict our weather by more than a couple of days.



In "Seeing the Wind", mathematician Sarah Wakes uses computational fluid dynamics to look at the effects of wind velocity and turbulence on dune landscapes and evaluate restorative measures to improve dune stability. Katharine Allard created an an echo of Wakes' research into wind modelling using marram grass ash material as a substrate for a fine metalpoint drawing.

Weather patterns collated in meteorological histories are used to predict future weather conditions and events and long-term effects on climate over an even longer period. The atmosphere is a complex and chaotic system. To paraphrase Robert Sapolsky, fixing clocks and fixing clouds require different mindsets. You can pull apart your clock and find the bit that is not working and fix the gearing (or whatever) and a clock will run again. But fixing clouds (to reflect more UV or produce more rain) is a different story. You can't dissect a cloud and put it together again – it is a complex system. A clock can be fixed by additive knowledge and technology, but clouds are non-linear and are at the whim of chaotic forces and elements.[6] These individually inconsequential differences, which can gather momentum to become consequential, are known as the "butterfly effect."[7] While long-term observations of weather patterns, as well as paleoclimate records, are used to investigate change and predict future scenarios, scientific understanding is only a part of the work that is needed to bring about change to mitigate the rapid changes we are causing to our planetary atmosphere.

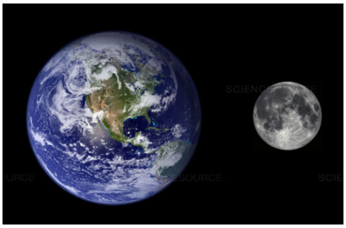


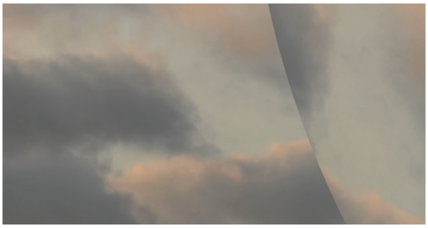
Longitudinal records of local air temperature were used by Jenny Rock working with 30 years of data (daily recordings) from her father's farm journals. (image – work in progress).

Jenny Rock also used air temperature data from MetService records in a social art engagement.

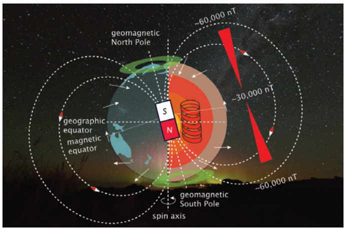
THIN BLUE LINE

Earth's atmosphere has a protective layer of ozone which is roughly the thickness of two coins.[8] Within the thin blue line of gas and dust encircling our planet is our air – a name we use for the mixture of gases making up Earth's atmosphere (from Greek *atmos* – gas or vapour – and *sphaira*, ball or sphere).[9] "Air" extends around the Earth's surface many kilometres around and up. Like water, air has tidal flows (fluid dynamics).





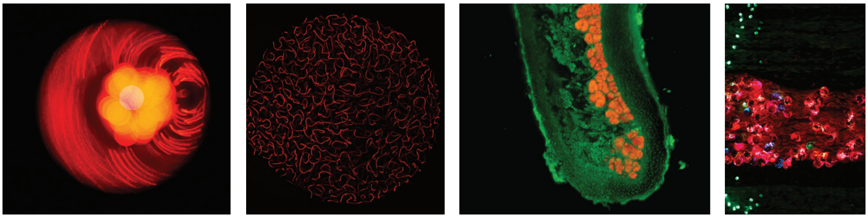
Tidal air flows were the confluence of interest in a work by artist Louise Beer, who worked with Geoff Wyvill. (Louise Beer, video still, at right).



