FEATURE

Meet the most misunderstood element on Earth.

C^6ARBON

THE UNAUTHORISED BIOGRAPHY

ATOM
AUSTRALIAN TEACHERS OF MEDIA

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https://theeducationshop.com.au
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STUDY GUIDE

SYNOPSIS

With Carbon in the news every day, you might think you know everything about her. But you'd be wrong. We're not at war with Carbon – we are made of Carbon! Yet, paradoxically, the element at the core of life is now the greatest threat to our survival.

This surprisingly unorthodox and creatively ambitious documentary pulls back the covers on the most talked about but least understood element on the planet. Actor Sarah Snook (*Succession*) lends a cheeky, powerful and immortal voice to Carbon, spinning the epic saga of how she was born in the violent heart of a star, sparked the earliest life and rode the journeys of evolution, and how she captures the sun's energy in photosynthesis, fuels our modern world, and keeps our planet's atmosphere in delicate balance.

The animations of renowned artist Bruce Alcock (*Global Mechanic*) trace Carbon's endless journeys, taking us on joyful and surprising rides through her atomic existence, from the formation of DNA to the metabolic circus taking place inside us every second, to million-year cycles from Earth's core to the atmosphere. Jonathan Kawchuk's striking orchestral music underpins the wonder and curiosity we feel as we witness Carbon's astonishing molecular dance.

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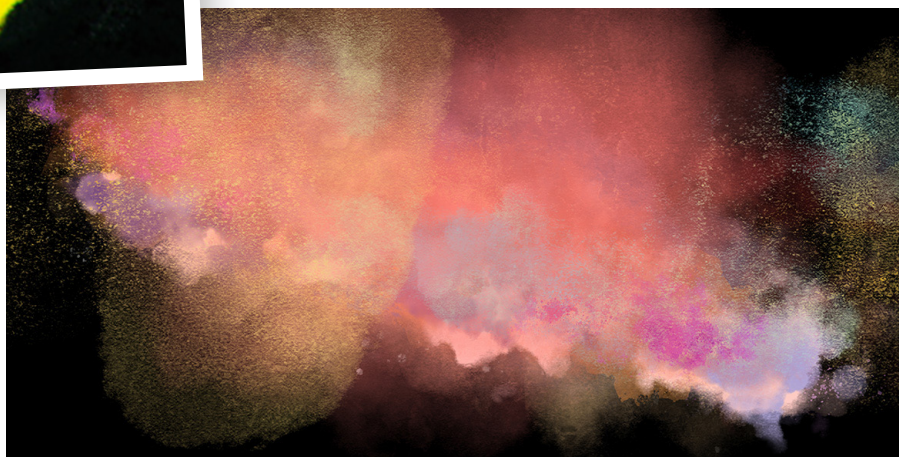
Spectacular, illuminating and surprisingly eccentric, Carbon is produced by the award-winning teams at Genepool Productions and Handful of Films. This story of life's core element promises to transform how we think of Carbon, from maligned destroyer towards a powerful enabler.

Carbon is not the enemy. Carbon is life!

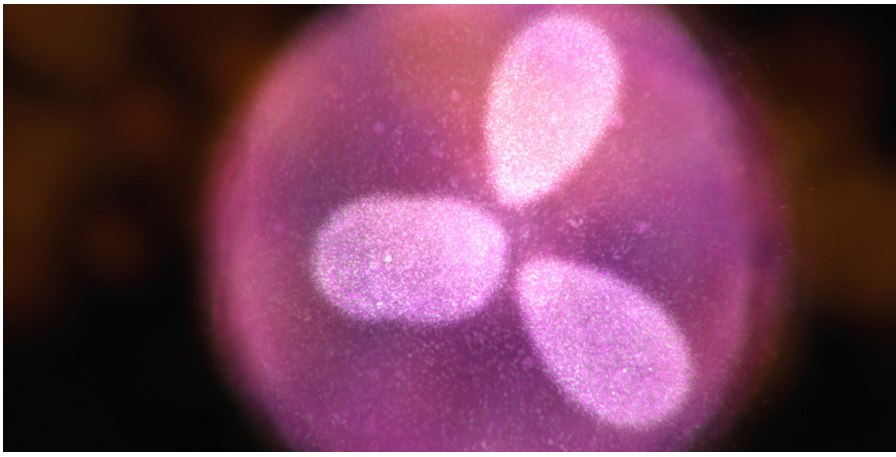


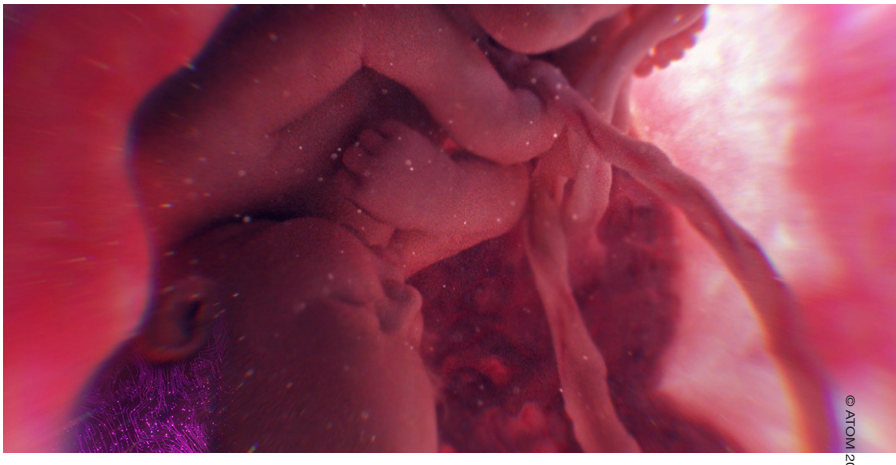
World-renowned experts, including astrophysicists Neil deGrasse Tyson and Tamara Davis, climate scientists Katharine Hayhoe and Will Steffen, forest ecologist Suzanne Simard, materials scientist Mark Miodownik, and historian David Christian translate this complex story with striking clarity and infectious enthusiasm.

Accompanying Carbon's own voice, our cast of experts transports us from life's earliest origins to the fossil-fuelled revolutions of modern civilisation, and to the terrible violence of fossil-fuelled warfare. They celebrate the alchemies of modern industry and the age of plastics, and reveal how by harnessing Carbon's chemical flexibility, we have built our world.

But now, as we liberate vast buried stores of it into our atmosphere to fuel the Anthropocene, we're discovering Carbon's dark side: she is the enabler of life, and she is also its destroyer.

How will humanity's grand affair with Carbon end – in reconciliation or ruin? We meet a new generation of Carbon-capture scientists, forest guardians and renewables entrepreneurs working hard to make peace with her, giving her places to hide.





Professor Tamara Davis

ABOUT…

THE VOICE OF CARBON: Sarah Snook

Sarah Snook was born and raised in Adelaide, South Australia. Showing promise in performing arts at a young age, Sarah was awarded a scholarship to study drama at Scotch College, Adelaide. After high school, she was accepted into the prestigious National Institute of Dramatic Arts (NIDA) and graduated in 2008 with a Bachelor of Fine Arts (Acting).

Having started out in theatre in Sydney, Sarah was the runner-up in the 2011 Australians in Film Heath Ledger Scholarship. She has since gone on to work extensively in film and television in Australia, receiving awards from the Australian Academy for Cinema and Television Arts (AACTA) for Best Actress in a Film, *Predestination* (2014), and Best Lead Actress in a Television Drama, Sisters of War (2010), the Film Critic's Circle of Australia (FCCA) for Best Actress - Lead Role, *Predestination* (2014) and *Not Suitable for Children* (2012), and the Australian Film Critics Association (AFCA) for Best Actress in a Supporting Role, *These Final Hours* (2013).

Internationally, Sarah has acted in numerous films, most notably *Steve Jobs* (2015) and *The Glass Castle* (2017). She also appeared in the Netflix series *Black Mirror* (2011). On stage, Sarah made her West End debut in 2016 alongside Ralph Fiennes in The Old Vic's production of Henrik Ibsen's "The Master Builder".

In 2017 Sarah wrapped on two Australian productions, *Winchester* (2018) and *Brothers' Nest* (2018). In 2018, Snook began starring as Siobhan "Shiv" Roy in the HBO satirical comedy-drama series *Succession.* For her role, she received a nomination for the Primetime Emmy Award for Outstanding Supporting Actress in a Drama Series in 2020, then won the Golden Globe for Best Supporting Actress – Television in 2022.

ASTROPHYSICIST: Dr Neil deGrasse Tyson: One of America's best-known scientists, astrophysicist Neil deGrasse Tyson has spent much of his career sharing his knowledge with others. He has a great talent for presenting complex concepts in a clear and accessible manner. After studying at Harvard University, he earned his doctorate from Columbia University in 1991. Tyson went to work for the Hayden Planetarium in 1996 before becoming its director. Additionally, he has served as host of NOVA ScienceNow and the StarTalk Radio podcast. Tyson remains a popular TV science expert today. Tyson is the fifth head since 1935 of the world-renowned Hayden Planetarium in New York City and the first occupant of its Frederick P. Rose Directorship. He is also a research associate of the Department of Astrophysics at the American Museum of Natural History.

ASTROPHYSICIST: Professor Tamara Davis: Astrophysicist Tamara Davis uses exploding stars known as supernovae, to investigate the elusive "dark energy" that's accelerating the expansion of the Universe. Supernovae are where much of the carbon in the universe was born. Her accolades include the Astronomical Society of Australia's Louise Webster Medal, the Australian Institute of Physics Women in Physics Lectureship, the Australian Academy of Science's Nancy Millis Medal, an Australian Research Council Laureate Fellowship, and a Member of the Order of Australia (AM).

