

# Dry Activities

## Activity 4A - Making biofuel molecules

**Learning objectives:** By the end of the session students should be able to:

- Construct some simple molecules.
- Describe the molecules involved in photosynthesis and used as biofuels.
- Suggest the properties of the substances that the models represent.

**Keywords** Bioenergy, biofuel, biodiesel, sustainable, renewable, biomass, yield, waste, photosynthesis, algae, varieties, chromatography.

### What you will need

Molymod<sup>®</sup> molecular model set for **basic organic chemistry**.

One class set will provide enough atoms and bonds for six groups to form carbon dioxide, water, methane, bioethanol and biobutanol molecules (but not all at the same time). The complete set will enable groups to combine their molecules and atoms to make the larger molecular structures including glucose, cellulose and biodiesel.

**Age Range:** This activity is suitable for GCSE or post-16 students.

**Duration:** 30-60 minutes.

**Suggested prior knowledge:** It is recommended that you elicit the existing student knowledge of atoms, compounds and molecules. An understanding of natural substances and metabolism will help students contextualize the use of models to represent fuels and natural substances in the exercise.

### Instructions

Provide each group of students with a pack of **basic organic chemistry** Molymod<sup>®</sup> molecular models.

#### Each pack contains:

- Ten hydrogens (white)
- Four carbons (black)
- Two oxygens (red)
- Two chlorines (green)
- One nitrogen (blue)
- Twenty single bonds
- Four multiple (flexible) bonds

Start off by explaining that you will be constructing the molecules that are important for plants to grow and make biomass then you will be moving on to the more complicated molecules that are formed from plants and used as biofuels. Provide each group or pair of students with one set of molecules and bonds and the diagrams below. The diagrams can be displayed on a powerpoint or provided on the activity sheet. Once the students have made each molecule and it has been checked they will need to take it apart in order to construct the next one. Once the group has made butanol they will need to join another group to be able to make the larger molecules.

# Dry Activities

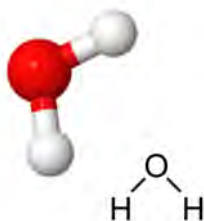
## Carbon dioxide

First of all introduce carbon dioxide and explain its role in photosynthesis. You may also want to explain the greenhouse gas properties of carbon dioxide and its production from combustion of fossil fuels. Instruct the students to make a model of carbon dioxide from two oxygen atoms (red), one carbon atom (black) and four multiple (flexible) bonds.



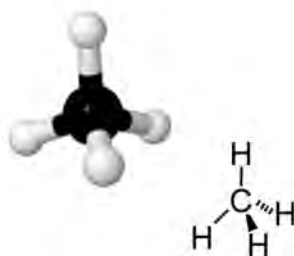
## Water

Explain the importance of water to plants and its role in photosynthesis. Instruct the students to make a model of water from two hydrogen atoms (white), one oxygen atom (red) and two single bonds.



## Methane

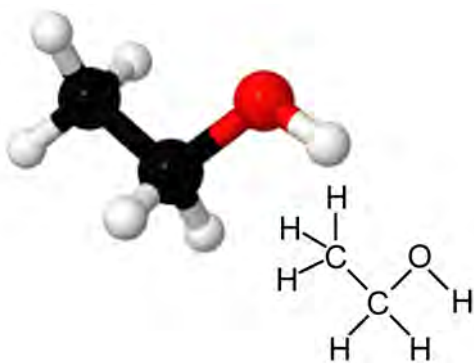
Introduce biogas and explain that the main constituent is methane. You may want to describe the production of biogas through anaerobic digestion as well as the environmental benefit and ease of production in developing countries. Instruct the students to make a model of methane from four hydrogen atoms (white), one carbon atom (black) and four single bonds.



# Dry Activities

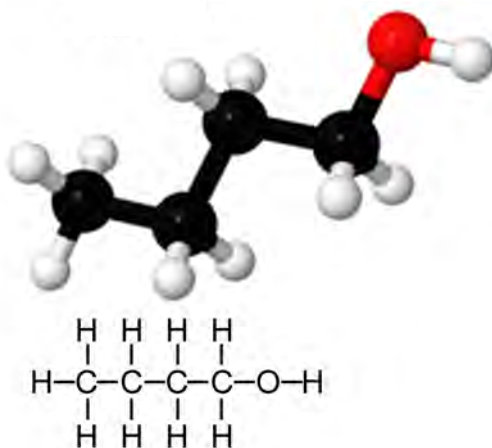
## Ethanol

Introduce bioethanol and explain that the final product is just the same as the ethanol found in alcohol. You may want to describe the production of bioethanol from fermentation of carbohydrate feedstocks. Instruct the students to make a model of ethanol from six hydrogen atoms (white), two carbon atoms (black), one oxygen atom (red) and eight single bonds.



## Butanol

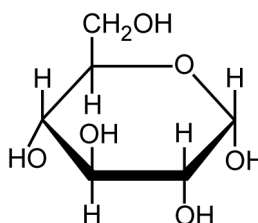
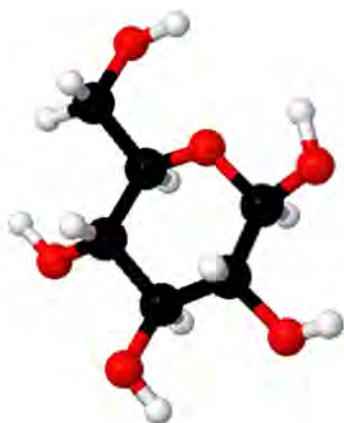
Introduce butanol and explain that it is a superior transport fuel to ethanol due to its higher energy content and the ability to use it in existing pipelines, infrastructure and engines without it needing to be blended with fossil fuels. You may also want to explain the research required to increase the range of feedstocks that can be used, the yield and the tolerance of the microorganisms to biobutanol for optimum production. Instruct the students to make a model of butanol from ten hydrogen atoms (white), four carbon atoms (black), one oxygen atom (red) and fourteen single bonds.



# Dry Activities

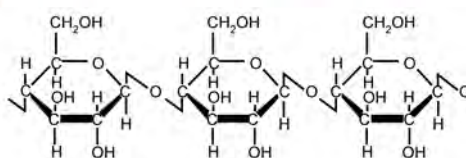
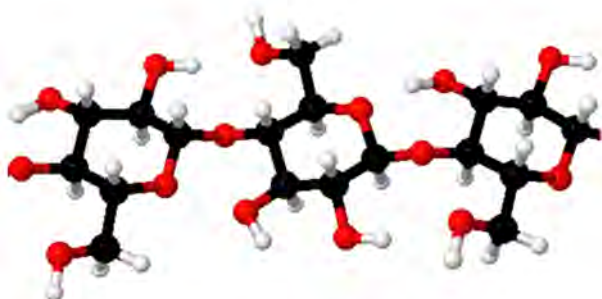
## Glucose

Introduce glucose and explain its production by plants through photosynthesis. You may also want to explain the use of glucose by yeast in fermentation. The students will now need join together to make the glucose molecule. Three packs are required to provide enough oxygen atoms to make a molecule of glucose. Instruct the students to make a model of glucose from twelve hydrogen atoms (white), six carbon atoms (black), six oxygen atoms (red) and twenty single bonds. Important: Once completed and checked, instruct the students not to take the model apart.



## Cellulose

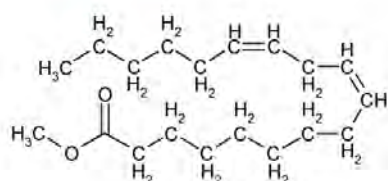
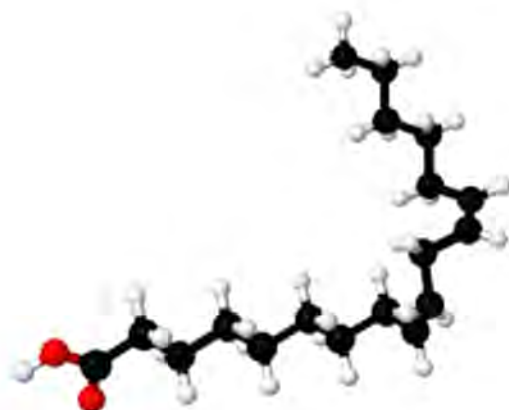
Introduce cellulose and explain its production by plants. You may also want to explain the use of cellulose in plant tissues and the research being undertaken to enable fermentation of lignocellulosic feedstocks. All the students will now need to join together to make a portion of a cellulose molecule featuring three repeating glucose subunits. Instruct the students to make the model of cellulose by joining together the glucose molecules already made. There are sufficient oxygen atoms (fourteen) to form the two connections between the glucose molecules but not the oxygens on the ends of the chain. Students will now need to take the model apart to be able to construct the model of biodiesel.



# Dry Activities

## Biodiesel (Methyl Linoleate)

Introduce biodiesel and explain its production from oils and fats. All the students will need to join together to make a biodiesel (methyl linoleate) molecule. Instruct the students to make the model from thirty four hydrogen atoms (white), nineteen carbon atoms (black), two oxygen atoms (red), six multiple (flexible) bonds and fifty single bonds.