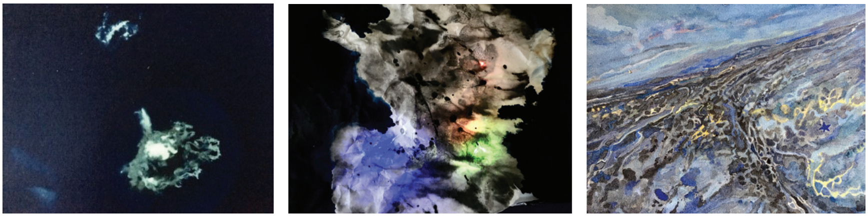
Earth's atmosphere is protected by a magnetic shield which is constantly entangled with the solar winds. The magnetosphere of excited oxygen is the research topic explored by Faye Nelson, with artist Christine Keller and astronomer/aurora chaser, Ian Griffin.
(concept image Christine Keller overlaid Ian Griffin aurora photograph).

Sunrises and sunsets reveal the dramatic and picturesque effects of volcanic aerosols in the stratosphere (at around 20-25km) above New Zealand). NIWA has recorded the aerosols which originated from the plume of gas and ash that was ejected when the Hunga Tonga-Hunga Ha'apai volcano erupted in January. They have been dispersing around the globe, with concentrations spiking in the New Zealand region since mid-May.
(© Otago Daily Times, Photograph: Stephen Jaquiery, image used with permission).

From geological evidence we know that this is Earth's third and current atmosphere. The first living organisms were anaerobic and lived underwater near volcanoes, using sulphur to drive their metabolism. The Great Oxidation Event (GOE) was caused by cyanobacteria which evolved three billion years ago to use photosynthesis to capture the sun's energy. Oxygen was produced as a side product and gradually began to accumulate in Earth's atmosphere.[10] Photosynthesis is a complex system, but many people learned a simplified equation which encapsulates the fundamentals at school: $CO_2 + 6\ H_2O > C_6H_{12}O_6 + O_2$. With the change in atmospheric chemistry many existing species died out. For this reason, the GOE is sometimes called the Great Oxidation Catastrophe: "Free oxygen also destroyed the ability of many nitrogen-fixing bacteria to do their thing, since oxygen tears the iron atoms at the heart of the nitrogenase enzyme."[11]

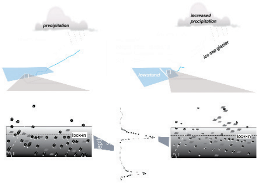


Cyanobacteria is the research area of botanist Tina Summerfield, who worked with Pam McKinlay on a woven light piece representing the symbiotic relationship with lichen. Another small work represented the fluorescence and fluorescence-decay of light-sensitive cells during photosynthesis in wild Nostoc cyanobacteria. (From left confocal microscopy of wild Nostoc by Tina Summerfield, Cyano-fluere video by Pam McKinlay, confocal microscopy of symbiotic Nostoc in lichen by Tina Summerfield, Interwoven flurochroma by PamMcKinlay, a tapestry of woven light).



Craig Cook experimented with a cyanotype process using algae to create indexical impressions on site at a location where the cyanotype-algae blooms. Samples of cyanobacteria were developed into cyanotype impressions.

"The past always sticks to the present," as author Nathan Harris puts it.[12] Mud and ice trap gases from deep time, and scientists have found ways of reading cores through various analytic lenses as geo-temporal texts. By unlocking the secrets of cores samples, it is possible to trace these geo-chemical timelines and the atmospheric conditions in which previous plants and organisms lived and breathed. Long-time schema are helping us prepare for our near-future atmosphere, brought about by human activity, that is upsetting the delicate balance of minor gases. Science writer Sam Kean puts the matter succinctly: "Nature simply can't bail fast enough to keep up … Fluctuations in CO_2, methane and other GHG have been responsible for climate changes over millennia, but concentrations and rate of change is faster now than geological processes such as forestation and phytoplankton can sequester."[13]