GEOLOGIST: Dr Robert Hazen: Robert M. Hazen is Senior Staff Scientist at the Carnegie Institution's Geophysical Laboratory and Clarence Robinson Professor of Earth Sciences at George Mason University. In 2008 Hazen was named Principal Investigator and in 2011 Executive Director of the Deep Carbon Observatory (DCO), a 10-year effort to achieve fundamental advances in understanding the chemical and biological roles of carbon in Earth. Author of many books including most recently, 'Symphony in C, Carbon and the Evolution of (Almost) Everything'.

MATERIALS SCIENTIST: Professor Mark Miodownik: For more than ten years Mark has championed materials research that links the arts and humanities to medicine, engineering and materials science. This culminated in the establishment of the UCL Institute of Making where he is Director and runs the research programme. His current research interests are animate materials, innovative manufacturing, and sensoaesthetic materials.

PALEOBIOGEOCHEMIST: Professor Martin Van Kranendonk: Martin's research interests span the lithosphere, biosphere & atmosphere, across a broad range of disciplines relating to early Earth, from global tectonics to early life, and pretty much everything in between. He is also the director of the Australian Centre for Astrobiology. Martin goes every year to the Pilbara to work on the earliest biosignatures of life on the Earth.

BIOLOGIST: Dr. Carin Bondar: Carin Bondar is a Canadian biologist, author, university-lecturer, and television personality. She is a host of *Outrageous Acts of Science, Stephen Hawking's Brave New World,* and *World's Oddest Animal Couples*. Her work focuses on increasing science literacy and communication, and STEM education for girls. She is an adventurer and explorer, having co-discovered 7 new species of beetles and snails in the remote jungles of Borneo.

HISTORIAN: Professor David Christian: David Christian is a distinguished professor in modern history at Macquarie University in Australia and the co-founder, with Bill Gates, of The Big History Project, which has built a free online syllabus on the history of the universe that unites different disciplines and is taught in schools all over the world. He received his doctorate from the University of Oxford and is a Fellow of the Australian Academy of the Humanities. He has given many keynote speeches, including Davos and TED, where his talk 'The history of our world in 18 minutes' has been viewed over seven million times.

HISTORIAN: Professor Ian Miller: Ian Miller is a history professor at Harvard, Boston USA. Ian was the co-chair of Harvard and Cambridge University's Energy History project (2011-2016). The project explored how the historical study of energy use and transformation an widen perspectives on economic, social, and environmental processes in the past. It also served as a forum for the historical discussion of energy in all its forms in a global and comparative context.

CLIMATE SCIENTIST: Professor Katharine Hayhoe: Katharine Hayhoe is an atmospheric scientist whose research focuses on understanding what climate change means for people and the places where we live. She is the Chief Scientist for The Nature Conservancy and a Horn Distinguished Professor & Endowed Professor of Public Policy and Public Law in the Dept. of Political Science at Texas Tech University. Katharine has been named one of TIME's 100 Most Influential People, the United Nations Champion of the Environment, and the World Evangelical Alliance's Climate Ambassador.

CLIMATE SCIENTIST: Emeritus Professor Will Steffen: Internationally renowned Earth System scientist. Emeritus Professor Will Steffen served on the Australian Multi-Party Climate Change Committee (MPCCC) in 2010-11 and is currently a Councillor with the Climate Council of Australia. He is a Senior Fellow at the Stockholm Resilience Centre, Sweden, and a member of the Anthropocene Working Group. From 1998 to mid-2004, Steffen served as Executive Director of the International Geosphere-Biosphere Programme, based in Stockholm.

ARCTIC AQUATIC ECOLOGIST: Dr Katey Walter Anthony: Katey Walter Anthony's research focuses on methane and carbon dioxide fluxes in arctic lakes and wetlands in Alaska and Siberia, and the processes involved in greenhouse gas emissions from lakes, including permafrost thaw, geology, and changes in lake area.

CLIMATE SCIENTIST: Dr Joëlle Gergis: Dr Joëlle Gergis is an award-winning climate scientist and writer from the Australian National University. She is an internationally recognised expert in Australian and Southern Hemisphere climate variability and change; based in the Australian Research Council (ARC) Centre of Excellence for Climate Extremes. Her research focuses on providing a long-term historical context for assessing recently observed climate variability and extremes. She is a lead author on the UN Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report Climate Change 2022: The Physical Science Basis.

TLA-O-QUI-AHT TRIBAL PARK GUARDIAN: Gisele Martin: Gisele Maria Martin (they/she) is an Indigenous Cultural Lifeways and Tla-o-qui-aht Tribal Parks Guardian, public speaker, educator, guide, ocean-going traditional canoe skipper, writer, photographer and artist.

ECOLOGIST: Professor Suzanne Simard: Suzanne Simard is a Professor of Forest Ecology at the University of British Columbia and the author of "Finding the Mother Tree: Discovering the Wisdom of the Forest." Suzanne is a pioneer on the frontier of plant communication and intelligence; and has been hailed as a scientist who conveys complex, technical ideas in a way that is dazzling and profound. Her work has influenced filmmakers (the Tree of Souls in James Cameron's *Avatar*) and her TED talks have been viewed by more than 10 million people worldwide.

CARBON CAPTURE SCIENTIST: Dr Phil De Luna: Phil De Luna (Ph.D, Materials Science) is a world-leading expert in carbon conversion technologies, artificial photosynthesis, clean energy materials, and machine learning for materials discovery. De Luna is currently the Vice Chair of Carbon Management Canada, a carbontech non-profit, and a Director at a Canadian national lab in Toronto.

SOLAR ENTREPRENEUR: Andy McCarthy: Andy McCarthy is a lifelong advocate for renewable energy, electric vehicles, a smarter and more responsive grid, and the economic and social opportunities that exist within the energy transition. He is passionate about creating improved social and environmental outcomes, diversity and inclusion in the workplace, and raising awareness of mental health and wellbeing. The founder of Gippsland Solar - which was acquired by RACV in December 2019 - Andy still leads the company as CEO and Director of RACV Solar.

HOW TO USE THIS STUDY GUIDE

Carbon – The Unauthorised Biography is suitable for secondary students undertaking:

- **Year 7 – 10 Science**
- **Senior Biology**
- **Senior Chemistry**
- **Senior Physics**
- **Year 7-10 Media Arts**

with further links to the Cross-curricular priority of Sustainability. In addition, the activities found within this Study Guide will have applications across Humanities and Social Sciences – specifically, [Modern] History and Geography – and English. While these activities are arguably unsuited for pure application within these subjects, there are numerous opportunities for cross-curricular collaborations across subjects, particularly in middle school.

This Study Guide has been divided into five topics, roughly corresponding to this quote: "the epic saga of how [carbon] was born in the violent heart of a star, sparked the earliest life and rode the journeys of evolution, and how she captures the sun's energy in photosynthesis, fuels our modern world, and keeps our planet's atmosphere in delicate balance." These topics are:

- **The birth of carbon**
- **Carbon-based life**
- **Embodied sunlight**
- **Fuelling our modern world**
- **Is carbon the enemy?**

Each of these five topics contains three loosely connected sub-activities. Each sub-activity identifies the year levels it is best suited to. While these activities are written independently, there are connections between and across topics to benefit classes that work through each activity in order. That said, teachers are encouraged to pick and choose activities that suit their curricular priorities and adapt activities to better suit the background knowledge and experience of their students. In addition, it's possible to adapt the activities to suit the year levels identified as required.

Quotes and specific sections from the documentary have been identified with timecodes in the form **[hours : minutes : seconds]** to assist teachers in locating the relevant excerpt from the program.

In addition, these five topics are preceded by a **Terminology** section which students should completed before commencing the subsequent activities, and followed by a **Summary** task which can be completed after students have engaged with the documentary and relevant activities.

Curriculum links have been identified across the subsequent pages. Teachers are advised to consult the Australian Curriculum online at https://www.australiancurriculum.edu.au/ and curriculum outlines relevant to their state or territory for further information.

CURRICULUM LINKS

Relevant Content Descriptors for Science

SCIENCE UNDERSTANDING		
Year 7	**Earth and space science:** Some of Earth's resources are renewable, including water that cycles through the environment, but others are non-renewable	ACSSU116
Year 9	**Biological sciences:** Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems	ACSSU176
Year 10	**Earth and space sciences:** Global systems, including the carbon cycle, rely on interactions involving the biosphere, lithosphere, hydrosphere and atmosphere	ACSSU189

SCIENCE AS A HUMAN ENDEAVOUR		
Year 7	**Use and influence of science:** Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations	ACSHE120
Year 9	**Use and influence of science:** Values and needs of contemporary society can influence the focus of scientific research	ACSHE228
Year 10	**Use and influence of science:** Values and needs of contemporary society can influence the focus of scientific research	ACSHE230

SCIENCE INQUIRY SKILLS		
Year 7	**Communicating:** Communicate ideas, findings and evidence based solutions to problems using scientific language, and representations, using digital technologies as appropriate	ACSIS133
Year 9	**Evaluating:** Critically analyse the validity of information in primary and secondary sources and evaluate the approaches used to solve problems	ACSIS172
	Communicating: Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations	ACSIS174
Year 10	**Evaluating:** Critically analyse the validity of information in primary and secondary sources and evaluate the approaches used to solve problems	ACSIS206
	Communicating: Communicate scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions and representations	ACSIS208

Relevant Content Descriptors for Senior Biology

SCIENCE UNDERSTANDING		
Unit 1	Biodiversity includes the diversity of species and ecosystems; measures of biodiversity rely on classification and are used to make comparisons across spatial and temporal scales	ACSBL015
	Human activities (for example, over-exploitation, habitat destruction, monocultures, pollution) can reduce biodiversity and can impact on the magnitude, duration and speed of ecosystem change	ACSBL028
	Models of ecosystem interactions (for example, food webs, successional models) can be used to predict the impact of change and are based on interpretation of and extrapolation from sample data (for example, data derived from ecosystem surveying techniques); the reliability of the model is determined by the representativeness of the sampling	ACSBL029
Unit 2	Photosynthesis is a biochemical process that in plant cells occurs in the chloroplast and that uses light energy to synthesise organic compounds; the overall process can be represented as a balanced chemical equation	ACSBL052