**IMPORTANT:** Ensure that all the atoms and bonds are counted up and returned at the end of the session so that lost parts can be identified and replaced before repeating the activity.

### Suppliers

Molymod® molecular models are available from Spiring Enterprises Limited  
Gillmans Industrial Estate, Natts Lane Billingshurst, West Sussex RH14 9EZ, UK +0044 (0) 1403 782 387

### Further reading

The Royal Society, January 2008. *Sustainable biofuels: prospects and challenges*, ISBN 978 0 85403 662 2.

Nuffield Council on Bioethics, April 2011, *Biofuels: ethical issues*

# Student activity sheet

## Making biofuel molecules



This activity will guide you through constructing models of the molecules that are important for plants to grow and make biomass as well as more complicated molecules that are formed from plants and used as biofuels.

You will need to work in small groups to begin with making the smaller molecules and then work in larger groups to make the larger molecules.

### What you will need

A pack of **basic organic chemistry** Molymod® molecular models.

Each pack contains:

- Ten hydrogens (white)
- Four carbons (black)
- Two oxygens (red)
- Two chlorines (green)
- One nitrogen (blue)
- Twenty single bonds
- Four multiple (flexible) bonds
- Carbon atoms are **Black** 
- Oxygen atoms are **Red** 
- Hydrogen atoms are **White** 

Diagrams are provided to help you construct your molecules.

Once you have made each molecule and it has been checked you will need to take it apart in order to construct the next one.

Once your group has made the butanol molecule you will need to join with another group to be able to make the larger molecules.

### Instructions

#### Carbon dioxide

Carbon dioxide is essential to photosynthesis. Photosynthesis converts carbon dioxide and water into organic compounds including sugars using the energy from sunlight. Combustion of fuels produces carbon dioxide and it is one of the greenhouse gases contributing to climate change.

To make a model of carbon dioxide you will need two oxygen atoms (red), one carbon atom (black) and four multiple (flexible) bonds. Once you have made your molecule and had it checked, take it apart.

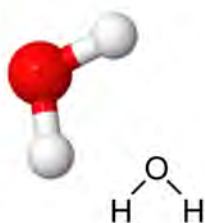


# Student activity sheet

## Water

Water is essential to photosynthesis. Water covers approximately 70% of the world's surface but only 2.5% is fresh water and most of that is frozen or found underground.

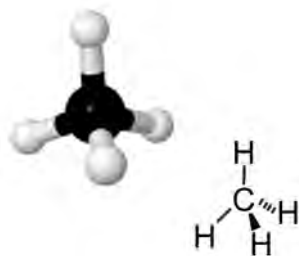
To make a model of water you will need two hydrogen atoms (white), one oxygen atom (red) and two single bonds. Once you have made your molecule and had it checked, take it apart.



## Methane

Biogas is produced by anaerobic digestion and the main constituent is methane. Biogas can be burnt to produce heat for cooking, warming homes and producing electricity. It can also be compressed and used as a transport fuel in specially converted vehicle engines.

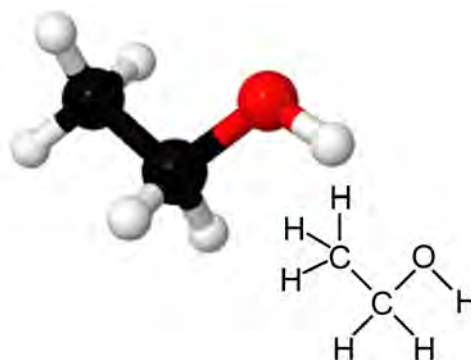
To make a model of methane you will need four hydrogen atoms (white), one carbon atom (black) and four single bonds. Once you have made your molecule and had it checked, take it apart.



## Ethanol

Bioethanol is produced from fermentation of carbohydrate feedstocks and the final product is just the same as the ethanol found in alcohol. Bioethanol is compatible with existing vehicle engines and can be mixed with fossil fuels. Up to 10% blends with petrol can be used without modifying vehicle engines.

To make a model of ethanol you will need six hydrogen atoms (white), two carbon atoms (black), one oxygen atom (red) and eight single bonds. Once you have made your molecule and had it checked, take it apart.

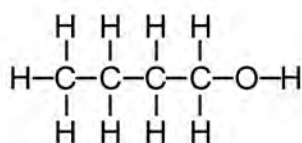
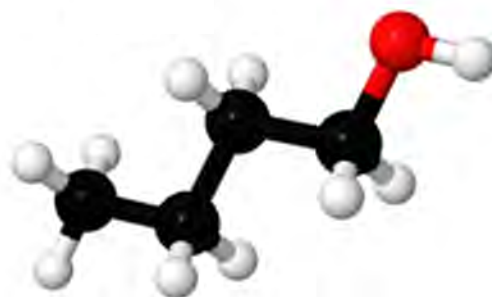


# Student activity sheet

## Butanol

Butanol is a superior transport fuel to ethanol due to its higher energy content and the ability to use it in existing pipelines, infrastructure and engines without it needing to be blended with fossil fuels. However, further research is required to increase the range of feedstocks that can be used as well as the yield and the tolerance of the microorganisms to biobutanol before it can be produced on an industrial scale.

To make a model of butanol you will need ten hydrogen atoms (white), four carbon atoms (black), one oxygen atom (red) and fourteen single bonds. Once you have made your molecule and had it checked, take it apart.

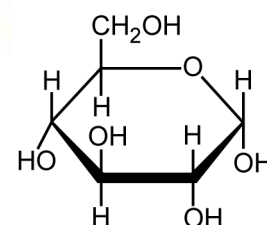
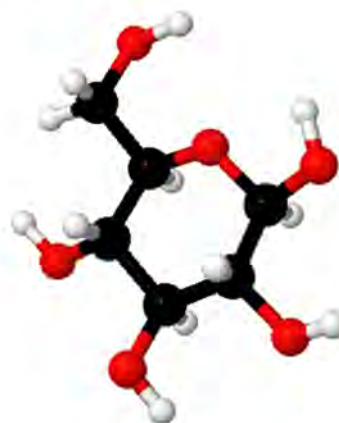


## Glucose

Glucose is a monosaccharide sugar produced by plants through photosynthesis. Glucose is the main source of energy for cells and is one of the sugars used by yeast in fermentation to produce ethanol.

You will now need to work with another two groups to make a glucose molecule. Three packs are required to provide enough oxygen atoms to make a molecule of glucose.

To make a model of glucose you will need twelve hydrogen atoms (white), six carbon atoms (black), six oxygen atoms (red) and twenty single bonds. Important: Once completed and checked, do not take the model apart.

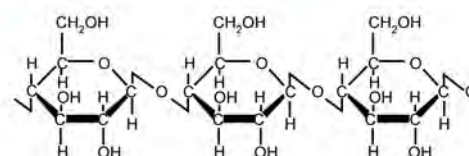
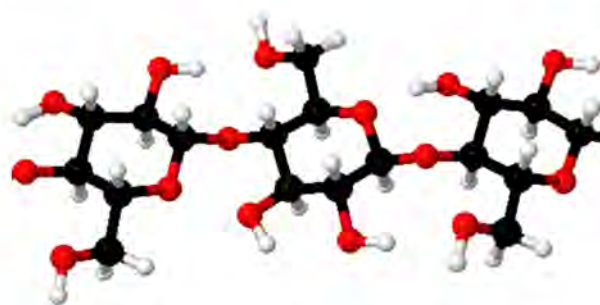


## Cellulose

Cellulose is a polysaccharide formed by plants from glucose molecules. It is the main structural component of cell walls in the form of lignocelluloses and research is being undertaken to enable it to be fermented to produce biofuels.

To be able to make a portion of a cellulose molecule you will now need to work together with three other groups to make a cellulose molecule featuring three repeating glucose subunits.

To make the model of cellulose join together the glucose molecules already made. There are sufficient oxygen atoms (fourteen) to form the two connections between the glucose molecules but not the oxygens on the ends of the chain. You will need to take the model apart to be able to construct the next model – biodiesel!



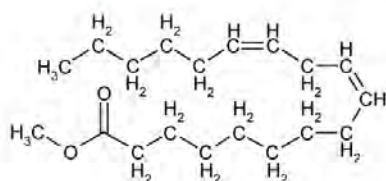
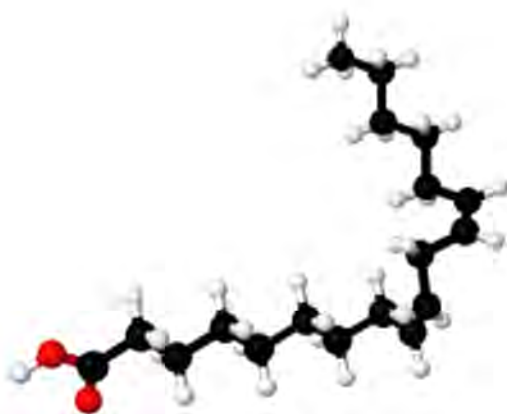


# Student activity sheet

## Biodiesel (Methyl Linoleate)

Biodiesel is produced from oils and fats mixed with methanol and a catalyst. Biodiesel can replace diesel or be further refined to produce synthetic kerosene suitable for use in aviation fuel.