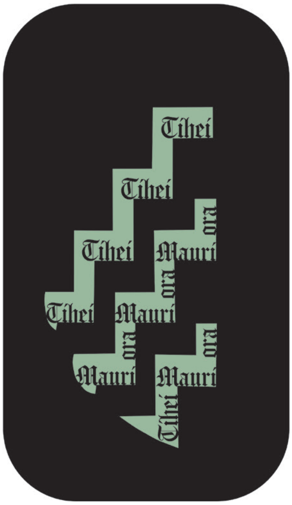


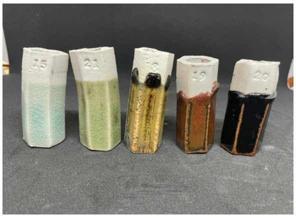
Past atmospheric conditions are captured in the mud washed off the Southern Alps and revealed in core samples collected off the coast of South Island Fjords. Locke Unhold experimented with material from core samples, often high in iron, in clay and glaze preparations, which were then processed at elevated temperature to metamorphose into different forms of the minerals.

RESPIRATION: SAVE YOUR BREATH

What happens when we breathe? How do other lifeforms 'breathe'? Like the sea, our breath begins somewhere else each day. Each breath is different; "the ghosts of breaths past continue to flit around you every second of every hour, confronting you with every single breath."[14] We share breath with anything and everything that ever lived … and we breathe on average 20,000 times a day. There is a thought experiment (Eurocentrically) named "Caesar's last breath" which simply asks the question, how many molecules of Caesar's last breath did we just inhale in our last breath?

Mike Palin (Geology Department) and Down the Rabbit Hole Art Collective made an interactive piece which acknowledged the relationship of the GOE and iron saturation to the notion of first breath drawn by animals. Visitors to the gallery sprayed the work with sea water to accentuate surface rusting in real time during the exhibition.

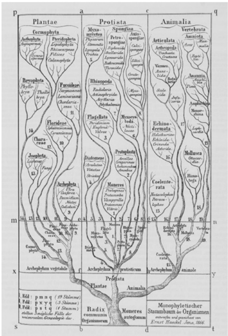


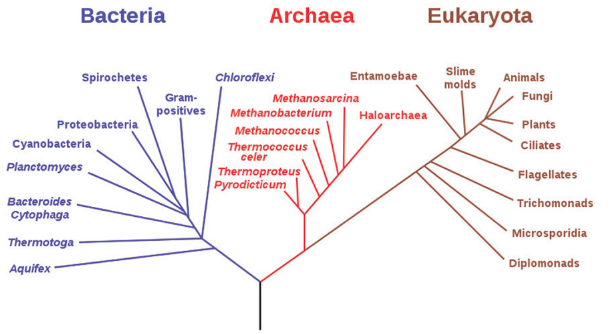


Mike Palin and Locke Unhold collaborated on another GOE project. Locke prepared several vessels with iron-rich glazes which were fired in oxidising and reduction firings to reveal the complex chemistry of these atmospheres in the kilns.

For the purposes of the exhibition (and a younger audience), we made the subject of our question "the last moa's breath." The experiment assumes that there is half a litre of air in each breath (it was small moa) and that the last breath is one full litre (enough to fill a balloon five inches in diameter). The last breath when exhaled is blown away and around the globe. The whole breath is dispersed but does not disappear – its molecules remain. According to calculations, each litre of air has 25 sextillion (21 noughts) molecules which is 0 … (19 noughts).1 percent of all our air. At the end of some mind-blowing calculations (spoiler alert!), one molecule of the last moa's breath will appear in our next breath and, over a day, thousands will be inhaled. [15]

Not all living things need air to breathe and sustain life, but all animals do. We can go without food for a week, water for a few days, but we cannot survive without breathing oxygen in our air. We do not even think to breath. We do it automatically. But what are we breathing? The oxygen we breathe needs to be continuously replaced in our bodies. Air is a mixture of gases, but it is the oxygen in this gaseous mix that animals need to survive. For us, breathing is a process of gas exchange. The oxygen in the air we inhale moves from the lungs to the blood, and at the same time carbon dioxide gas moves from our blood to be exhaled.



