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4 The Light and Dark Bottle Experiment

VOCABULARY

[Scientific words used in the Text and elsewhere that are not explained in this vocabulary may be found in the general vocabulary on p. 205.]

alkaline iodide /'ælkəlaɪn 'aɪədaɪd/ 14 potassium /pə'tæsjəm/ iodide (KI) or sodium iodide (Na I)
calibrate /'kælibreɪt/ 21 to give a scale to: 'The volume of sodium thiosulfate† needed can be calibrated to indicate the concentration of oxygen in milligrams'
count /kaunt/ 49 See Explanatory Notes, p. 39
curve /kɜ:v/ 60 a line plotted↓ on a graph↓ whether it is curved or not: 'a diurnal↓ curve may be plotted'
data (*pl.*) /'deɪtə/ 78 factual information, usually in the form of figures: 'the quantity of data that can be gathered'
determine /dɪ'tɜ:mɪn/ 50 to find out: 'the phytoplankton↓ is removed by a filter that is "counted"↑ by a detector to determine the amount of radioactive carbon fixed↓'
diurnal /daɪ'ɜ:nəl/ 59 covering 24 hours: 'a diurnal curve↑ may be plotted↓'
ecological /i:kə'lɒdʒɪkl/ 79 adj./ecology /i:'kɒlədʒi/, the study of organisms in relation to their surroundings, or environment: 'ecological research' (Gk *oikos* a house, *logos* a branch of knowledge)
elemental /,elə'mentl/ 15 free, not part of a chemical compound: 'This treatment releases elemental iodine'
fix /fɪks/ 7 See Explanatory Notes, p. 38
fixation /fɪk'seɪʃən/ 31 See Explanatory Notes 7, p. 38
foil /fɔɪl/ 5 metal in the form of a very thin sheet: 'One or more bottles are covered with aluminium foil'
graph /grɑ:f/ 42 a diagram expressing a mathematical relationship: 'A graph of bottle values plotted↓ against depth can be constructed' (Gk *grapho* to draw)

† American spelling

hypo /'haɪpə/ 19 the popular name for sodium↓ thiosulphate: 'the "hypo" used to fix↑ photographs'
laborious /lə'beɪrɪəs/ 72 requiring much repetitive work: 'The somewhat↓ laborious . . . method of estimating oxygen described above'
location /lou'keɪʃən/ 56 a place: 'a new sampling↓ location'
manganous sulfate† /'mæŋgənəs 'sʌlfeɪt/ 14 manganous sulphate, MnSO₄
net /net/ 27 resulting from what is gained minus what is lost: 'the net photosynthesis (that is, net result of photosynthesis and respiration)' See Explanatory Notes 25, p. 38
oceanographic /,ouʃəno'græfɪk/ 52 adj./oceanography /,ouʃə'nɒgrəfi/, the scientific study of the sea: 'This method is widely used in oceanographic work' (ocean + Gk *grapho* to draw)
phytoplankton /'faɪtə,plæŋktən/ 45 that part of plankton↓ which is composed of plants (Gk *phytos* a plant + plankton)
plankton /'plæŋktən/ 2 very small plants and animals that swim or float near the surface of the sea or lakes (Gk *plagktos* wandering)
plot /plɒt/ 42 to mark a position on a diagram or graph↑: 'a graph of bottle values plotted against depth can be constructed'
precision /pri'si:ʒən/ 78 accuracy, exactness: 'the development of new methods that increase both the precision and the quantity of data↑'
procedure /prə'si:dʒə*/ 75 the method of doing a thing: 'Such electronic procedures are now in the experimental stage of development'
resuspend /'ri:səspend/ 52 to suspend, or hang, again: 'it is not necessary to resuspend bottles in the sea'
sample /'sɑ:mpəl/ 3 a specimen: 'A portion of a sample of water from each of several levels'
sampling /'sɑ:mpəlɪŋ/ 55 the taking of samples↑: 'a new sampling location↑' See Explanatory Notes, p. 40
sediment /'sedɪmənt/ 68 the solid that may settle at the bottom of a liquid: 'physical exchange of oxygen . . . between water and sediments must be estimated'
shift /ʃɪft/ 35 a change of place or position: 'a simple shift of decimal'
sodium thiosulfate† /'səʊdʒəm θaɪə'sʌlfeɪt/ 20 sodium thiosulphate, Na₂S₂O₃
somewhat /'sʌmwɒt/ 72 rather: 'The somewhat laborious↑ . . . method'
stand by /stænd baɪ/ 53 to wait in a state of preparation: 'it is not necessary to . . . stand by for 24 hours'
string /strɪŋ/ 12 a series of things connected by string or thread: 'the string of bottles'
sulfuric acid /sʌl'fjuəri:k 'æsɪd/ 15 sulphuric acid, H₂SO₄
titrate /taɪ'treɪt/ 18 to treat a chemical substance with a known