You will need to work together as one large group to make a biodiesel (methyl linoleate) molecule. To make the model of biodiesel you will need thirty four hydrogen atoms (white), nineteen carbon atoms (black), two oxygen atoms (red), six multiple (flexible) bonds and fifty single bonds.



**IMPORTANT:** Ensure that all the atoms and bonds are counted up and returned at the end of the session so that lost parts can be identified and replaced before repeating the activity.

# Dry Activities

## Activity 4B - Biofuel feedstocks

**Learning objectives:** By the end of the session students should be able to:

- Classify biofuel feedstocks according to the fuels they produce, their relation to food crops or using their own classification scheme
- Compare biofuel feedstocks
- Suggest the pros and cons of the biofuel feedstocks according to their properties

**Keywords** Bioenergy, biofuel, biodiesel, sustainable, renewable, biomass, feedstock, yield, waste, varieties,

### What you will need

One set of Biofuel feedstock resin samples and a set of feedstock cards. A limited number of these feedstock packs are available from BBSRC by contacting Tristan Bunn [Tristan.Bunn@bbsrc.ac.uk](mailto:Tristan.Bunn@bbsrc.ac.uk)

**Age Range:** This activity is suitable for secondary students.

**Duration:** 10-30 minutes.

**Suggested prior knowledge:** It is recommended that you elicit the existing student knowledge of plants, food and non-food crops, properties of materials and classification. An understanding of processing of natural substances in agriculture as well as the energy and food industries will help students imagine the way the feedstocks can be used to produce biofuels.

## Instructions

Pass the feedstock resin samples around the class to enable students to take a close look at them. Provide students with the images of the feedstocks for the classification and ranking activities or if there are a small number of students the feedstock themselves.

**Categorising the feedstocks.** Start off by explaining that biofuel feedstocks can be categorized in a variety of ways. Allow students to discuss how they would categorize the feedstocks and come up with their own classification system. Ask students to group the feedstocks according to the following levels of development or final products;

Current biofuel feedstocks are **Rapeseed, Soya Beans, Maize, Castor Beans, Jatropha curcas, Wheat Sweet Sorghum, Sugar beet, Sugar cane**

Advanced biofuel feedstocks are **Barley stems, Miscanthus, Willow**

Biodiesel feedstocks are **Rapeseed, Soya Beans, Maize, Castor Beans, Jatropha curcas**

Bioethanol feedstocks are **Wheat, Maize, Sweet Sorghum, Sugar beet, Sugar cane**

Lignocellulosic bioethanol feedstocks are **Barley stems, Miscanthus, Willow**

# Dry Activities

**Ranking the feedstocks.** Ask students to rank the feedstocks in order of lowest to highest according to measurements such as amount used for fuels, the amount of land that would be required to grow them in the UK to replace fossil fuels, the amounts imported into the UK or the biofuel yields from different crops. The following figure may be helpful.

## Feedstocks used for fuel in the UK 2009-2010

- 28% soy
- 18% sugar cane
- 13% oilseed rape
- 11% tallow
- 6% palm oil

## UK arable land needed to produce 5% of the UK transport fuels

- 12% needed for sugar beet
- 25% needed for cereals
- 40% needed for oilseed rape derived biodiesel
- 45% needed for wheat straw lignocellulosic bioethanol

## Biofuel feedstock imports 2009-2010

- 20% Argentinean soy
- 20% Brazilian sugar cane
- 7% American soy
- 7% German oilseed rape
- 4% Malaysian palm oil

## Biofuel yields

- 6000l/ha bioethanol from sugarcane
- 5000l/ha bioethanol from sugar beet
- 3000l/ha bioethanol from maize
- 1000l/ha bioethanol from barley
- 5000l/ha biodiesel from oil palm
- 1400l/ha biodiesel from oilseed rape
- 1000l/ha biodiesel from castor beans
- 800l/ha biodiesel from soybean

Data sourced from: Department for Transport and *Sustainable biofuels: prospects and challenges*

# Rapeseed



# Soya Beans



## Castor Beans



© Thinkstock®

# Jatropha Curcas



## Wheat ears



© John Innes Centre



## Maize



# Sweet Sorghum



## Sugar beet



## Sugar cane



## Barley stems



© John Innes Centre

# Miscanthus



© Rothamsted Research

## Willow



© Rothamsted Research

# Dry Activities

## Suppliers

Biofuel feedstock resin samples can be obtained from the BBSRC Inspiring Young Scientists coordinator Tristan Bunn [Tristan.Bunn@bbsrc.ac.uk](mailto:Tristan.Bunn@bbsrc.ac.uk).

## Further reading

The Royal Society, January 2008. *Sustainable biofuels: prospects and challenges*, ISBN 978 0 85403 662 2.

Nuffield Council on Bioethics, April 2011, *Biofuels: ethical issues* [www.nuffieldbioethics.org/biofuels\\_0](http://www.nuffieldbioethics.org/biofuels_0)



# Dry Activities

## Activity 4C – Bioenergy crosswords

Crosswords are provided for use at a range of educational levels Primary, Key Stage 3, Key Stage 4 and Post-16. The crosswords cover vocabulary and concepts associated with bioenergy research that students are expected to be familiar with at the educational level specified. There will also be a few words that are included that may be specific to bioenergy research and not covered in the curriculum, designed to stretch students and enrich their understanding of the topic. It would be advisable to introduce students to the words and their meanings in the course of the learning session.

Crosswords support the literacy component of science and will help with spelling, reading, writing, scientific communication, understanding, revision of the terminology and definitions

### The crosswords can be used in many ways:

- introduction to the topic to elicit prior knowledge
- recapping a previous session
- to build up word lists for wall display
- a fun end of session exercise
- as a takeaway activity

Crosswords and wordsearches provide many levels of differentiation. They can be completed individually or as a group, with or without support sheets listing the words.

They can be used to differentiate by task allowing the student to select a crossword or wordsearch. If the wordsearch is completed with ease then the student can be encouraged to attempt the crossword. Students will have recently found the same words in the wordsearch and so feel more confident in attempting the crossword.

A solution for each crossword and wordsearch is provided which allows students to check their own work and thereby allow you to spend more time engaging with other students.

Word exercises such as sentence loops allow students to expand their vocabulary specific to the subject, and when completed within a group the activities promote discussion and therefore promote their oracy skills.