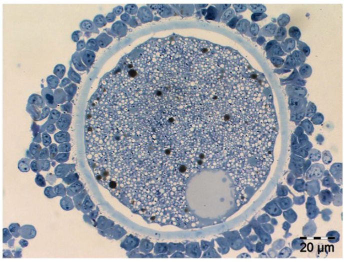


Photosynthesising cyanobacteria not only changed the geochemistry of the planet, they transformed the tree of life, enabling development opportunities for multicellular life on Earth as we know it now, including plants and animals. These were the first breaths to be taken on Earth. (image Ernst Haeckel (1834–1919). See also a modern phyolgenic tree. showing the three life domains: bacteria, archaea, and eukaryota. (images Wikimedia commons).

Artist Heramaahina Eketone, worked with ASPIRE 2025 (Research for a tobacco-free Aotearoa) research led by Janet Hoek, looking at notions of hauora and being smoke-free through a Te Ao Māori lens.

We got a sense of the mechanics of breathing in the tomography of lungs and oxygen delivery in a work by Sophie White, Scientist, Lab technician, preparator, dissector.

"Our bodies, suffused with atmospheres, ancestors and chemical compounds produced by sunlight, are 'meterontological,'" according to Janine Randerson. "We are the weather."[16] A clutch of tuatara eggs will have their sex determined after they are laid by the environmental conditions they experience, including air temperature and humidity. If temperatures in the nest are high, then the eggs will hatch as male. Animals also owe a debt to another aerobic pioneer called mitochondria. Each of our cells contain mitochondria which use oxygen to extract the chemical energy from sugars like glucose. We need a constant supply of oxygen to supply our mitochondrial batteries from the very first hint of life. Nano-research into mitochondria looks at the causes of human embryo failure, triggered by changes in mitochondrial form (which affects vital function).



"Dreaming of Oocytes" was a collaborative artwork made by artists Vivien Dwyer and Andrea Muggeridge with scientist Karen Reader using bead and wire-work and tiny felted balls. Their collaborative creation was based on the nano microscopy of Karen Reader. (image: light microscope image of a section through a sheep oocyte surrounded by cumulus cells.)

PHOTOSYNTHESIS: BREATH-TAKING SPLENDOURS AND THE WOOD-WIDE WEB

> In the top six inches of the forest floor lies a vast and flourishing communication system as old as photosynthesis itself. This is where we find an exquisitely balanced symbiotic relationship between mycorrhizal fungi and tree roots which provide a network of channels for resources and messages between individual trees. The resulting plant chatter is as complex and efficient as our own worldwide web. In recent research, biologists have discovered the existence of Mother trees: larger, older specimens that, with the help of their fungi, serve as system hubs in life and as nutrient sources in death. This mycorrhizal network thus connects and stabilizes the forest, and by extension, our entire planet's biosphere. (Lorraine Roy)[17]

Living things also need nitrogen to make new cells, but they cannot take it directly from the nitrogen gas in the air. As a result, we all live in symbiosis with other life-forms that can convert atmospheric nitrogen into usable forms – including those living organisms we rely on for photosynthesis (and once again our oxygen production). The unique ecology and biology of tree–fungi relationships shows that there is so much more to the world of plants than what we can see. Hidden in the soil, tangled among the tree roots, is the "wood-wide-web" of fungi that both *take* energy and *give* energy to the trees. Trees need the fungi and the fungi need the trees.[18] They live in a complex entanglement of relationship to each other – in cooperation, mutuality, support and alliance.

Suzanne Simard's book *Finding the Mother Tree* is one woman's story of discovery regarding the incredible mutualism unfolding under our forests. It is more efficient for a plant to invest in cultivating fungi than growing more roots, because fungal walls are thin, lack cellulose and lignin and require far less energy to make:

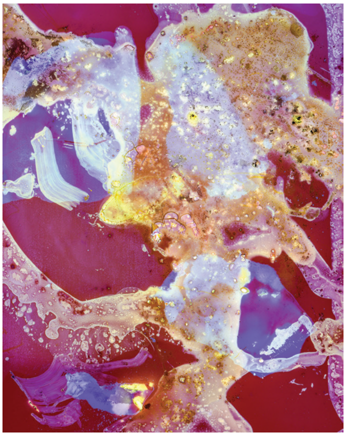
> The mycorrhizal fungal threads grow between the cells of the plant roots in a web around each plant cell. The plant passes the photosynthetic sugars through its cell walls to the adjacent fungal cell. The fungus needs this sugary meal to grow its network of fungal threads through the soil to pick up water and nutrients. The fungus is a co-operator, a mediator, a helper.[19]




Large areas of Te Wai Pounamu are covered in native southern beech forest (Nothofagus). There are many hundreds of species of native mycorrhizal mushrooms associated with these including purple pouch fungus varieties.