† American spelling

quantity of another substance in order to determine the quantity of the former: 'The brown water is then titrated in the laboratory by adding sodium† thiosulfate†'

TEXT

Light and dark bottles are suspended in a pond to measure oxygen changes resulting from the metabolism of the plankton organisms. A portion of a sample of water from each of several levels is placed in glass bottles. One or more bottles are covered with aluminium foil or black tape so that no light can reach the sample; these are called the 'dark' bottles, in contrast with the 'light' bottles that have no such cover. Other bottles are 'fixed' with reagents immediately so that the amount of oxygen in the samples at the beginning of the experiment can be known. Then pairs of light and dark bottles are suspended in the pond at the levels from which the water samples were drawn. At the end of the 24-hour period the string of bottles is removed from the pond and oxygen in each 'fixed' by addition of a succession of the three reagents: manganous sulfate†, alkaline iodide, and sulfuric† acid. This treatment releases elemental iodine in proportion to the oxygen content. The water in the bottles is thus now brown in color†; the darker the color† the more oxygen. The brown water is then titrated in the laboratory by adding sodium thiosulfate† (the 'hypo' used to fix photographs) until the color disappears. The volume of sodium thiosulfate needed can be calibrated to indicate the concentration of oxygen in milligrams or milliliters† per liter†; milligrams per liter is also parts per million, another way in which oxygen content of water is expressed.

The decline of oxygen in the dark bottles indicates the amount of respiration in the water column whereas the oxygen change in the light bottles indicates the net photosynthesis (that is, net result of photosynthesis and respiration); the two quantities added give an estimate of total photosynthesis or total food production for the 24-hour period, since oxygen production by green plants is directly proportional to fixation of light energy. One method of calculating photosynthetic rate of the water

† American spelling

column on a square meter† basis is to average values for each meter level and convert to oxygen per cubic meter (a simple shift of decimal since milligrams per liter = grams per cubic meter); the values for each meter level when added give an estimate of total oxygen production per square meter of pond surface. In the simplest case, if bottles had been placed at 0.5, 1.5, and 2.5 meters deep then each pair could be considered as sampling the first, second, and third cubic meter; the sum of these would give an estimate for a column 3 meters deep. Alternatively, a graph of bottle values plotted against depth can be constructed and the area under the curve used to estimate the column.

Where phytoplankton density is very low, as in large deep lakes or the open ocean, the sensitivity of the light and dark bottle method can be greatly increased by adding a radio-active carbon tracer to the bottles. After an interval of time the phytoplankton is removed by a filter that is 'counted' by a detector to determine the amount of radioactive carbon fixed. This method, which indicates the net photosynthesis, is widely used in oceanographic work. At sea it is not necessary to resuspend bottles in the sea and stand by for 24 hours; the samples can be subjected to the light and temperature conditions of the sea on the deck of the ship as it moves to a new sampling location.