# Introductory Crossword Clues

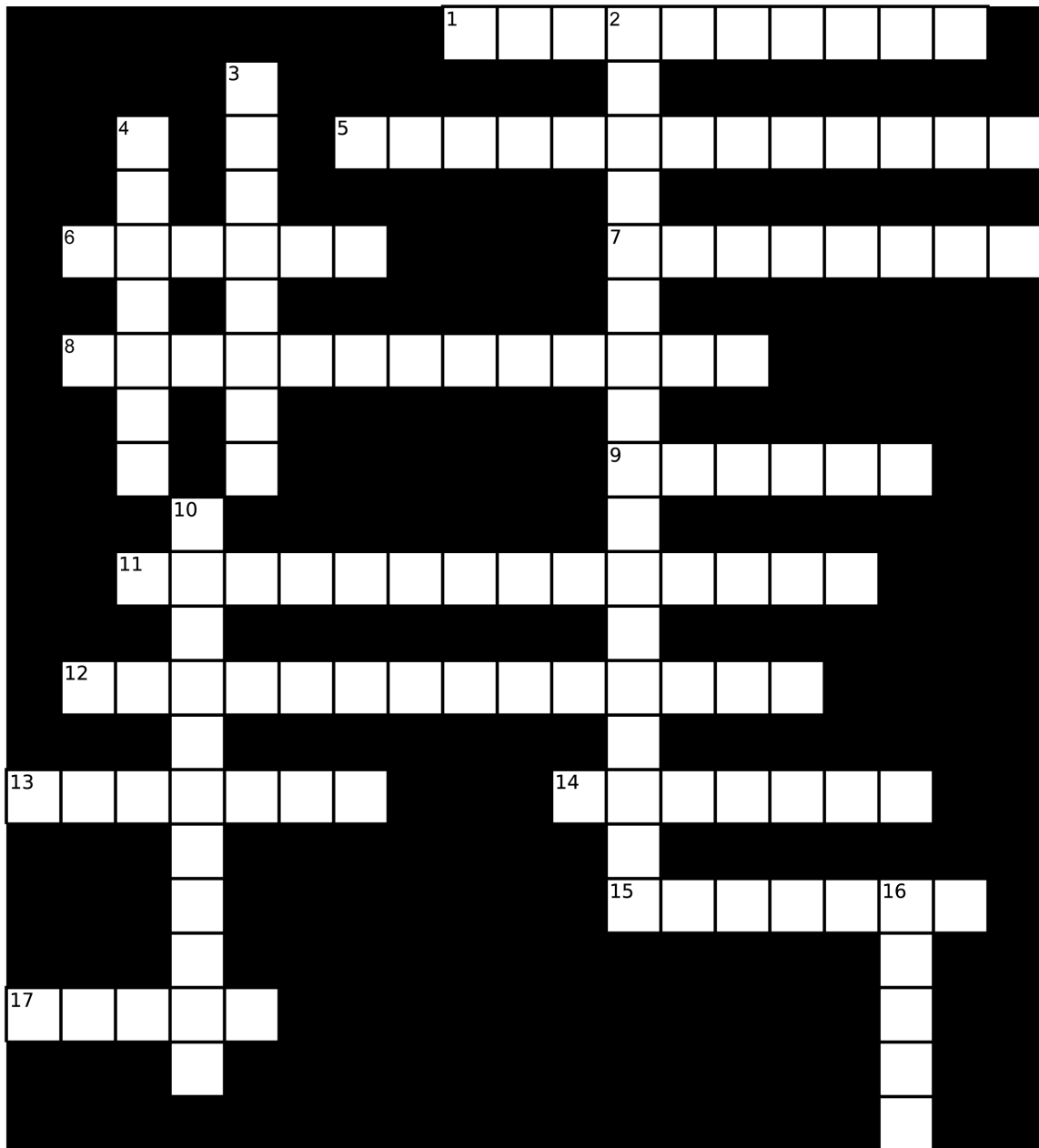
## Across

1. Non-renewable fuel, such as coal, oil and gas (6, 4)
5. The steady increase in the temperature of the Earth's atmosphere (6, 7)
6. An insoluble carbohydrate found in plants and plant products
7. A substance that increases the rate of a reaction
8. A gas produced by the burning of fuels and used in photosynthesis (6, 7)
9. A group of proteins that speed up reactions in living things
11. A method of separating substances where they move at different speeds
12. A process carried out in green plants that uses light
13. With oxygen
14. A renewable fuel produced from biological material
15. The specific sugar made by photosynthesis
17. A measure of the amount of crop produced

## Down

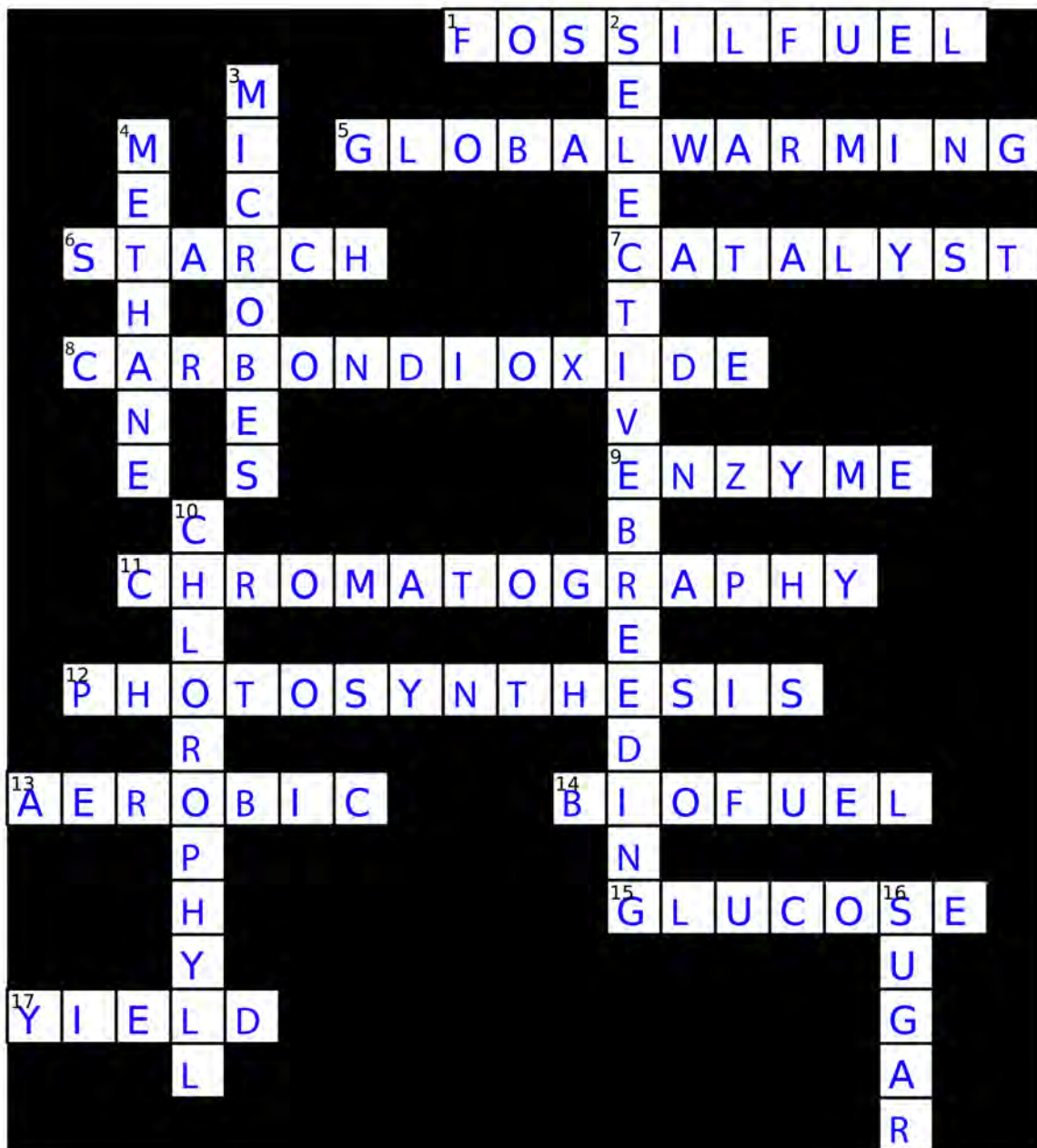
2. The process of producing desirable characteristics in the next generation (9, 8)
3. Very small living things that can only be seen with a microscope
4. A gas that is found with crude oil and produced in decomposition
10. The green chemical in plants that absorbs light energy
16. A carbohydrate that is a source of energy in respiring cells

# Introductory Crossword



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# Introductory Crossword Answers