SCIENCE AS A HUMAN ENDEAVOUR		
Unit 1 & 2	Advances in science understanding in one field can influence other areas of science, technology and engineering	ACSBL010
	The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations	ACSBL011
	Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions	ACSBL013
	Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability	ACSBL014

SCIENCE INQUIRY SKILLS		
Unit 1 & 2	Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes	ACSBL001
	Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships; qualitatively describe sources of measurement error, and uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions	ACSBL004
	Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments	ACSBL005
	Select, construct and use appropriate representations, including classification keys, food webs and biomass pyramids, to communicate conceptual understanding, solve problems and make predictions	ACSBL006
	Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports	ACSBL007

Relevant Content Descriptors for Senior Chemistry

SCIENCE UNDERSTANDING		
Unit 1	Atoms can be modelled as a nucleus surrounded by electrons in distinct energy levels, held together by electrostatic forces of attraction between the nucleus and electrons; atoms can be represented using electron shell diagrams (all electron shells or valence shell only) or electron charge clouds	ACSCH018
	The properties of atoms, including their ability to form chemical bonds, are explained by the arrangement of electrons in the atom and in particular by the stability of the valence electron shell	ACSCH020
	Isotopes are atoms of an element with the same number of protons but different numbers of neutrons; different isotopes of elements are represented using atomic symbols	ACSCH021
	Isotopes of an element have the same electron configuration and possess similar chemical properties but have different physical properties, including variations in nuclear stability	ACSCH022
Unit 3	Chemical systems may be open or closed and include physical changes and chemical reactions which can result in observable changes to the system	ACSCH089
	All physical changes are reversible, whereas only some chemical reactions are reversible	ACSCH090

SCIENCE AS A HUMAN ENDEAVOUR		
Unit 1 & 3	Advances in science understanding in one field can influence other areas of science, technology and engineering	ACSCH010
	The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations	ACSCH011
	Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions	ACSCH013
	Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability	ACSCH014

SCIENCE INQUIRY SKILLS		
Unit 1 & 3	Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes	ACSCH001
	Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships; qualitatively describe sources of measurement error, and uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions	ACSCH004
	Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments	ACSCH005
	Select, construct and use appropriate representations, including classification keys, food webs and biomass pyramids, to communicate conceptual understanding, solve problems and make predictions	ACSCH006
	Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports	ACSCH007

Relevant Content Descriptors for Senior Physics

SCIENCE UNDERSTANDING		
Unit 1	The nuclear model of the atom describes the atom as consisting of an extremely small nucleus, which contains most of the atom's mass and is made up of positively charged protons and uncharged neutrons surrounded by negatively charged electrons	ACSPH026
	Some nuclides are unstable and spontaneously decay, emitting alpha, beta and/or gamma radiation over time until they become stable nuclides	ACSPH028
	Alpha, beta and gamma radiation have sufficient energy to ionise atoms	ACSPH030
	Alpha and beta decay are examples of spontaneous transmutation reactions, while artificial transmutation is a managed process that changes one nuclide into another	ACSPH032
	Nuclear fusion is a reaction in which light nuclides combine to form a heavier nuclide, with the release of energy	ACSPH035

SCIENCE AS A HUMAN ENDEAVOUR		
Unit 1	Advances in science understanding in one field can influence other areas of science, technology and engineering	ACSPH010
	The use of scientific knowledge is influenced by social, economic, cultural and ethical considerations	ACSPH011
	Scientific knowledge can enable scientists to offer valid explanations and make reliable predictions	ACSPH013
	Scientific knowledge can be used to develop and evaluate projected economic, social and environmental impacts and to design action for sustainability	ACSPH014

SCIENCE INQUIRY SKILLS		
Unit 1	Identify, research and construct questions for investigation; propose hypotheses; and predict possible outcomes	ACSPH001
	Represent data in meaningful and useful ways; organise and analyse data to identify trends, patterns and relationships; qualitatively describe sources of measurement error, and uncertainty and limitations in data; and select, synthesise and use evidence to make and justify conclusions	ACSPH004
	Interpret a range of scientific and media texts, and evaluate processes, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments	ACSPH005
	Select, construct and use appropriate representations, including classification keys, food webs and biomass pyramids, to communicate conceptual understanding, solve problems and make predictions	ACSPH006
	Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports	ACSPH007

Relevant Content Descriptors for Geography

KNOWLEDGE AND UNDERSTANDING		
Year 7	Causes, impacts and responses to an atmospheric or hydrological hazard	ACHGK042
Year 8	Ways of protecting significant landscapes	ACHGK052
Year 10	Human-induced environmental changes that challenge sustainability	ACHGK070
	Environmental world views of people and their implications for environmental management	ACHGK071
	The application of systems thinking to understanding the causes and likely consequences of the environmental change being investigated	ACHGK073
	The application of geographical concepts and methods to the management of the environmental change being investigated	ACHGK074

GEOGRAPHICAL SKILLS		
Year 7-10	**Observing, questioning and planning**	
	Develop geographically significant questions and plan an inquiry that identifies and applies appropriate geographical methodologies and concepts	ACHGS047 ACHGS055 ACHGS063 ACHGS072
	Collecting, recording, evaluating and representing	
	Evaluate sources for their reliability, bias and usefulness and select, collect, record and organise relevant geographical data and information, using ethical protocols, from a range of appropriate primary and secondary sources	ACHGS048 ACHGS056 ACHGS064 ACHGS073
	Represent multi-variable data in a range of appropriate forms, for example scatter plots, tables, field sketches and annotated diagrams, with and without the use of digital and spatial technologies	ACHGS049 ACHGS057 ACHGS065 ACHGS074
	Interpreting, analysing and concluding	
	Apply geographical concepts to synthesise information from various sources and draw conclusions based on the analysis of data and information, taking into account alternative points of view	ACHGS052 ACHGS060 ACHGS068 ACHGS077
	Communicating	
	Present findings, arguments and explanations in a range of appropriate communication forms, selected for their effectiveness and to suit audience and purpose; using relevant geographical terminology, and digital technologies as appropriate	ACHGS054 ACHGS062 ACHGS070 ACHGS079

Relevant Content Descriptors for History

HISTORICAL KNOWLEDGE AND UNDERSTANDING		
Year 10	**The environment movement (1960s – present)**	ACDSEH125
	The intensification of environmental effects in the twentieth century as a result of population increase, urbanisation, increasing industrial production and trade	
	Responses of governments, including the Australian Government, and international organisations to environmental threats since the 1960s, including deforestation and climate change	ACDSEH128

HISTORICAL SKILLS		
Year 10	**Historical questions and research**	
	Identify and select different kinds of questions about the past to inform historical inquiry	ACHHS184
	Identify and locate relevant sources, using ICT and other methods	ACHHS186
	Analysis and use of sources	
	Process and synthesise information from a range of sources for use as evidence in an historical argument	ACHHS188
	Perspectives and interpretations	
	Identify and analyse different historical interpretations (including their own)	ACHHS191
	Explanation and communication	
	Develop texts, particularly descriptions and discussions that use evidence from a range of sources that are referenced	ACHHS192

Relevant Content Descriptors for Media Arts

CONTENT DESCRIPTIONS		
Year 7–8	Experiment with the organisation of ideas to structure stories through media conventions and genres to create points of view in images, sounds and text	ACAMAM066
	Analyse how technical and symbolic elements are used in media artworks to create representations influenced by story, genre, values and points of view of particular audiences	ACAMAR071
Year 9–10	Experiment with ideas and stories that manipulate media conventions and genres to construct new and alternative points of view through images, sounds and text	ACAMAM073
	Evaluate how technical and symbolic elements are manipulated in media artworks to create and challenge representations framed by media conventions, social beliefs and values for a range of audiences	ACAMAR078

Cross-Curricular Priorities under the Sustainability heading

- The biosphere is a dynamic system providing conditions that sustain life on Earth.
- All life forms, including human life, are connected through ecosystems on which they depend for their wellbeing and survival.
- Sustainable patterns of living rely on the interdependence of healthy social, economic and ecological systems.
- World views that recognise the dependence of living things on healthy ecosystems, and value diversity and social justice, are essential for achieving sustainability.
- World views are formed by experiences at personal, local, national and global levels, and are linked to individual and community actions for sustainability.
- The sustainability of ecological, social and economic systems is achieved through informed individual and community action that values local and global equity and fairness across generations into the future.
- Actions for a more sustainable future reflect values of care, respect and responsibility, and require us to explore and understand environments.
- Designing action for sustainability requires an evaluation of past practices, the assessment of scientific and technological developments, and balanced judgements based on projected future economic, social and environmental impacts.
- Sustainable futures result from actions designed to preserve and/or restore the quality and uniqueness of environments.

TERMINOLOGY [YEAR 7 – 12]

Before commencing the following activities associated with *Carbon – The Unauthorised Biography,* discuss with your class your understanding of the following terms used in the documentary. After this discussion, record definitions and explanations of this terminology, researching where required.

- **Carbon**
- **Carbon Dioxide**
- **Electrons**
- **Carbon-Carbon bonds**
- **Photosynthesis**
- **Photons**
- **Ions**
- **Coal**
- **Fossil Fuels**
- **Polymers**
- **Plastics**
- **The Greenhouse Effect**
- **Climate Change**
- **Methane**
- **Permafrost**
- **Biodiversity**
- **Direct Air Capture**

THE BIRTH OF CARBON

***Carbon – The Unauthorised Biography* begins with birth. We follow Carbon – given voice and personality – as her life cycle mirrors the creation of human life. Across the following activities, you will explore how carbon is born, how carbon travels across the universe and even travel back to the dawn of the universe and search for carbon in the intensity and chaos following the Big Bang.**

Understanding Carbon. Year 7 – 9

During and after watching *Carbon – The Unauthorised Biography,* complete the following table with notes and observations on carbon and its impact on our world

After completing this table, gather into a small group (with 2 or 3 other students) and compare your **KNOW** and **NEW AND INTERESTING** columns, collating your information into a fact sheet on carbon.