David Orlovich's research, focussing on symbiotic fungi, is explored in the etched-glass work of Danielle Munro (concept drawing above).

Thomas Lord also responded to David Orlovich's research, using the indexical qualities of camera-less photography to grow mycelium onto 4 x 5 inch colour sheet film which he buried in the forest and then developed and printed. Film was buried in the forest under the spot where a mushroom had been collected so it was most likely the same mycelium interacting with the film surface (above right).

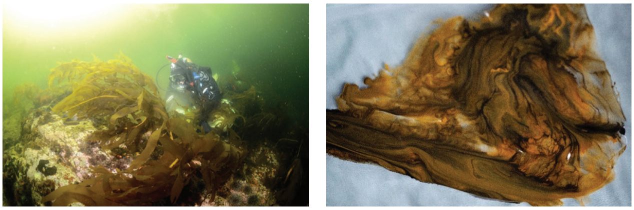


In another work Thomas collected Russula from the forest, cloned specimens using a petrie dish and then transferred onto the film for a month, before processing and printing. (image: Thomas Lord photo, Russula, 2022).

FLOW | AUTOFLUORESCENCE

We think of terrestrial trees and plants as the "lungs of the Earth," providing a kind of essential bio-service for us as photosynthesising oxygen producers and air scrubbers. However, every second breath we take was made in the ocean. Marine macro-algae, seaweeds, are photosynthetic aquatic organisms vital to the functioning of our marine ecosystems, not only for gas exchange but by providing habitat and crucial nursery environments. In Te Ao Māori, Hinemoana was the creator of all forms of seaweed, critical in the whakapapa of all shellfish and kai moana.[20]

There are three main types of macroalgae, differentiated by pigment: green, brown and red. They are not closely related and have different evolutionary paths, but have similar physical characteristics because of the environment they share.[21] They vary enormously in size, shape and growth. The smallest macroalgae can only be properly seen with a microscope, whereas giant kelp can form massive forests reaching for more than 30m. There are an estimated 48 species of introduced seaweeds now flourishing in New Zealand waters. Of these, *Undaria pinnatifida*, a species highly valued for food in Asia,[22] is not welcome in our waters. Because of its size, ability to live in a wide range of habitats and its reproductive output, *Undaria* is outcompeting our native species.



Teina Ellia made flowing painted works which responded to Gaby Keelermay's research on the invasive kelp Undaria pinnatifida. Undaria can slowly monopolise reef space and resources by outcompeting native seaweeds, which can eventually alter the ecosystem. Gaby's research shows it may be possible to reduce this impact by divers manually removing the invader from the reef, thus slowing the spread of Undaria in our harbours and along our coastlines.Seaweeds are ecosystem engineers that provide structure and oxygen to the underwater world.

Our marine environments are also at the mercy of air quality including the consequences of ocean acidification. While we have become familiar with the devastation caused by bleaching in coral reefs, there are also grave consequences deriving from an increase in average ocean temperatures and localised marine heat waves on the unsung photosynthesising heroes of the seas: the phytoplankton. In 2018, a species of plankton, *Syracosphaera azureaplaneta*, was named after the television series *Blue Planet* and its world-renowned narrator Sir David Attenborough, who stated, "If you said that plankton, the phytoplankton, the green oxygen-producing plankton in the oceans is more important to our atmosphere than the whole of the rainforest, which I think is true, people would be astonished."[23]

In "Too Hot to Handle," with scientist Linn Hoffman (Botany), the importance of photosynthesising phytoplankton and effects of elevated carbon dioxide levels on coccosphere form and function was explored in a community outreach piece (Pam McKinlay photo and 3D model by James Perrelet[24], printing by Willian Early). Creative workshops were faciliatated by Vivien Dwyer (crochet cocco workshop) and Finn McKinlay (origami cocco workshop).