# Intermediate Crossword Clues

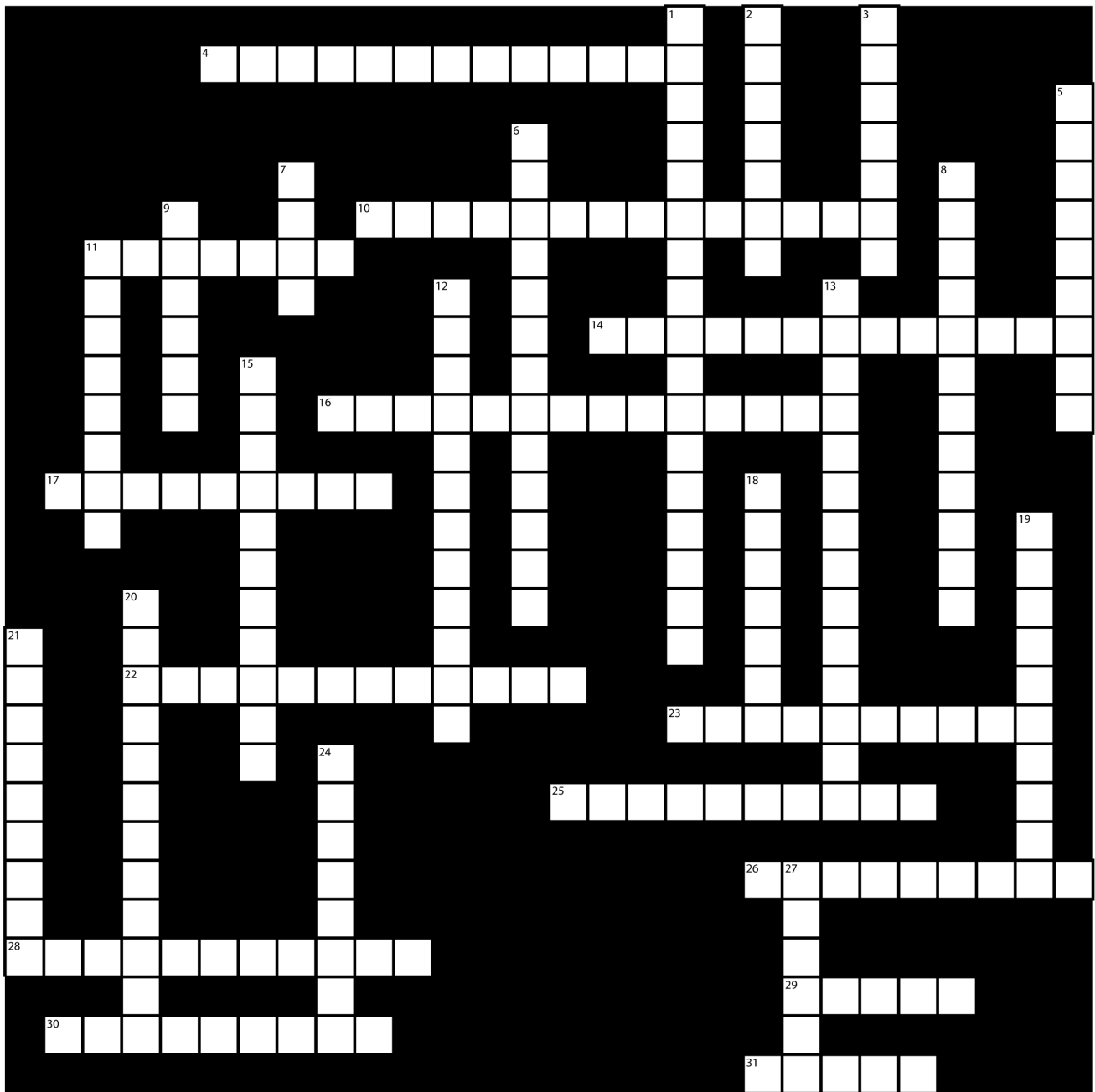
## Across

4. A gas produced by the burning of fuels and used in photosynthesis (6, 7)
10. A process carried out in green plants that uses light
11. A gas that is found with crude oil and produced in decomposition
14. Gas such as carbon dioxide that traps heat in the atmosphere (10, 3)
16. A method of separating substances where they move at different speeds
17. A resource that can be replaced more quickly or at the same rate as it is being used
22. A process in which liquids are purified or separated by heating to form a gas and then condensed back into a liquid
23. Non-renewable fuel, such as coal, oil and gas (6, 4)
25. A layer of gases that surrounds the Earth
26. The material from which the plant cell walls are made
28. The green chemical in plants that absorbs light energy
29. A measure of the amount of crop produced
30. A measurement of the 'thickness' of a fluid
31. Name for the fungus that is single-celled most of its life, used in the production of alcohol and capable of fermenting carbohydrates

## Down

1. The process of producing desirable characteristics in the next generation (9, 8)
2. A renewable fuel produced from biological material
3. The specific sugar made by photosynthesis
5. An organic compound derived from oil or fat that can be used as a transport fuel
6. The steady increase in the temperature of the Earth's atmosphere (6, 7)
7. Part of a chromosome that contains the 'instructions' for a particular characteristic such as leaf shape
8. An anaerobic cellular process in which organic foods are converted into simpler compounds such as alcohol
9. An insoluble carbohydrate found in plants and plant products
11. Very small living things that can only be seen with a microscope
12. The tiny structures inside plant cells where photosynthesis occurs
13. A complex carbohydrate composed of a chain of monosaccharides joined together by glycosidic bonds
15. A compound that contains double or triple bonds
18. The term for the dry weight of a living thing that can be used as a fuel
19. A chemical reaction where a compound, such as starch or cellulose, is broken down by reaction with water into smaller components.
20. Chemicals that are made only from hydrogen and carbon
21. without oxygen
24. A substance that increases the rate of a reaction
27. A group of proteins that speed up reactions in living things

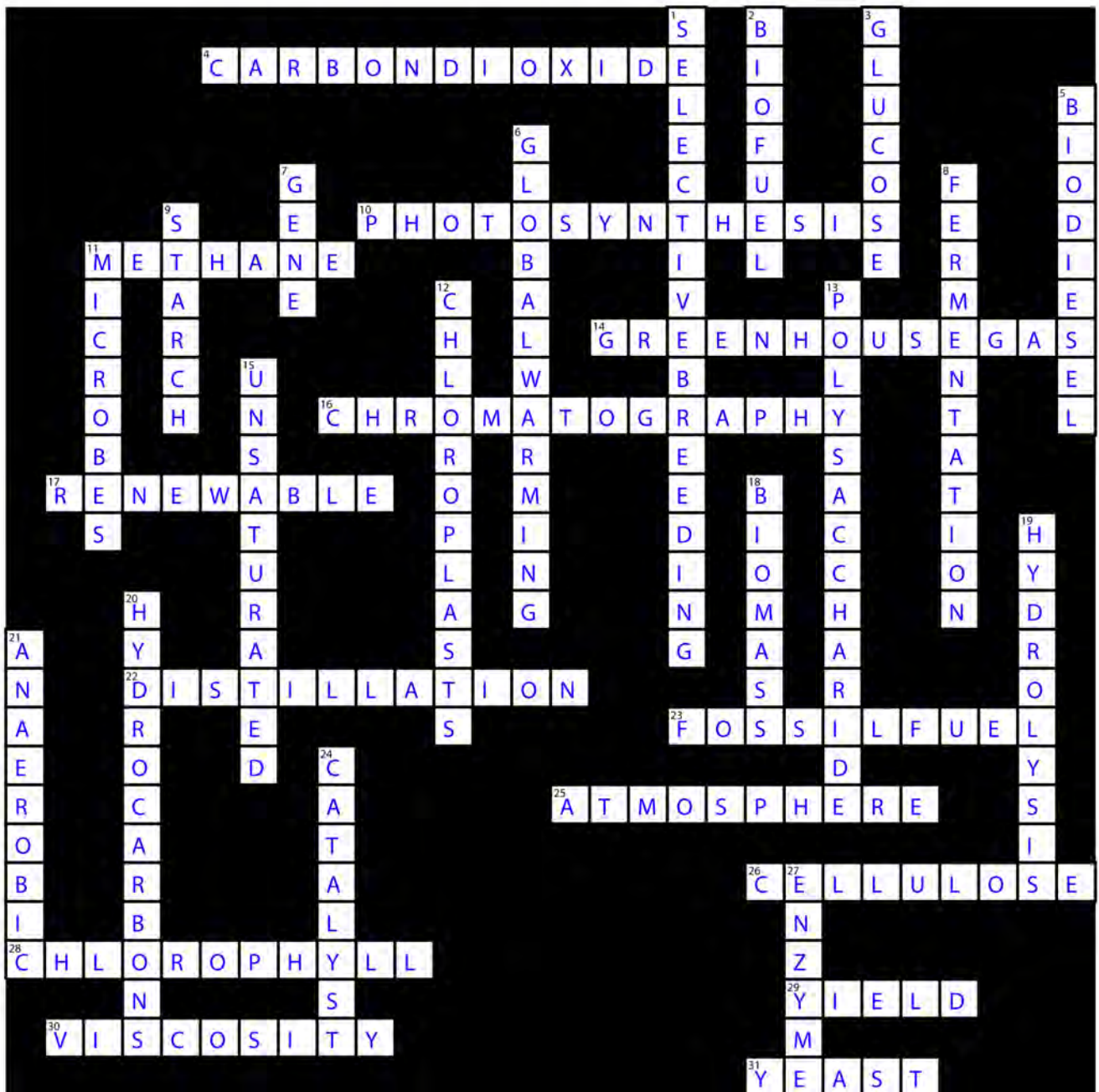
# Intermediate Crossword



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# Intermediate Crossword Answers