Then choose one **WANT TO KNOW** question from your group – try to select the most challenging and interesting question! – and research the answer to this question as a group.

YOU CAN COMPLETE THIS PAGE IN ACROBAT

YOUR NAME:

KNOW	NEW AND INTERESTING	WANT TO KNOW
What did you learn about carbon from the program? List facts and observations below.	Choose two interesting facts about carbon that you learned from the program.	After watching the documentary, what's a question you have about carbon?

The Carbon Cycle. Year 7 – 12

Carbon is one of the most abundant elements found in nature, both in the wider universe and on Earth. Where does carbon come from, and how does it circulate within our atmosphere?

This process is referred to as the carbon cycle, and we are privy to much of its intricacies across the course of the documentary *Carbon – The Unauthorised Biography.* For this activity, you'll represent this all-important cycle in three different ways.

The carbon cycle shows that we're all irretrievably connected … we're all in this together.
- Suzanne Simard, **[1:11:11]**

Before beginning this activity, get into a group with two or three other students. Examine and discuss **one** of the following infographics and websites on the carbon cycle, as assigned by your teacher:

- 'Infographic: Earth's carbon cycle is off balance ', *NASA,* <https://climate.nasa.gov/climate_resources/136/infographic-earths-carbon-cycle-is-off-balance/>
- 'Carbon cycle', *Understanding Global Change,* <https://ugc.berkeley.edu/background-content/carbon-cycle/>
- 'The Carbon Cycle', *National Geographic,* <https://www.nationalgeographic.org/photo/carbon-cycle/>
- Fabiola Soares, 'Carbon cycle and greenhouse effect – A scientific infographic', *Mind the Graph,* <https://mindthegraph.com/blog/carbon-cycle-greenhouse-effect/>, 21 May 2019

Afterwards, each group will share their infographic with the class and what they learned from it – consider both the scientific facts you learned, and how the infographic chose to represent them.

Discuss as a class which of these resources you found the most informative and useful, and why. What did you learn from these resources? Did anything surprise you?

As a group, reflect upon this discussion: What information did you learn from the other groups' infographics that wasn't contained in the one assigned to your group?

In your group, produce three different representations of the carbon cycle. Each representation will be targeted at a different audience, so its content and presentation should differ to accommodate your reader. Before beginning work on this project, carefully assign roles to your group members.

- **Your first representation** will be targeted at lower primary-aged students being introduced to the concept. Ensure that the cycle is simplified, the language is accessible and the visuals are engaging.
- **Your second representation** will be aimed at middle school students. This representation should be more detailed than the first representation and use more specific, sophisticated vocabulary.
- **Your third and final representation** will be more scientifically rigorous; think upper secondary high school students or even first year university students. As such, the priority should shift towards scientific specifics rather than engaging visuals[1].

Ensure that your group works together, comparing each representation as you go. Try to avoid having group members work entirely on one representation of the three without collaborating with those working on the other representations.

Having completed the task, share your representations with your class and individually reflect on the following questions.

- How did you work as a group? What would you change if you were to complete this task again?
- Which representation do you feel was best suited to its target audience?
- Which representation do you feel was the most accurate and effective, regardless of audience?
- How did these representations of the carbon cycle compare to the resources you looked at prior to preparing your representation?
  How do you think these resources may have influenced the choices you made as a group?

Creating Carbon. Year 11 – 12

Carbon – The Unauthorised Biography details the origins of its eponymous element. As astrophysicist Professor Tamara Davis explains (from **[0:04:50]** to **[0:06:48]**), the process for creating carbon isn't easy:

You've got to have two heliums bash together, which forms beryllium, but that's really unstable. It doesn't last for long. It basically disintegrates as soon as it is born and in that fraction of a second – a millionth of a billionth of a second when it's still hanging around – it needs to be hit by another helium and when that happens, then you form carbon.

- Using the conventions of nuclear physics, represent the reaction described above.
- This reaction is often called the 'triple-alpha process'. Research this process and explain the origins of the name and its relationship to your representation of this reaction.
- Explain why beryllium is "really unstable" in the triple-alpha process. Why can the beryllium element be found naturally if it's so unstable in this context?
- Can we replicate the triple-alpha process artificially? Why or why not? Support your answer with scientific reasoning.

Stardust. Year 7 – 12

The carbon cycle refers specifically to the cycle of carbon within the Earth's atmosphere. But parts of *Carbon – The Unauthorised Biography* explore the exciting origins of carbon – born in the fiery core of stars and forming the foundation of life itself! As she herself tells us, "Your body, your mind, they are born of my collisions. You are made of stardust. So is almost everything else." **[0:09:19]**

Produce an infographic that could supplement your representations from the preceding activity, **The Carbon Cycle**, by representing the origins of carbon in the universe and how it found its way to the Earth's surface.

Try to explore a more creative infographic than those from the prior activity – perhaps you could take inspiration from the documentary's representation of Carbon as a living being? Or try something entirely different!

CARBON-BASED LIFE

"It's my greatest achievement," says Carbon (Sarah Snook). "The chemical chain that became the code for life, forever re-formed in every single cell of every living thing." [0:17:19]

As *Carbon – The Unauthorised Biography* makes very clear, "without [carbon], life would not exist." [0:14:26] The documentary delves into the distant past, as chemical reactions in volcanic hot springs link the element together into the backbone of life as we know it – DNA.

Across these three activities, you'll investigate the chemical composition of DNA, explore the significance of carbon in organic compounds and consider if alternatives to carbon exist.

The Code for Life.[2] *Year 9 – 10*

As the documentary makes clear, the way carbon bonds with other molecules is critical to the formation and function of DNA – deoxyribonucleic acid – which forms the backbone for life. In this activity, we're going to explore *Carbon – The Unauthorised Documentary*'s representation of carbon as key to life – and specifically DNA – by researching and even building it ourselves!

In pairs, watch the following 5:23 YouTube video on the nature and composition of DNA. Take brief notes of the relevant points; this will help set you up for the activity that follows.

- 'What is DNA and How Does it Work?', *Stated Clearly,* <https://www.youtube.com/watch?v=zwibgNGe4aY>, 31 August 2021

To better understand DNA, we're going to use some tasty snacks to model it physically. Your teacher will provide your pair with the following resources (don't eat them!):

- **Four colours of gumdrops (or similar soft lollies)**
- **Liquorice**
- **Toothpicks**

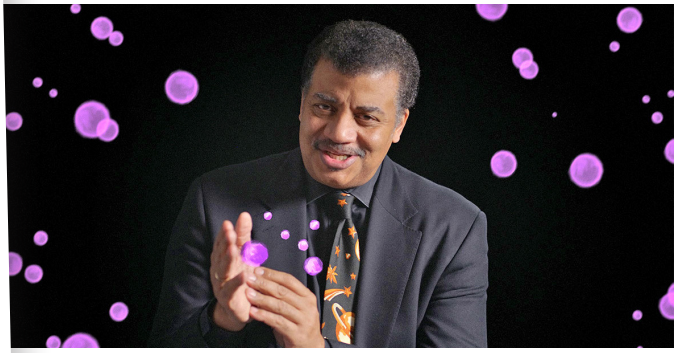
Decide which colours each of the provided gumdrops/lollies represent of the four DNA nucleobases (adenine, cytosine, guanine and thymine).

Use the provided materials to create a model for DNA. You should use the liquorice as the frame for your DNA 'ladder', with toothpicks connecting matching nucleobases, before twisting the structure into DNA's famous double helix structure. Once completed, swap your model with another pair to confirm each other's model and connections.

Discuss the following questions as a class:

- What do each of the components in your model represent?
- Is this an effective representation of a DNA double helix? Why or why not?
- What significance does carbon have in this model?

Propose a more advanced model for a DNA structure that would explicitly identify the significance of carbon in the DNA chain. If time permits, try to produce this model with the materials provided!

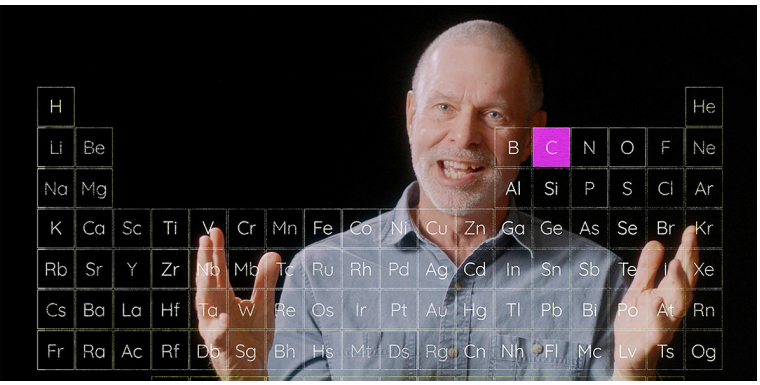


Organic Chemistry. Year 11–12

In the documentary, we learn about how carbon is "always up for a dance" – referring to the element's spectacular propensity for bonding with a whole range of other elements. As Robert Hazen explains:

Carbon is a pretty promiscuous atom. She likes to hook up with just about any other element in the periodic table. I mean, you got a carbon here and she, she, she loves to bond with hydrogen. That's, that's a big one. You find a lot of carbon-hydrogen bonds but she goes over to oxygen. She takes nitrogen. She does phosphorous and she'll go down she'll bond with iron and nickel and cobalt, zirconium. **[0:13:07]**

- What does Hazen mean by "promiscuous" in this context? Is this a useful way of conceptualising the concept he's trying to convey?
- What is it about carbon that allows it to, uniquely, bond more successfully and with more versatility than any other element?
- Compare carbon's tendency to bond with other elements to another commonly found element. What atomic properties makes carbon more receptive to bonding than this element?