"There's a crack in my Ocean" looked at Grace Duke's PhD research on diatom based reconstruction of ocean environment and circumpolar changes with effects on the Southern Ocean. Cooling and warming effects on sea ice affected the position of the polar front with corresponding shifts in atmospheric conditions during the warm period of the Pliocene, when carbon dioxide levels were at ~400ppm. Down the Rabbit Hole Art Collective 2022 (Pam McKinlay, with technical assistance from Brendon Monson 3D modelling and printing, Locke Unhold glazing. Image: work in progress).

TIAKINA TE ĀNGI | PROTECT OUR AIR

The air we breathe, the water we drink, the soil we grow our food in and the raw materials we make our shelter from, are all under threat as shifts in greenhouse gases change our atmosphere, with catastrophic consequences. The Art+Science exhibition gives audiences an opportunity to negotiate the implications of scientific reasoning through a narrative lens, allowing the viewer to engage with these realities at their own pace and from the bedrock of their own cultural background and experience. The answers we seek are blowing in the wind. Each artwork in "AIR: Life's a Gas" draw our attention to our intimate relationship with air. Their stories demand that we turn our attention urgently to global atmospheric changes that are driving us dangerously close to our planetary boundaries.

We currently also find ourselves in a pandemic where the threat is more personal. Covid-19 is the result of our unsatiated encroachment into wild. A silent assassin has left the wild places and the viral lion is at the door. As it invades our collective air cavities, it makes bold inroads into our collective consciousness. Across the world, as we relentlessly destroy natural habitats and disable essential bio-eco services, we need to take stock of what we are doing to ourselves. Will we remember when this current crisis passes, and we can breathe more easily, that we are not separate and *apart* from, but a *part* of a global system which we call nature.

The sky has no borders, so I will leave the last word to a public health message that appears on the giant screen in Beijing's Tiananmen Square when red alerts are posted for high pollution levels:

保护大气环境人人有责

protecting the atmospheric environment is everyone's responsibility[25]

The Art+Science Project 2022 team was led by Pam McKinlay from the Dunedin School of Art, with the assistance of Dr Jenny Rock and others.

Pam McKinlay (https://orcid.org/0000-0002-1731-6437) is an art historian with work and research experience in applied science, art and in publishing. Her work is concerned with the transference of ideas and knowledge – the process and practice of making, and the process and practice of making available to the public important findings in contemporary science via the various platforms she supports. She is the curator of the *Art+Science* project.

Acknowledgement:
Dr Jenny Rock has been involved with the *Art+Science* Project for many years in different roles: as co-coordinator, researcher (examining its collaborative effects on artists, scientists, and the viewing public), social art practitioner for public works. and as an artist. She has an interdisciplinary background in biological science and the arts/humanities, and is an applied and academic researcher in both spaces - often focusing on their integration.

1 Christina Grammatikopoulou, "Remembering the Air: Luce Irigaray's Ontology of Breath," *interartive*, https://interartive.org/2014/05/irigaray-air.

2 Ibid.

3 Anne Salmond, *Tears of Rangi: Experiments across Worlds* (Auckland: Auckland University Press, 2017), 13. Hau is the force that drives the entire world, not just human relations.

4 The Art+Science initiative was originated by Peter Stupples (Dunedin School of Art) and Ruth Napper (University of Otago) in 2013. Prompted by an annual theme, artists and scientists in specific disciplines share their ideas and experience, and produce an exhibition based on their resulting collaborations. The aim of the project has always been creative cooperation – not the illustration of scientific research.

5 Peter Moore, *The Weather Experiment: The Pioneers who Sought to See the Future* (New York: Farrar, Straus & Giroux), introduction.

6 Robert Sapolsky, *22. Emergence and Complexity*, Stanford University, Biology 101, 21 May 2010, https://www.youtube.com/watch?v=o_ZuWbX-CyE.