# Advanced Crossword Clues

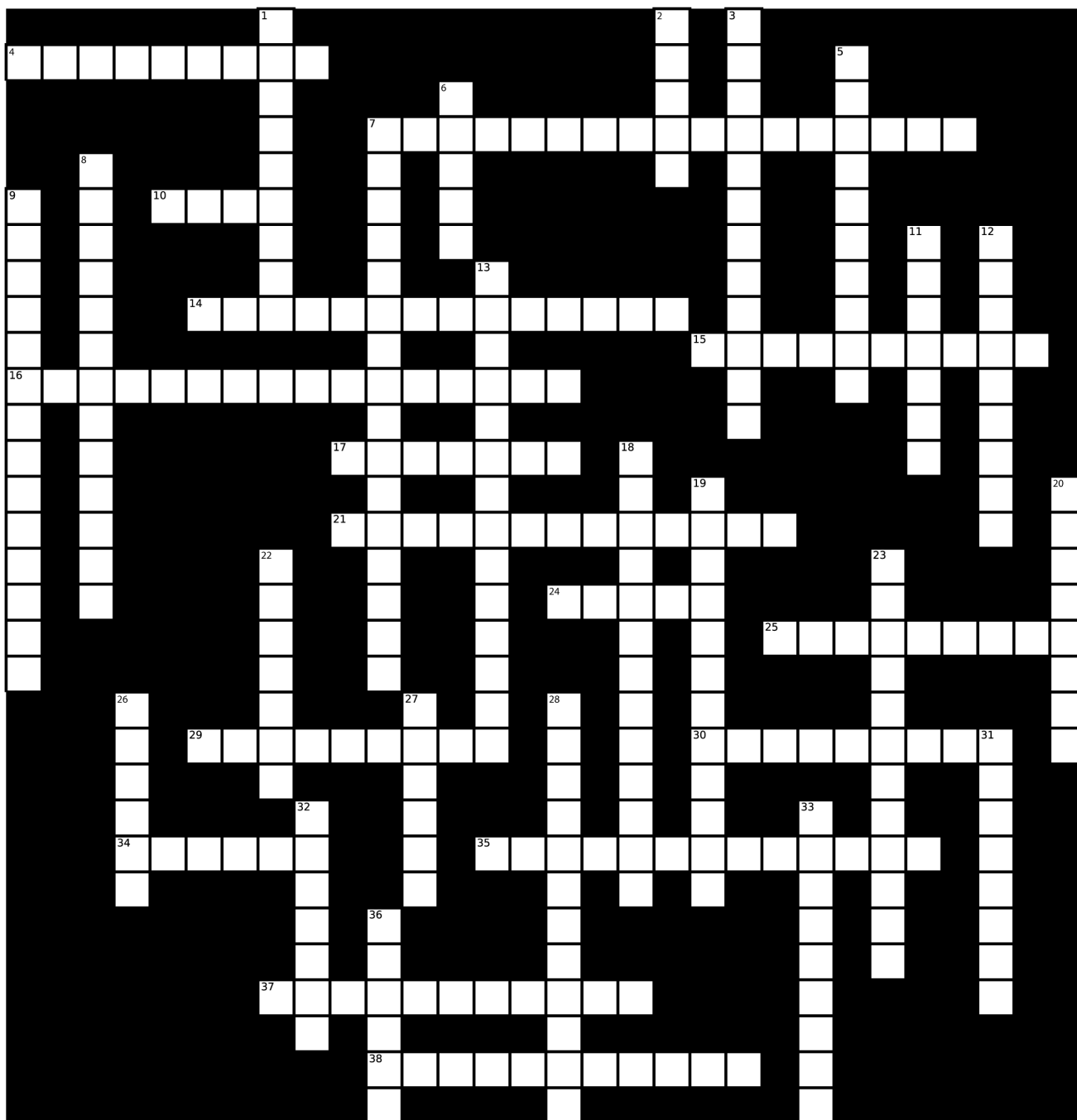
## Across

- A group of long chain hydrocarbons derived from the breakdown of fats with a single carboxylic group and aliphatic tail (5, 4)
- The process of producing desirable characteristics in the next generation (9, 8)
- The fundamental, physical, and functional unit of heredity
- A complex carbohydrate composed of a chain of monosaccharides joined together by glycosidic bonds
- Non-renewable fuel, such as coal, oil and gas (6, 4)
- A new and growing science that focuses on re-designing and re-building natural biological systems synthetically from the ground up (9, 7)
- The term for the dry weight of a living thing that can be used as a fuel
- A gas produced by the burning of fuels and used in photosynthesis (6, 7)
- Name for the fungus that is single-celled most of its life, used in the production of alcohol and capable of fermenting carbohydrates
- The material from which plant cell walls are made
- A measurement of the 'thickness' of a fluid
- Without oxygen
- A group of proteins that speed up reactions in living things
- Traps heat in the atmosphere (10, 3)
- A hydrocarbon that contains double or triple bonds
- The green chemical in plants that absorbs light energy

## Down

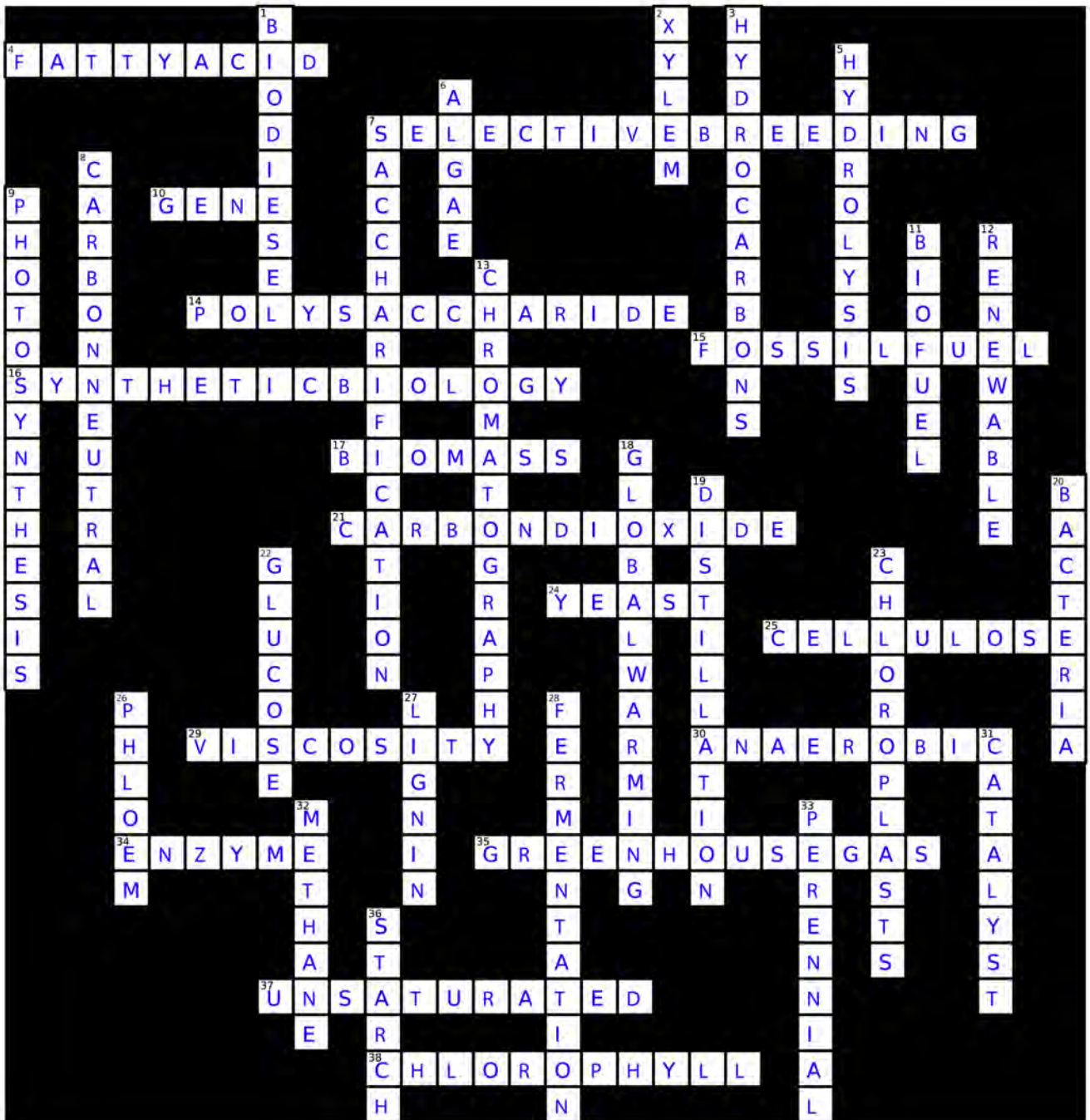
- A transport fuel derived from oil or fat
- A type of vascular tissue in terrestrial plants primarily involved transporting water and nutrient and providing structural support
- Chemicals that are made only from hydrogen and carbon
- A chemical reaction where a compound, such as starch or cellulose, is broken down by reaction with water into smaller components
- Phototrophic eukaryotic microorganisms
- The process of converting complex carbohydrate into simple monosaccharide components through hydrolysis
- Applies to a process which occurs without any change in the total amount of carbon dioxide present in the atmosphere (6, 7)
- A process carried out in green plants that uses light
- A renewable fuel produced from biological material
- A resource that can be replaced more quickly or at the same rate as it is being used
- A method of separating substances where they move at different speeds
- The steady increase in the temperature of the Earth's atmosphere (6, 7)
- A process in which liquids are purified or separated by heating to form a gas and then condensed back into a liquid
- Microscopic, single-celled organisms that possess a prokaryotic type of cell structure
- The specific sugar made by photosynthesis
- The tiny structures inside plant cells where photosynthesis occurs
- A tissue in a vascular plant that functions primarily in transporting organic food materials from the photosynthetic organ to all the parts of the plant
- Organic substance which act as a binder for the cellulose fibre in wood and certain plants and adds strength and stiffness to the cell walls
- An anaerobic cellular process in which organic foods are converted into simpler compounds such as alcohol
- A substance that increases the rate of a reaction
- A gas that is found with crude oil and produced in decomposition
- Lasting through the year or for several years
- An insoluble carbohydrate found in plants and plant products

# Advanced Crossword



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# Advanced Crossword Answers



# Dry Activities

## Activity 4D – Bioenergy wordsearches

Wordsearches are provided for use at a range of educational levels Primary, Key Stage 3, Key Stage 4 and Post-16. The wordsearches cover vocabulary and concepts associated with bioenergy research that students are expected to be familiar with at the educational level specified. There will also be a few words that are included that may be specific to bioenergy research and not covered in the curriculum designed to stretch students and enrich their understanding of the topic. It would be advisable to introduce students to the words and their meanings in the course of the learning session.

Wordsearches support the literacy component of science and will help with spelling, reading, writing, scientific communication, understanding, revision of the terminology and definitions

### The wordsearches can be used in many ways:

- introduction to the topic to elicit prior knowledge
- recapping a previous session
- to build up word lists for wall display
- a fun end of session exercise
- as a takeaway activity

Crosswords and wordsearches provide many levels of differentiation. They can be completed individually or as a group, with or without support sheets listing the words.