In another approach the whole pond can be considered as a dark and light bottle. If oxygen measurements are made at 2- or 3-hour intervals throughout a 24-hour cycle, a diurnal curve may be plotted that shows rise of oxygen during the day when photosynthesis is occurring and decline during the night when only respiration is occurring. The daytime period is equivalent to the light bottle and the night to the dark bottle. The advantage of this diurnal curve method is that photosynthesis of the whole pond including plants growing on the bottom (which would not be included in bottles) would be estimated. The difficulty is that physical exchange of oxygen between air and water and between water and sediments must be estimated to obtain the correct estimate for oxygen production of plants in the pond. Usually, the bottle methods give a sort of minimum and the diurnal curve a sort of maximum estimate.

The somewhat laborious but tried and true chemical method of estimating oxygen described above may soon be replaced by

75 the 'oxygen electrode', which will permit continuous recording of oxygen in a bottle or in a body of water. Such electronic procedures are now in the experimental stage of development. As in any branch of science the development of new methods that increase both the precision and the quantity of data that can be gathered is one of the primary concerns of ecological research.

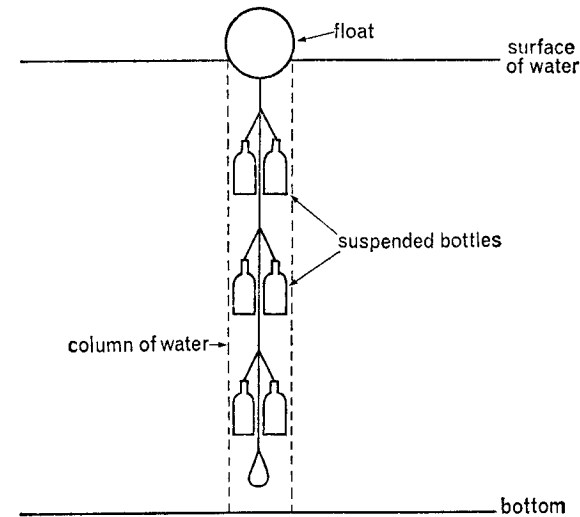
80 E. P. ODUM *Ecology* (1963)

EXPLANATORY NOTES

- 4 *levels*: levels, or depths, beneath the surface of the pond
- 6 '*dark*': the inverted commas are used here and in 7 and 49 because the words concerned do not denote what they normally denote; and in 19 and 74 they are used for popular names.
- 7 *Other bottles are 'fixed' with reagents*: It is, of course, not the bottles themselves that are 'fixed', but the oxygen inside them, which combines chemically with the reagents, thereby releasing iodine (15). The use of *fix* in this way is also found in 50. In 19 *fix* refers to the stabilization of shades or colours in a photo so that they do not change. In 31 the noun *fixation* is used with reference to the storing of light energy in a chemical compound such as starch.
- 17 *the darker the color† the more oxygen*: the darker the colour is, the more oxygen there is
- 22 *milliliter†*: millilitre
- 22 *milligrams per liter† is also parts per million*: For the use of the singular verb (*is*), see Grammar and Usage, p. 6.
- liter†*: litre
- 25 *The decline of oxygen in the dark bottles indicates the amount of respiration in the water column whereas the oxygen change in the light bottles indicates the net photosynthesis . . . the two quantities added give an estimate of total photosynthesis or total food production for the 24-hour period, since oxygen production is directly proportional to fixation of light energy*: Photosynthesis releases oxygen, whereas respiration uses it up. If, in the light bottle, the number of units of oxygen released by photosynthesis is 4, and the number of units used in respiration is 1, the net result of photosynthesis and respiration will be 3 units of oxygen. In the dark bottle, where there is no photosynthesis, there will be a loss of 1 unit of oxygen. Thus 1 + 3 gives the number of units of oxygen released in photosynthesis, which is directly proportional to the amount of food produced in the process.