Carbon's 'promiscuity' underpins organic chemistry. Organic chemistry is an important field of chemistry, but it could just as easily have been called *carbon* chemistry. Organic chemists study – as you might expect – organic compounds, but organic compounds are defined as those containing carbon as a crucial component.

Answer the following questions relating to the field of organic chemistry. You may be able to draw upon your prior knowledge from your science studies, but research is encouraged; some links are provided further down the page to give you a head-start.

- What characterises a covalent bond? How does this compare to a *polarised* covalent bond, and why is this relevant to organic compounds?
- Some key organic compounds are listed below. Write a short definition of each:
  - **Enzymes**
  - **Lipids**
  - **Carbohydrates**
  - **Adenosine triphosphate (ATP)**
- Contrast and compare the properties of organic and inorganic compounds; consider their solubility, conductivity, flammability and the forces and bonds that exist between molecules.
- Select one of the organic compounds listed below and provide a specific description of how its bonds operate, considering its molecular orbitals. Your description should be supported by a diagram.
  - **Methane**
  - **Ethylene**
  - **Acetylene**

Helpful links:

- 'Organic chemistry', *Khan Academy,* <https://www.khanacademy.org/science/organic-chemistry>
- 'Organic Chemistry Portal', *Organic Chemistry Portal,* <https://www.organic-chemistry.org/>
- 'Introduction', *University of Sydney,* <https://www.sydney.edu.au/science/chemistry/~george/intro.html>

Carbon's Cousins? Year 11–12

As established in the preceding activities, carbon is integral to organic compounds – including DNA and, thus, life itself. But do things have to be this way? Carbon's unique properties – explored in **Organic Chemistry** – position it as a uniquely important element. In this case, you'll investigate just how unique carbon is.

For this task, you'll research and prepare a scientific report (1000 – 1500 words in length) exploring the possibility of another element substituting for carbon in organic compounds, especially DNA. Some scientists have proposed silicon as an alternative; what is it about silicon that makes it a plausible substitute for carbon? What conditions would need to exist for it to effectively replace carbon. And are there any other known elements that could fulfil a similar role – why or why not?

Telling Carbon's Story. Year 7–10

Carbon – The Unauthorised Biography is an engaging take on what could be very dry subject matter; core scientific principles are presented to the audience in an engaging fashion buoyed by enthusiasm, colour and creativity.

For this activity, you'll examine the documentary from a filmmaker's perspective, considering the aesthetic and creative choices made by directors Daniella Ortega and Niobe Thompson and evaluating how they shape the film's effectiveness and effect on audiences.

After watching the film, answer the following questions individually:

- The documentary uses a number of interviewees – 'talking heads.'
  What sort of interviewees were chosen for *Carbon – The Unauthorised Biography* – is there a common theme across those interviewed?
  What editing and cinematographic choices are used to convey enthusiasm and dynamism in these sections?
  Compare the documentary's representation of talking heads to an analogous documentary, identifying the similarities and differences.
- The filmmakers have chosen to personify Carbon, with actress Sarah Snook's narration creating an overarching narrative.
  How does this choice affect your experience of the documentary as a viewer?
  Why might the filmmakers have made this creative decision?
  How do you think the structure of the documentary would have differed had *Carbon – The Unauthorised Biography* had a more conventional framing?
- How was the animation used in the documentary? Much of the animation is hand drawn and artistically represented. Discuss the effectiveness of animation in this context and what alternative methods could have been used to convey this information?
- Is *Carbon – The Unauthorised Biography* an educational film or an advocacy film – or both?
  Justify your answer with specific references to aesthetic and narrative choices made in the documentary, including a definition of the difference between the two modes.

After answering each of these questions, discuss your answers as a class.

EMBODIED SUNLIGHT

"When you're looking at a tree," says Dr Carin Bondar in *Carbon – The Unauthorised Biography,* "what you're actually looking at is sunlight – embodied sunlight – because plants have this ability to pull carbon right out of the air and use the energy from sunlight to make it into themselves. So, in this way, trees are the air. Thanks to photosynthesis." [0:21:37]

In the Creating Carbon activity, we've seen the nuclear processes required to form carbon: processes that occur in the fiery depths of stars like our Sun. As this documentary reveals, the relationship between the Sun and carbon goes even deeper. Across the subsequent activities, you'll study photosynthesis, consider solar power and compare it to other forms of renewable energy.

Photosynthesis. Year 7–10

"Photosynthesis is the most incredible process that nature ever invented." *Carbon – The Unauthorised Biography* provides a detailed explanation of photosynthesis by Dr Bondar from **[0:23:00]** to **[0:26:40]3**. Across this sequence, we bear witness to an exciting animation demonstrating how the sun's rays are converted into energy, unpacking the underpinning chemistry in the process.

After rewatching this sequence, answer the following questions (you may need to complete additional research):

1. Dr Bondar explains that "photons, or the energy packets from the sun, are being captured" by plants' leaves. What components of the plant are used in this process?
2. Provide a scientific explanation for what Dr Bondar means when she says that "these hydrogen ions are like little packets of sunshine."
3. These "little packets" are used in "a chemical Ferris wheel" to bond carbon into glucose molecules. Provide a brief explanation of the chemical reactions that create these molecules in the process of photosynthesis, identifying the reactants and products in each step.
4. Why is glucose, "the ultimate product of photosynthesis", important to plants' survival?

We can explore the impact of photosynthesis on plant growth with a simple experiment – either in the classroom or at home. Sprinkle an equal amount of seeds (grass, bean, basil or similar) into three different cups of potting mix, then cover with a thin layer of soil. Water each cup until it is moist and then place them in three different locations:

- In direct sunlight
- In indirect sunlight
- Out of the sun as much as possible

Over approximately two weeks, check in on each cup, watering as required and taking notes. What do you observe, and how does this compare to your expectations of the experiment?

Solar Power. Year 7 – 10

While much of *Carbon – The Unauthorised Biography* examines carbon's key role in fossil fuels – as you'll explore in more detail in the subsequent **Fuelling the Modern World** section of this Study Guide – carbon's importance to energy production isn't limited to its key role in coal and oil.

In the documentary, we're introduced to Andy McCarthy, a solar entrepreneur working on renewable energy in a region – the La Trobe Valley – dominated by coal. The excerpt focusing on McCarthy runs from **[1:15:45]** through **[1:18:56].**

- McCarthy states that "2010 wasn't the greatest time to be starting a renewable energy business". **[1:16:30]**
  What reasons does he give for expressing this sentiment?
- McCarthy goes on to talk about how solar power has "come a long way." **[1:17:10]**
  Conduct individual research then discuss as a class how solar power has changed in the last decade – considering opinions, uptake and the effectiveness of the technology.
- What does McCarthy mean when he states that his investment in solar energy is "not ideological at all"? **[1:17:45]**

Individually or as a class watch the following 8:48 YouTube video on the science behind solar power. As you watch the video, answer the questions that follow, pausing when required.

- 'How Do Solar Panels Work? (Physics of Solar Cells)', *The Science Asylum,* <https://www.youtube.com/watch?v=8RjGHmlOu58>, 5 January 2019
- What's the difference between a solar array, solar panel and solar cell?
- What are the layers that make up a solar cell?
- What scientific phenomenon does the anti-reflection coating use to reduce reflection?
- What is a semi-conductor and why is it important in a solar cell?
- What does 'doping' mean in the context of a solar cell?
- What elements are used to 'dope' silicon in a solar cell?
- What's the purpose of the metal grid and metal plate in the solar cell?
- Why is there a metal grid on 'top' and a metal plate on the 'bottom' of the cell?

*[Note: the following assumes you have completed the preceding **Photosynthesis** activity.]*

After answering these questions, join up with a partner and discuss the similarities and differences between the operation of solar cells as detailed in this video and how photosynthesis operates in nature.

Once you have completed this discussion and summarised your thoughts, refer to the following article:

- Richard Gaughan, 'Similarities of Solar Cell and Photosynthesis', *Sciencing,* <https://sciencing.com/similarities-solar-cell-photosynthesis-3733.html>, 25 April 2017

Are there are any points in the article you missed, or points that you brought up that aren't addressed in this link?

Renewable Energy. Year 7 – 10

Choose one of the following forms of renewable energy:

- **Wind**
- **Geothermal**
- **Biomass**
- **Hydropower**

…and compare its benefits and limitations compared to solar power. Consider the scientific foundations of your selected source of renewable energy – including, where relevant, its connections to carbon (both in terms of emissions and its roles in the chemical process of energy production) – and the associated economic, social and environmental impacts.

FUELLING OUR MODERN WORLD

"Every one of us lives in a carbon world," we're told by Dr Robert Hazen at the top of the documentary. "We have to learn to get along with carbon." [0:03:09]

That carbon world doesn't just stem from the carbon forming the core component of our cells and DNA; our modern infrastructure and industries rely on carbon-rich fuels formed millions and millions of years ago. *Carbon – The Unauthorised Biography* chronicles carbon's significance to these fossil fuels such as coal and oil; here, you'll explore their scientific origins and associated political complexities.

Fossil Fuel Formation. Year 7–12

"In Coal, I am the buried remnants of ancient forests. In Oil, I am the remains of ancient marine life, buried undersea. In Oil, I gain potency." **[0:37:47]**

So says Sarah Snook's personification of Carbon. As we'll explore later in this Study Guide, coal and oil are key components of modern life for many reasons. It's therefore important to understand the scientific processes that led to the creation of so much coal and oil – and why these so-called fossil fuels are becoming increasingly scarce.