They can be used to differentiate by task allowing the student to select a crossword or wordsearch. If the wordsearch is completed with ease then the student can be encouraged to attempt the crossword. Students will have recently found the same words in the wordsearch and so feel more confident in attempting the crossword.

A solution for each crossword and wordsearch is provided which allows students to check their own work and thereby allow you to spend more time engaging with other students.

Word exercises such as sentence loops allow students to expand their vocabulary specific to the subject, and when completed within a group the activities promote discussion and therefore promote their oracy skills.

# Introductory Wordsearch

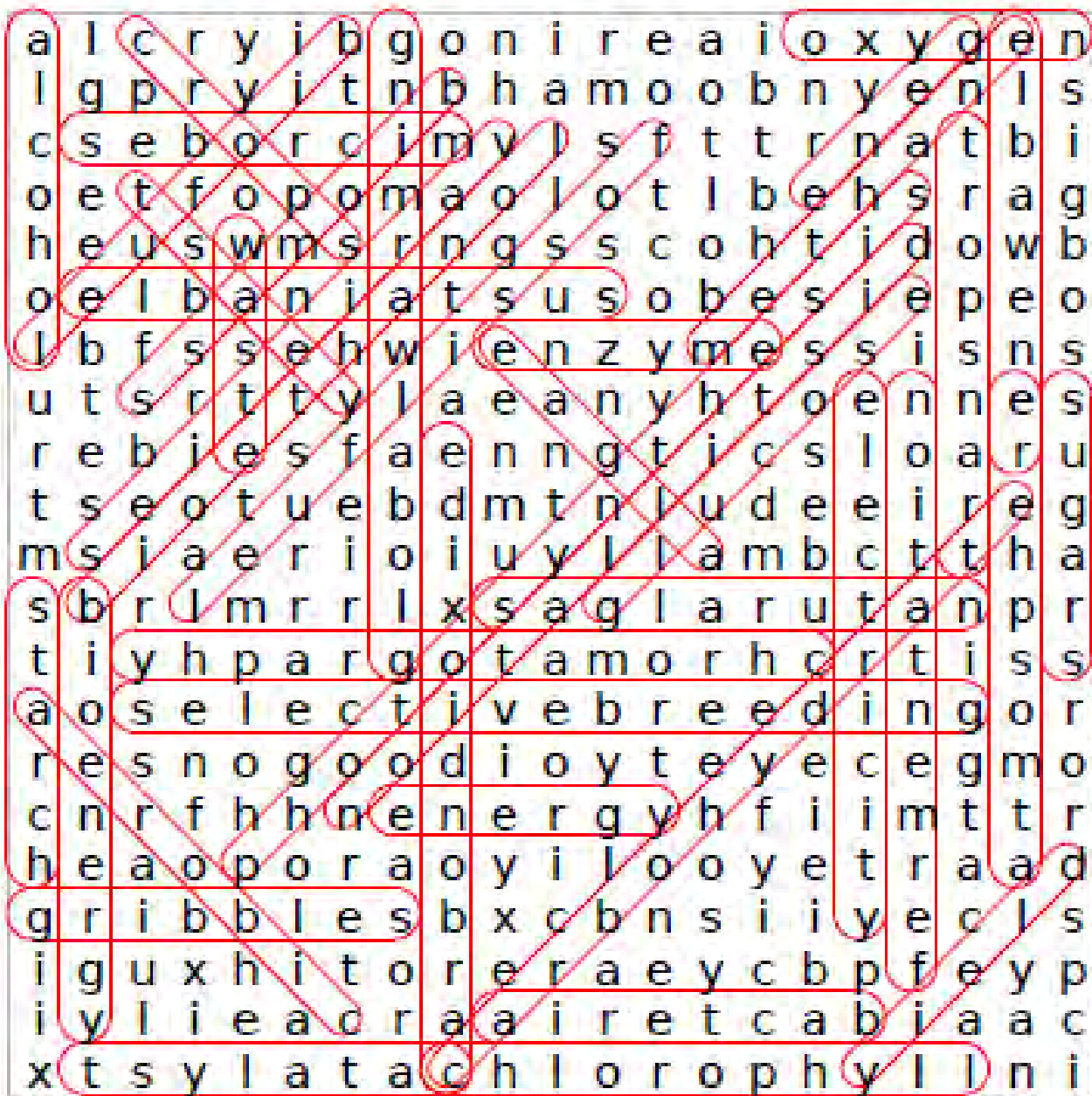
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 l g p r y i t n b h a m o o b n y e n l s  
 c s e b o r c i m v l s f t t r n a t b i  
 o e t f o p o m a o l o t l b e h s r a g  
 h e u s w m s r n g s s c o h t i d o w b  
 o e l b a n i a t s u s o b e s i e p e o  
 l b f s s e h w i e n z y m e s s i s n s  
 u t s r t t y l a e a n y h t o e n n e s  
 r e b i e s f a e n n g t i c s l o a r u  
 t s e o t u e b d m t n l u d e e i r e g  
 m s i a e r i o i u y l l a m b c t t h a  
 s b r l m r r l x s a g l a r u t a n p r  
 t i y h p a r g o t a m o r h c r t i s s  
 a o s e l e c t i v e b r e e d i n g o r  
 r e s n o g o o d i o y t e y e c e g m o  
 c n r f h h n e n e r g y h f i i m t t r  
 h e a o p o r a o y i l o o y e t r a a d  
 g r i b b l e s b x c b n s i i y e c l s  
 i g u x h i t o r e r a e y c b p f e y p  
 i y l i e a c r a a i r e t c a b i a a c  
 x t s y l a t a c h l o r o p h y l l n i

bioenergy  
 biofuel  
 fossil fuel  
 bioethanol  
 alcohol  
 carbohydrate  
 energy  
 carbon dioxide  
 oxygen  
 natural gas  
 methane  
 sustainable  
 renewable  
 transport

biomass  
 yield  
 waste  
 microbes  
 yeast  
 fermentation  
 catalyst  
 enzyme  
 gribbles  
 photosynthesis  
 algae  
 varieties  
 electricity

crops  
 starch  
 sugars  
 chromatography  
 distillation  
 atmosphere  
 aerobic  
 glucose  
 bacteria  
 gene  
 chlorophyll  
 selective breeding  
 global warming

## Introductory Wordsearch Answers





# Intermediate Wordsearch



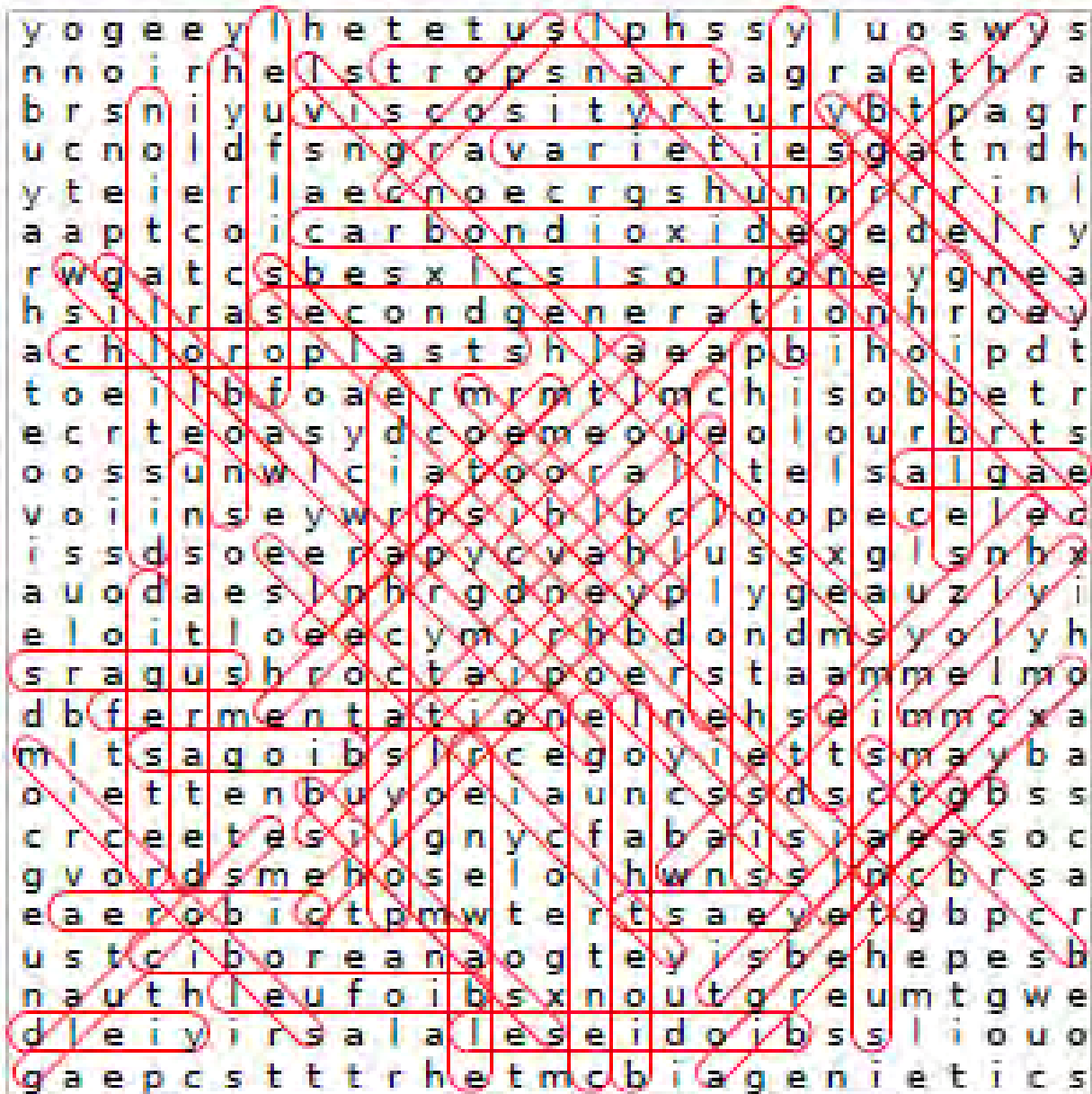
bioenergy  
biodiesel  
oxygen  
sustainable  
waste  
anaerobic  
second generation  
chloroplasts  
transport  
hydrolysis  
viscosity  
atmosphere  
gene  
phloem  
greenhouse gas