7 Edward N Lorenz, "Predictabiilty; Does the Flap of a Butterfly's Wings in Brazil Set off a Tornado in Texas?," paper presented at the American Association for the Advancement of Science, 139th Meeting, 29 December 1972, https://eapsweb.mit.edu/sites/default/files/Butterfly_1972.pdf.

8 NASA, "NASA Ozone Watch," https://ozonewatch.gsfc.nasa.gov/facts/dobson.html. The average amount of ozone in the atmosphere is roughly 300 Dobson Units, equivalent to a layer three millimetres (0.12 inches) thick – the height of 2 pennies stacked together.

9 Sam Kean, *Caesar's Last Breath: The Epic Story of the Air around Us* (New York: Doubleday, 2017). The term "atmosphere" was coined by astronomer and mathematician Willebrord Snellius (1580-1626) to refer to the gaseous sphere enveloping Earth and other planets.

10 Kean, *Caesar's Last Breath*. As the keenly observant will notice, the end sugar contains six oxygens. "More to the point, it contains just six of the 18 oxygens available at the beginning. Conservation of mass says that atoms can neither be created nor destroyed, so we can conclude from this that photosynthesis must produce free oxygen gas (O2) as a by-product."

11 Ibid.

12 "Nathan Harris: Intimate Civil War Tale Treads New Ground," interview by Kim Hill, Saturday Morning, *RNZ*, 23 October 2021, https://www.rnz.co.nz/national/programmes/saturday/audio/2018817601/nathan-harris-intimate-civil-war-tale-treads-new-ground.

13 Kean, *Caesar's Last Breath*, 316.

14 Ibid., 1-14.

15 Ibid..

16 Cited in Carol Brown, "The Air between Us," *Performing Ecologies*, https://static-cdn.edit.site/users-files/dcc4ea29081b5fbd9f330e0b0ddde4aa/theair-betweenus_performing-ecologies(2).pdf?dl=1.

17 "Gallery – Woven Woods 2017-2022," *Lorraine Roy Art Textiles*, https://www.lroyart.com/gallery.php?cat=28.

18 Suzanne Simard, *Finding the Mother Tree: Uncovering the Wisdom and Intelligence of the Forest* (London: Allen Lane, 2021), 60.

19 Ibid., 232.

20 Elsdon Best, *Maori Religion and Mythology Part 2: Origin of Shellfish, Etc*, http://nzetc.victoria.ac.nz/tm/scholarly/tei-Bes02Reli-t1-body-d4-d3-d8.html.

21 Wendy Nelson, *New Zealand Seaweeds: An Illustrated Guide* (Wellington: Te Papa Press, 2020), 118.

22 Miek Zwamborn, *Seaweed: An Enchanting Miscellany*, trans. Michele Hutchison (Vancouver, BC: Greystone Books, 2020), 125. Each April 14 a seaweed festival is held in Uto, Japan, in honour of Dr Kathleen Drew-Baker, who is honoured as "The Mother of the Sea" in Japan for her work on nori, from her study of *Porphyra umbilicalis* in Wales. The British algologist unravelled the complex reproductive cycle of red seaweed in a private seaside lab, work which led to the commercial cultivation of nori.

23 David Shukman, "Plankton Named after BBC Blue Planet Series," *BBC News*, 17 April 2018, https://www.bbc.com/news/science-environment-43796939.

24 Jamie Perrelet, 3D printing file "3D Printing the Long Term Carbon Cycle", https://www.fractalteapot.com/portfolio/3d-printing-carbon-cycle/, Printing by William Early. Acknowledgement to Lynn Taylor of the Sandpit Collective (Lynn Taylor and Jenny Rock) for assistance with file. Lynn was part of an earlier project in Art+Oceans, 2018.

25 "Beijing Watches Fake Sunrise on Video Screen amid Smog Emergency (PHOTOS)," *Huffington Post*, 17 January 2014, http://www.huffingtonpost.com/2014/01/17/beijing-fake-sunrise_n_4618536.html.