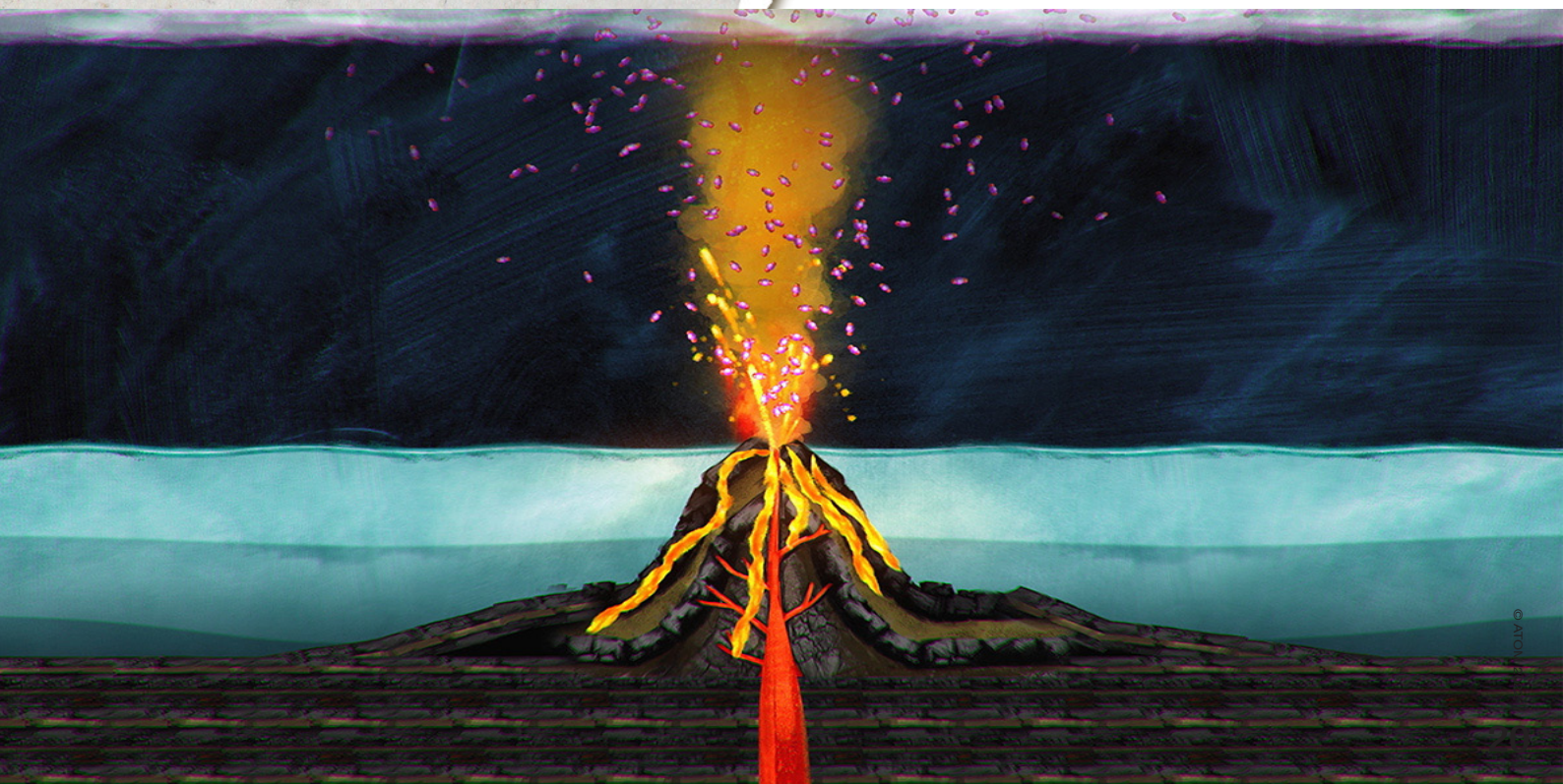
- For this task, create two infographics, each detailing the geological processes that led to the creation of coal and oil, respectively. These should be targeted at middle school students (or above) with some familiarity with scientific concepts.

The following links may assist you in generating your infographics:

- 'Petroleum', *National Geographic,* <https://www.nationalgeographic.org/encyclopedia/petroleum/>
- 'Coal Formation', *Energy Education,* <https://energyeducation.ca/encyclopedia/Coal_formation>, 4 January 2019
- Sarah Zielinski, 'Explainer: Where Fossil Fuels Come From', *ScienceNews for Students,* <https://www.sciencenewsforstudents.org/article/explainer-where-fossil-fuels-come>, 20 September 2018

After completing these two infographics, write a reflection based on the following prompts:

- Why does *Carbon – The Unauthorised Biography* state that "In oil, [carbon] gains potency"?
- What similarities and differences are there between the processes for forming coal and oil?
- How are these similarities and differences reflected in the chemical structures and function of these two fossil fuels?
- Why are coal and oil called fossil fuels; how do they resemble fossils?
- What other fossil fuels exist and how do they compare in formation and function to coal and oil?



Creating Coal. Year 10–12

One might imagine the accumulation of coal as a gradual geological process, with the substance accumulating at a linear rate as years pass. Not so; science tells us that there was an explosion of coal creation during the Carboniferous Period (the fifth interval of the Paleozoic Era, occurring roughly 300 million years ago). In *Carbon – The Unauthorised Biography,* geologist Dr Hazen outlines the process (from **[0:31:01]** to **[0:32:30]**):

So about 400 million years ago, life learned to creep on the land. And within tens of millions of years, you had forests on earth for the very first time. […] And so what happens, these forests grow and as they grow, the plants get tall, a tree like plants that were 30, 40, 50 feet tall, and they'd grow and then they'd die and they'd fall over …but they did something strange.

You know, if a tree falls over today in the woods, you come back two or three years later and the fungus has gotten in dissolves and it's just goes back to the soil. The trees would fall and they'd just sit there. They wouldn't rot in the same way. And, so, a tree would fall, another tree would fall and you got layer upon layer. And you'd get these accumulations of 50, a hundred, 200, 300 feet. And you find those fossils, these incredible fossils with leaves of plants that were growing 300 million years ago in these thick, thick forests on top of dead plants, …this has never happened before.

Dr Hazen is here referring to a popular explanation for this explosion of coal, crediting it to the inability for fungus of the period to break down lignin – an organic polymer that's believed to have evolved around this time. It's a fascinating account, and one supported by plenty of literature – see Robert Krulwich, 'The Fantastically Strange Origin of Most Coal on Earth', *National Geographic,* <https://www.nationalgeographic.com/science/article/the-fantastically-strange-origin-of-most-coal-on-earth>, 7 January 2016. But, as can be common in science, there are other theories as well.

A 2016 research article from Matthew P. Nelsen *et al* – published shortly after the aforementioned *National Geographic* article – "rejects this evolutionary lag hypothesis". This article is linked below, along with a summary more suitable for middle school students.

- Matthew P. Nelsen, William A. DiMichele, Shanan E. Peters, and C. Kevin Boyce, 'Delayed fungal evolution did not cause the Paleozoic peak in coal production', *PNAS,* <https://www.pnas.org/content/113/9/2442>, 1 March 2016
- Scott K. Johnson, 'Why was most of the Earth's coal made all at once?', *Ars Technica,* <https://arstechnica.com/science/2016/01/why-was-most-of-the-earths-coal-made-all-at-once/>, 23 January 2016

Refer to Nelsen's article (or Johnson's summary of same) to answer the following questions:

- What alternative explanation is offered by Nelsen for the Carboniferous explosion of coal?
- Is there more or less evidence to support Nelsen's hypothesis than the explanation from the documentary? Have the textbooks been altered to support the newer theory?
- Science, as a discipline, is built upon theories that support their underlying hypothesises with evidence and peer-tested experiments. Why might we then find situations like this where scientists have diverging explanations for the same phenomenon? How should we approach such situations as scientists?

Beyond the Industrial Revolution. Year 9–10

"In burning coal, you first seized my buried power," intones Carbon, "and when you did – it fuelled a revolution!" **[0:33:31]**

The documentary is here referring to the industrial revolution, a period from the late 18th to early 19th century where advanced manufacturing processes – powered by the efficiency of coal – transformed a number of countries' economies and societies. In this activity, we'll explore the after-effects of the industrial revolution, and how it has shaped modern science and society.

Carbon's significance, then, not only comes from understanding the scientific history of the world – but its social history, too. For this activity, you'll choose one of the following prompts to write a research essay (~1500 words) about. Your essay should pose an argument, supported by primary and secondary sources, supporting or rejecting the claim in the prompt.

- The industrial revolution could not have occurred without coal.
- Due to carbon emissions, the industrial revolution has had a net negative effect on society.
- Coal has had a more significant impact on modern history than oil.
- Fossil fuels have caused more wars in the past century than any other impetus.
- Carbon is the most important social issue of the 21st century.

IS CARBON THE ENEMY?