† American spelling

26 *the water column*: the imaginary column, or cylinder, of water in which the bottles are suspended, thus:



- 29 *estimate*: Compare the pronunciation of this noun ['estimat] with that of the corresponding verb ['estimeit], which occurs in 66 and elsewhere.
- 32 *photosynthetic rate of the water column*: the rate of photosynthesis in the water column
- 33 *meter†*: metre
- to average values*: to take the average of values
- 34 *a simple shift of decimal*: a change in decimal values from milligrams per litre to grams per cubic metre, which is simple because there is no change in figures or in the position of the decimal point
- 38 *placed at 0.5, 1.5, and 2.5 meters† deep*: This is rather an unusual construction. A more usual one would be either (a) *placed at depths of 0.5, 1.5, and 2.5 metres* or (b) *placed 0.5, 1.5, and 2.5 metres beneath the surface*.
- 42 *bottle values*: values for oxygen production obtained as above (25).
- 43 *the area under the curve used to estimate the column*: the area under the curve can be used to estimate the column
- 44 *estimate the column*: estimate the oxygen production, or photosynthesis, in the column
- 49 *a filter that is 'counted'*: a filter whose radioactivity is determined by an instrument such as a Geiger counter
- 50 *This method, which indicates the net photosynthesis*: It does not indicate total photosynthesis any more than a measurement of oxygen

† American spelling

production does (25), for although carbon dioxide is utilized in photosynthesis it is released in respiration.

- 55 *a new sampling location*: a new place to take samples from
 61 *decline*: This is a noun, not a verb, being the second of the two direct objects of the verb *shows* (60), i.e. *a diurnal curve may be plotted that shows . . . decline during the night*
 72 *tried and true*: frequently practised in the past and comparatively accurate
 74 *recording*: Pronounced [rə'kɔ:diŋ], i.e. with the stress on the second syllable, since this noun is derived from the verb *record* [rə'kɔ:d], not the noun ['rekɔ:d].
 79 *one of the primary concerns*: one of the most important aims or objects

GRAMMAR AND USAGE

THE PASSIVE

Examples of the passive of the six tenses that occur in the texts in this book (see p. 17) are given below:

- 4.9 Then pairs of light and dark bottles *are suspended* in the pond at the levels from which the water samples *were drawn*. [Present and past]
 1.11 Tetraploid cells, with four sets of chromosomes, *have been found* to have 12×10^{-9} milligrams of DNA per nucleus. [Present perfect]
 4.38 if bottles *had been placed* at 0.5, 1.5, and 2.5 meters† deep then each pair could be considered as sampling the first, second and third cubic meter† . . . [Past perfect]
 16.44 In the following pages examples *will be given* of each of the eight possibilities outlined above. [Future]
 4.64 The advantage of the diurnal curve method is that photosynthesis of the whole pond . . . *would be estimated*. [Conditional]
 It will be seen that the passive is formed by the appropriate tense of the verb *to be* (*are, were, etc.*†) and the past participle of the verb concerned. The passive infinitive is formed by the infinitive *to be* (with or without *to*) and the past participle of the verb concerned:
 4.59 a diurnal curve may *be plotted* . . .
 2.11 Reptile eggs, like bird eggs, do not need *to be immersed* in water.

The general reason for using the passive is that, in the context, the thing on which the action is performed is of more significance than the thing or person performing the action. The thing acted upon, such as bottles (4.9, 4.38†) or tetraploid cells (1.11†), therefore becomes the grammatical subject of the sentence, while the thing or person who acts (i.e. what would be the subject in a construction using the active voice) may, as in the above examples, get no mention at all. If he (or it) does get a mention, it is as the grammatical agent.