biofuel  
carbohydrate  
biogas  
renewable  
microbes  
catalyst  
lignocelluloses  
algae  
crops  
polysaccharide  
chromatography  
aerobic  
chlorophyll  
selective breeding  
miscanthus

fossil fuel  
energy  
methane  
biomass  
yeast  
enzyme  
steam explosion  
varieties  
starch  
hydrocarbons  
distillation  
glucose  
cellulose  
carbon neutral  
willow

bioethanol  
carbon dioxide  
digester  
yield  
fermentation  
gribbles  
photosynthesis  
electricity  
sugars  
unsaturated  
centrifuge  
bacteria  
xylem  
global warming  
barley

# Intermediate Wordsearch Answers



# Advanced Wordsearch



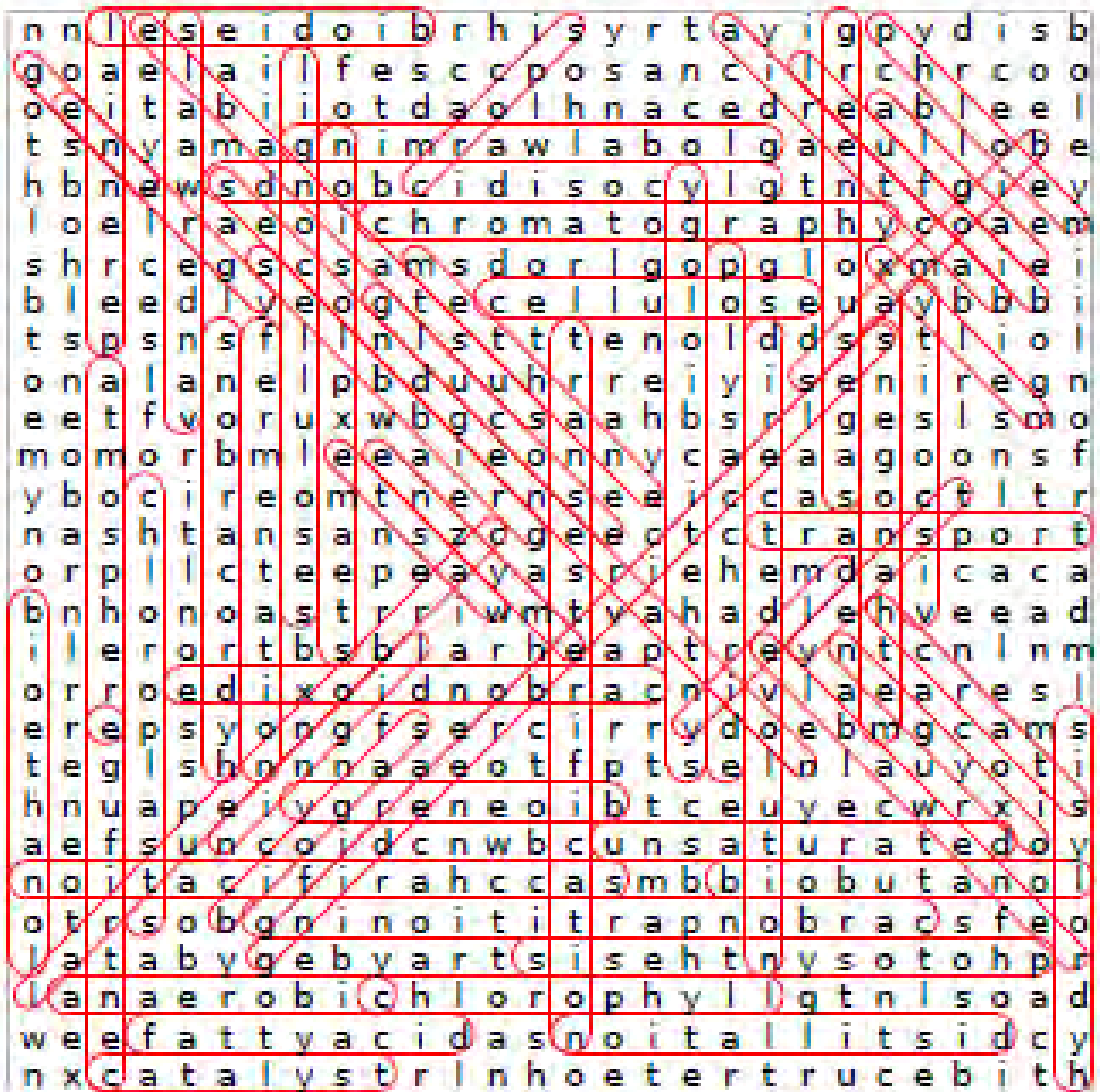
bioenergy  
 biobutanol  
 biogas  
 biomass  
 fermentation  
 glycosidic bonds  
 lignin  
 chloroplasts  
 perennial  
 hydrocarbons  
 chromatography  
 transesterification  
 methanogens  
 xylem  
 global warming  
 synthetic biology

biofuel  
 energy  
 methane  
 yield  
 anaerobic  
 enzyme  
 lignocelluloses  
 algae  
 starch  
 unsaturated  
 distillation  
 atmosphere  
 gene  
 phloem  
 greenhouse gas

bioethanol  
 carbon dioxide  
 sustainable  
 waste  
 catalyst  
 gribbles  
 steam explosion  
 transport  
 hydrolysis  
 viscosity  
 centrifuge  
 glucose  
 chlorophyll  
 selective breeding  
 carbon partitioning

biodiesel  
 oxygen  
 renewable  
 yeast  
 saccharificatio  
 second generation  
 photosynthesis  
 crops  
 polysaccharide  
 Van der waals  
 fatty acid  
 bacteria  
 cellulose  
 carbon neutral  
 directed evolution

# Advanced Wordsearch Answers



# Dry Activities

## Activity 4E - Bioenergy sentence loops

Sentence loops should be printed out, cut into separate strips and laminated. The words and definition are on separate strips and students match up the correct definition and words arranging them in a loop in order to complete the exercise correctly.

## Bioenergy sentence loops

### Biodiesel

A green house gas that is used by plants in photosynthesis to create biomass.



### Carbon dioxide

A resource that can be renewed more quickly or at the same rate as it is being used or is unlikely to run out due to inexhaustible supplies.



### Renewable resource

A process carried out in green plants that uses light energy captured by chlorophyll to convert carbon dioxide and water to carbohydrates and oxygen.



### Photosynthesis

Biofuel consisting of ethanol produced by the fermentation of plant material rich in sugar or lignocellulose.



### Bioethanol

The use of resources to meet the need of present generations without compromising the need of future generations by balancing environmental, social and economic factors.



### Sustainability

A cellular process occurring without oxygen, in which organic foods such as sugars are converted into simpler compounds such as bioethanol, and chemical energy (ATP) is produced.



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# Bioenergy sentence loops

**Fermentation**

Without oxygen



**Anaerobic**

A group of proteins that speed up reactions in living things.



**Enzyme**

The green chemical in plants that absorbs light energy for photosynthesis.



**Chlorophyll**

Non-renewable fuels, such as coal, oil and gas, formed over millions of years from the decomposition, in anaerobic conditions, of plant and animal remains.



**Fossil Fuels**

Renewable fuel comprised of approximately 60% methane, produced by anaerobic digestion of organic material by microorganisms. Can be used as a transport fuel or for generating heat and electricity.



**Biogas**

An organic compound derived by processing and transesterification of plant oil or animal fats that can be used as a transport fuel in replacement of diesel derived from fossil fuel.





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