Carbon – The Unauthorised Biography **underlines the power and potential of carbon. But it's also quick to remind its audience that carbon – or carbon dioxide – has significant negative effects too.**

Carbon and Climate Change. Year 7–10

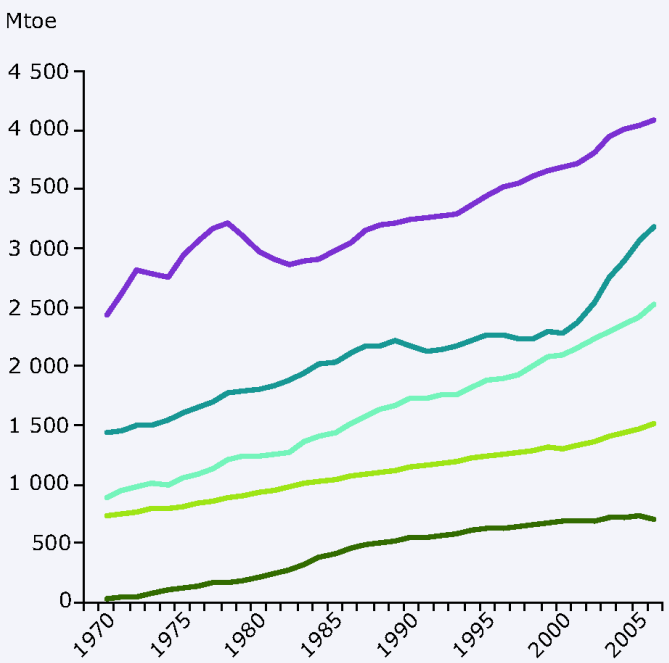
"If there's more carbon dioxide or more methane in the atmosphere, those are carbon-based gases," explains Dr Hazen in the documentary. "Then you warm things up. If there's less then you cool things down." **[0:53:37]**

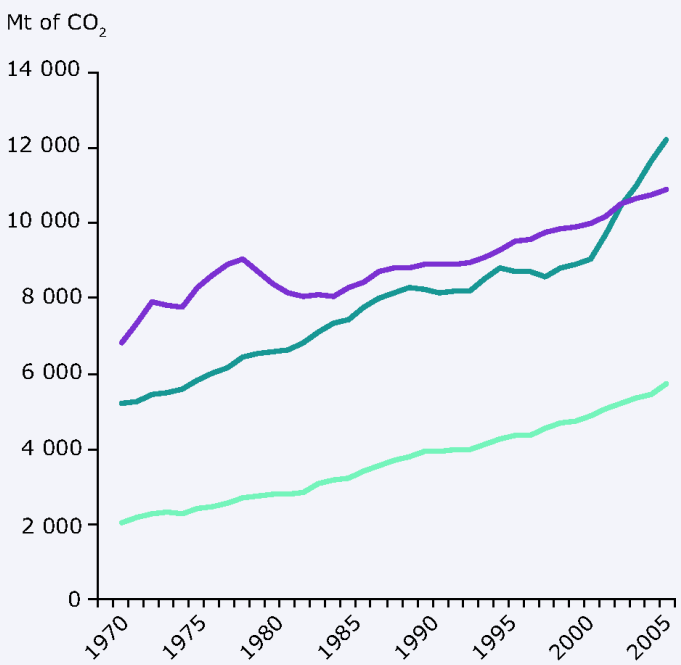
Or, as Neil de Grasse Tyson puts it: "You will create a level of warmth on this earth that civilization has never seen. And that's a problem." **[0:55:26]**

Carbon, then, is a key cause of climate change. As explained by the documentary, one of the defining characteristics of climate change is an increase in average global temperatures.

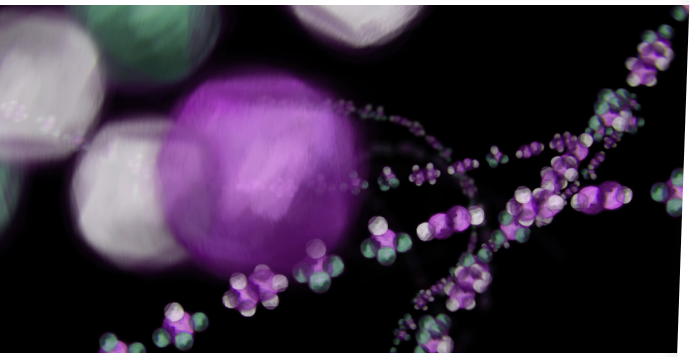
The graphs shown below plot, from 1969 to 2007, the world's primary energy use (measured in millions of tonnes of oil equivalent) and the world's CO2 emissions (measured in million of tonnes of CO2), both separated in fuel type.

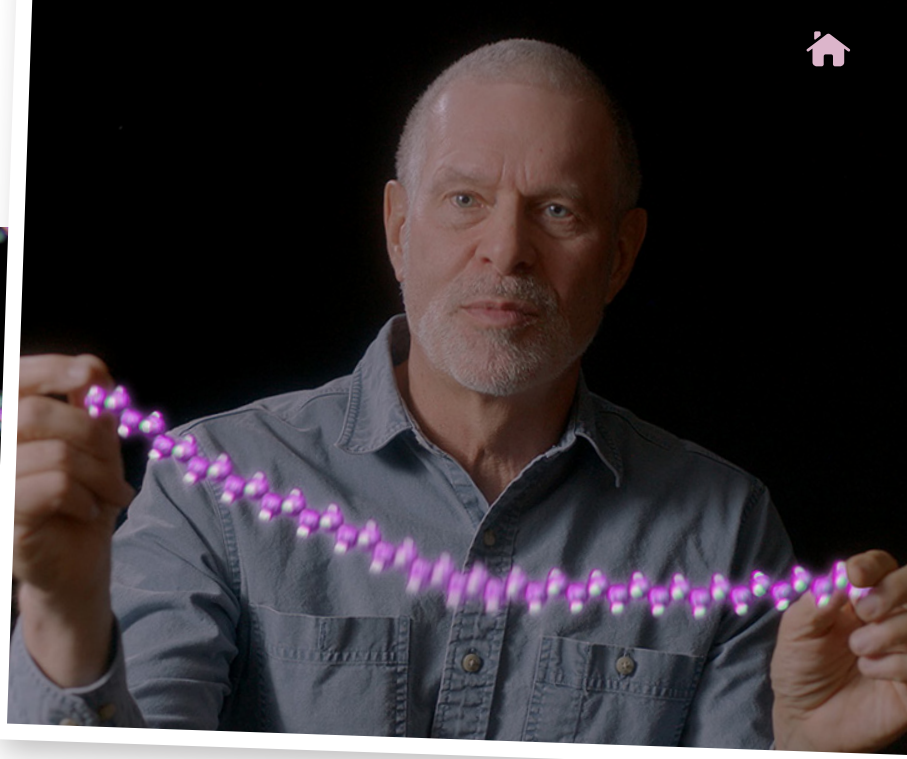
- In pairs, compare these graphs to the average global temperature over this period of time. What conclusions can you draw from these data?
- Collect comparable data on energy use, CO2 emissions and global temperatures since 2007, and link these data to a quantitative statement about the temperature trends observed and how this relates to the human impact on climate change.





Solid fuels · Liquid fuels · Gaseous fuels · Nuclear · Renewables and waste





In the documentary, Neil de Grasse Tyson's asserts that "I'm thinking don't blame carbon… you know, it's not carbon's fault! […] So now we say that's carbon, I'm saying it's carbon dioxide, please." **[0:55:26]**

Here, de Grasse Tyson is referring to the fact that CO2 emissions – rather than pure carbon – are the driving force behind contemporary climate change. Research the causes of carbon emissions and rank the following sources from largest to smallest contributor:

- Transportation (the fuel burned to power cars, buses, boats, planes)
- Agriculture (the carbon emissions from livestock and crop production)
- Domestic (caused by the burning of fuels to generate heat)
- Electricity (emissions from the burning of fossil fuels for electricity production)
- Forestry (consider the loss of carbon dioxide absorption caused by land clearing)

Discuss what key sources of carbon dioxide omissions are missing from this list, and present an argument as to which sources would be easier to reduce than others to limit the greenhouse effect.

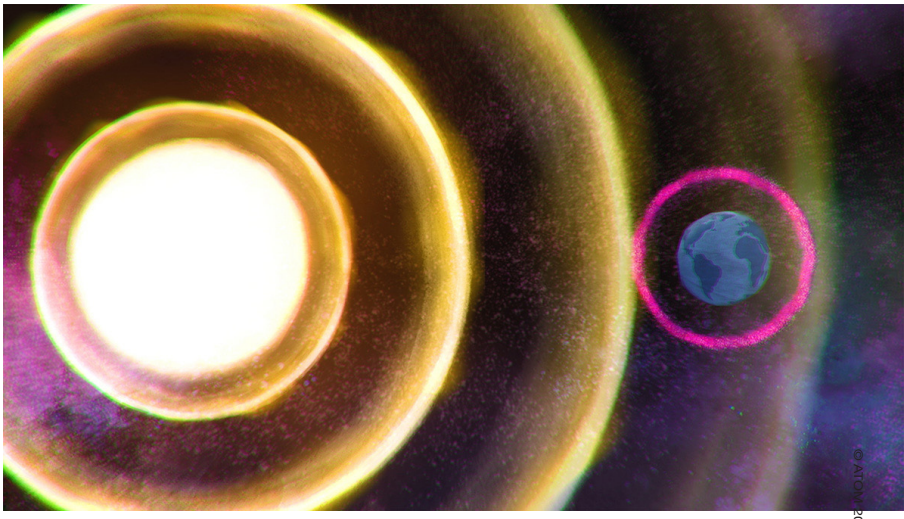
The documentary also explores other applications of carbon relevant to our environment. One such innovation are polymers. Materials scientist Mark Miodownik introduces us to this "strange unbreakable form." **[0:42:26]**

- What differences are there – if any – between polymers and plastics?
- Why are polymers so effective for industrial usage? Consider the chemical structure of human-derived polymers (polyethylene or polystyrene) in your response.
- What are man-made polymers created from and how does that process work?
- What are the environmental risks associated with human-derived polymers?

Discuss the short- and long-term impacts of the prevalence of polymers in modern society; the links below will aid you in preparing your response.

Useful links:

- Justin King, 'Environmental Problems Caused by Synthetic Polymers', *Sciencing,* <https://sciencing.com/environmental-problems-caused-by-synthetic-polymers-12732046.html>
- Jessica A. Knoblauch, 'Environmental toll of plastics', *Environmental Health News,* <https://www.ehn.org/plastic-environmental-impact-2501923191.html>, 9 April 2020
- Jonathan Trinastic, 'Plastic rock: the new anthropogenic marker in the geologic record', *Scitable,* <https://www.nature.com/scitable/blog/eyes-on-environment/plastic_rock_the_new_anthropogenic/>, 22 July 2015



Biodiversity and the Great Barrier Reef. Year 7 – 10

One of the threats posed by climate change as identified by *Carbon – The Unauthorised Biography* strikes close to home: the Great Barrier Reef.