† American spelling

- 4.48 After an interval of time the phytoplankton is removed by *a filter* that is 'counted' by *a detector*. . . .
 1.48 When these cations are removed by *Versene*, the nucleic acid and protein disaggregate.
 5.34 Vegetative reproduction is secured through *fragmentation*, whilst asexual reproduction is brought about by *the well-known compound multiflagellate zoospores*
 The normal preposition for use with the agent is *by*, although *through* (5.34†) is sometimes used when the agent is a process. The preposition *with* is not normally used with an agent. In the following two examples there are no agents.
 12.22 The proteins are hydrolysed with the formation of polypeptides.
 11.4 The swim bladder is distensible and is filled with air or other gases

In 12.22 the passive (*are hydrolysed*) is used, but the meaning is not that the hydrolysis of proteins is caused by the formation of polypeptides, but that it *results in* their formation. In 11.4 there is no passive; the words after the second *is* make up an adjective phrase (see p. 30) that corresponds grammatically with *distensible*, and that describes a state, not an action.

The passive occurs often in scientific writing, where the individual is by tradition expected to hide himself behind the facts and the experiments, and make it sound as if these existed without him. It is nearly always used by writers when they describe their own scientific work; it is also often used (as in text 4) when they give instructions for performing an experiment. The alternative here would be the imperative (see Exercise V, p. 44), but this occurs more in the elementary type of textbook and in handbooks, such as those on cookery.

Apart from the reason for using the passive that has already been discussed, there are other minor reasons for using it that are exemplified below:

- 16.104 In these the development of the adult organs *is delayed* until a late stage and then takes place rapidly by means of imaginal discs.
 7.17 There can, however, be no doubt that the lash possesses structure, for all evidence goes to show that it is the lash itself which is contractile, and that it *is not moved* by some means from the inside of the cell.
 16.74 The female-producing genes act as temporary inhibitors to the production of male characters in the gipsy moth up to the time at which the male-producing factors win, and the animal *is switched over* from one sex to the other.
 16.47 If it be true that a structure *is formed* at a certain time as a result of a reaction of a certain speed, then if the speed *is increased* the structure *will be formed* earlier.

5.39 The chloroplasts and nuclei congregate in the apex of a filament before the septum *is laid down* . . .

3.68 A different pattern *is found* in the gymnosperms . . .

In sentences like 16.104 and 7.17 it would in any case be very difficult to convert the passive verb into an active one. Where would one find a subject for it? There is no grammatical agent in either sentence; *means* is not the agent in 7.17, since *by some means* is equivalent to *in some way*. In 16.74 an active verb could be used with the same subject (*the animal switches over*), but would remove from the subject the idea of passivity. The use of the passive in 16.47, however, is largely a matter of convention, and here the active could be used with the same subjects without a change in meaning (*a structure forms*, etc.). In 5.39, the verb is an alternative (but which can only be used in the passive) to *is formed* or *forms*. Similarly, *is found* in 3.68 is a passive alternative to the active *occurs*.

Another point worth mentioning is that many verbs which in the active form may be followed by *that*, such as *see*, *know*, *show*, *suppose*, have a passive construction with the infinitive.

3.76 The sieve-tubes are commonly supposed *to be* the main conducting channels of food substances . . .

The active version of this (although not so appropriate) might be 'Botanists commonly suppose *that* sieve-tubes are the main conducting channels of food substances.' An alternative passive construction would be 'It is commonly supposed *that* sieve-tubes. . .'

EXERCISES

- I *Rewrite the following statements to show that you fully understand the meaning of each. Expand them if necessary and use diagrams if these will help:*
- 1 ' . . . a graph of bottle values plotted against depth can be constructed and the area under the curve used to estimate the column.' (4.42)
 - 2 'The water in the bottles is thus now brown in color†; the darker the color† the more oxygen.' (4.16)
 - 3 'The decline of oxygen in the dark bottles indicates the amount of respiration in the water column whereas the oxygen change in the light bottles indicates the net photosynthesis . . .' (4.25)
 - 4 'At sea it is not necessary to resuspend bottles in the sea and stand by for 24 hours; the samples can be subjected to the light and temperature conditions of the sea on the deck of the ship as it moves to a new sampling location.' (4.52)
 - 5 'After an interval of time the phytoplankton is removed by a filter that is "counted" by a detector to determine the amount of radioactive carbon fixed. This method, which indicates the net photosynthesis, is widely used in oceanographic work.' (4.48)