Per Dr Joelle Gergis:

For instance, in a country like Australia, that we've now lost 50% of the Great Barrier Reef in just a handful of years… 50%, and it means that there are people that have kids right now that will never see that. They'll only learn about that from David Attenborough documentaries or archival footage that exists. **[1:06:13]**

This threat extends beyond the loss of a potential tourist attraction. One of the casualties of a changing climate is biodiversity; as Gisele Martin laments, "The legacy that [our ancestors] left us, that they dedicated their lives to was leaving, biodiversity." **[1:07:43]**

Research the Great Barrier Reef to develop an understanding of the 'biodiversity' of the reef; in other words, the number of different species that live in and around the reef.

Useful links:

- https://coral.org/coral-reefs-101/coral-reef-ecology/coral-reef-biodiversity/
- http://www.gbrmpa.gov.au/about-the-reef/animals
- https://www.coral-reef-info.com/coral-reef-plants/
- https://www.livescience.com/6290-great-barrier-reef.html

How many species are estimated to live on the Great Barrier Reef? How does this compare to other coral reefs around the world?

Create a poster or presentation featuring the different species found on the Great Barrier Reef. You may wish to use these categories as a guide[4]:

MARINE MAMMALS	BIRDS
SEA SNAKES	SHARKS
CRUSTACEANS	MOLLUSCS
SEA ANEMONES	JELLYFISH
MARINE TURTLES	CROCODILE
RAYS	ECHINODERMS
HARD CORAL	SOFT CORAL
SPONGES	FISHES

After completing your poster or presentation, identify some key interactions between these species – how do these organisms rely on one another for their survival? What might occur to the reef if one of these species were removed from the ecosystem? Discuss these questions with your class.

Discuss as a class the effect that climate change would have on this biodiversity, reflect upon your answers to the above questions.

What Is It Good For? Year 11 – 12

As the program explains, carbon – and the energy it produces – is a key component of modern warfare. As our Carbon incarnate explains, "Within oil I fuel lightning-fast innovations, weapons of war far stronger and deadlier than ever imagined." **[0:38:35]**

Carbon's association with war is not purely limited to the energy efficiency it provides to fuel weaponry. Many historical wars are described as 'oil wars', driven by one nation's desire for control over rich oil fields, though this descriptor is somewhat controversial.

For this activity, you'll investigate carbon – specifically, oil – and its significance to a modern historical conflict of your choosing. Select one of the following conflicts (or research another of your choice, with your teacher's permission):

- **The Chaco War between Bolivia and Paraguay (1932 – 1935)**
- **Germany's invasion of the Russian Caucasus (1941 – 1942)**
- **Japan's invasion of the Dutch East Indies (1941 – 1942)**
- **The Falklands War (1982)**
- **Iraq's invasion of Kuwait (1990)**
- **The U.S. invasion of Iraq (1993)**

Write a research essay (1200 – 1500 words) arguing that your chosen conflict is either fairly or unfairly characterised as an oil war, considering the importance of oil to the nations involved and the politics of the time. Your argument should be supported by fully-referenced primary and secondary sources.

Carbon Emission and Sequestration. Year 11–12

Towards the end of *Carbon – The Unauthorised Biography,* we meet Steve Oldham, CEO of carbon-capture company Carbon Engineering. Oldham's company "captures carbon dioxide directly out of the atmosphere."5

The documentary presents innovations like those of Carbon Engineering as a potential solution to the carbon-dioxide-driven climate crisis, but – as noted by Dr Phil de Luna – "these direct air capture facilities need to scale up and they need to scale out. They need to not only increase in size, but they also need to increase in number." **[1:14:10]**

For this activity, you'll compare the current efficacy – and potential – of carbon sequestration facilities with the effects of reducing carbon emissions.

- What is the science behind carbon sequestration? How has it changed over the past decade and what potential is there for processes to be improved?
- How many carbon sequestration facilities like Carbon Engineering would need to exist to capture the CO2 currently being released through man-made emissions? Support your calculations with referenced research.
- Write a report comparing the effectiveness of carbon capture and the reduction of carbon emissions and identify how you believe resources should be allocated. Again, support your argument with appropriate evidence and research.

Summary. Year 7–12

After completing selected activities from this study guide, discuss the following prompts and questions in small groups then share your answers with the class.

Collect your responses into a mind map or a similar representation to summarise your class's thoughts on the documentary, including any discussions that branch off from these prompts.

- What was the most surprising thing you learned from *Carbon – The Unauthorised Biography*?
- Identify the **three** major ways that carbon influences life on Earth.
- Is carbon the most significant element in the universe? Why or why not?
- Has your understanding of climate change evolved after watching this program? If so, what have you learned?
- Would our modern society be better or worse without the post-industrial utilisation of fossil fuels? *Is* carbon the enemy?
- What's a more significant source of carbon-based energy – photosynthesis, coal or solar power?
- How does the documentary characterise carbon – as a net positive or net negative?
- From a historical perspective, what influence has carbon has on warfare and other international conflicts?
- What the world – or the universe – look like without carbon?

LINKS AND SOCIALS

For more information about the film including bonus videos, links to additional resources and an education kit (Australia) go to: www.thecarbonmovie.com

To follow the film on socials, head to:

- https://www.facebook.com/thecarbonmovie
- https://www.instagram.com/thecarbonmovie/
- https://www.twitter.com/thecarbonmovie

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Endnotes

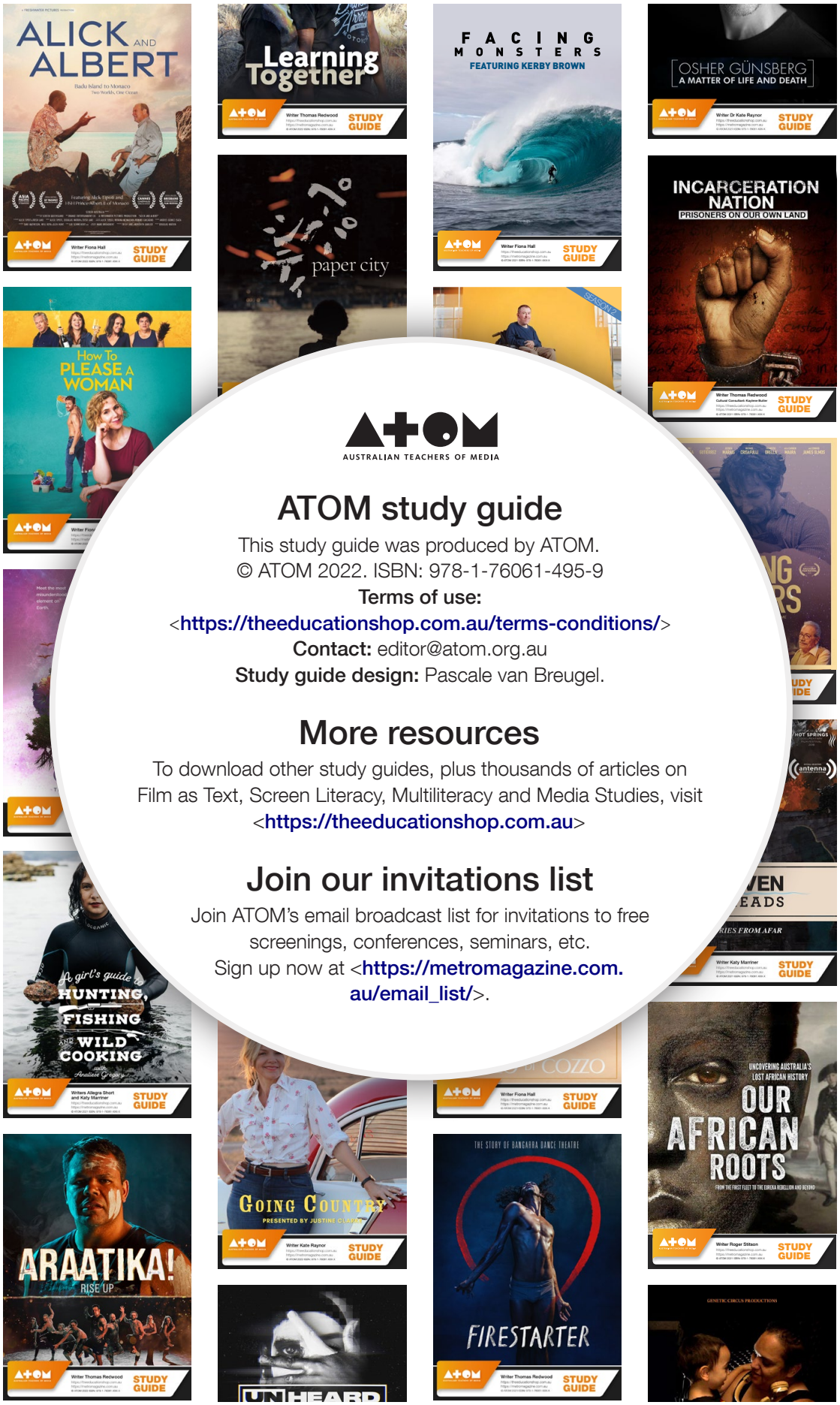
1 Teacher note: You may wish to omit this representation when working with middle school students.

2 Adapted from https://study.com/academy/popular/dna-structure-lesson-plan.html

3 *Note: I'm using the timecodes from the provided Vimeo link at this point; I suspect these may need to be adjusted (or deleted altogether if that's easier) from the final copy.*

4 Adapted from http://www.gbrmpa.gov.au/about-the-reef/animals

5 https://carbonengineering.com/



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