† American spelling

- II *Re-write the following sentences with suitable prepositions in the spaces:*
- 1 Oxygen production . . . green plants is directly proportional . . . fixation . . . light energy.
 - 2 The physical exchange of oxygen . . . air and water and . . . water and sediments must be estimated.
 - 3 In the construction of the graph, oxygen values are plotted . . . depth.
 - 4 A portion . . . a sample of water . . . each of several levels is placed . . . glass bottles.
 - 5 This treatment releases elemental iodine . . . proportion . . . the oxygen content.
 - 6 Pairs of light and dark bottles are suspended . . . the pond . . . the levels . . . which the water samples were drawn.
 - 7 The object is to measure the oxygen changes resulting . . . the metabolism . . . the plankton organisms.
 - 8 Oxygen measurements are made . . . 2- or 3-hour intervals . . . a 24-hour cycle.
 - 9 The oxygen content . . . water can be expressed . . . milligrams . . . litre.
 - 10 The samples can be subjected . . . the light and temperature conditions . . . the sea . . . the deck of the ship as it moves . . . a new sampling location.
 - 11 . . . the end of the 24-hour period the string of bottles is removed . . . the pond and oxygen in each 'fixed' . . . addition . . . a succession . . . three reagents.
 - 12 The rate of photosynthesis in the water column can be calculated . . . a square metre basis . . . averaging values . . . each metre level and converting them . . . oxygen . . . litre . . . oxygen . . . cubic metre.
- III *In the following sentences replace the italicized words by one word of similar meaning, making any changes in word order that may be necessary:*
- 1 The *method of doing things* in both experiments is fundamentally the same.
 - 2 The physical exchange of oxygen between water and *solids settled on the bottom* must be estimated.
 - 3 One or more bottles are covered with aluminium metal *in the form of a very thin sheet*.
 - 4 The quantity of *factual and numerical information* that can be gathered may be increased.
 - 5 This is a method *requiring much repetitive work*.
- IV *Write down the nouns that correspond to the following verbs used in the text: measure (4.1), release (4.15), titrate (4.18), calibrate (4.21), add (4.29), convert (4.34), indicate (4.51), estimate (4.66), replace (4.73).*

- V *The following sentences give instructions similar to those in the text, but the verbs are in the imperative (see p. 41). Re-write the sentences changing these verbs into the passive.*
- 1 Add the two quantities in order to obtain a figure for total photosynthesis.
 - 2 Remove the string of bottles from the pond at the end of the 24-hour period.
 - 3 Cover the bottles with black tape or similar material.
 - 4 Plot bottle values against depth and use the area under the curve to estimate oxygen production in the water column.
 - 5 Titrate the prepared solution in the laboratory with sodium thio-sulphate.
- VI *Re-write the following sentences putting the italicized verbs into the passive (see p. 40), leaving out or changing other words when necessary or advisable:*
- 1 A. E. Mirsky *has obtained* pure chromosomal material for analysis.
 - 2 The decline of oxygen in the dark bottle *indicates* the amount of respiration in the water column.
 - 3 We *know* very little of the manner in which the transport of food substances takes place.
 - 4 The 'oxygen electrode' may soon *replace* the method of estimating oxygen described above.
 - 5 Research workers *have found* that tetraploid cells have 12×10^{-9} milligrams of DNA per nucleus.
 - 6 Removal of the phloem, the tissue containing the sieve-tubes, *brings* food conduction to a standstill.
 - 7 In surface view we *see* that the pits are collected into groups or lattices.
 - 8 Treating chromosomes with deoxyribonuclease *removes* the DNA but *leaves* a shadow of the chromosome structure.
 - 9 The two quantities added *give* an estimate of total photosynthesis.
 - 10 Workers *have shown* that chromosomes contain DNA, RNA and several kinds of proteins.