A-level Biology: Fieldwork and beyond

Mark Ward
Field Studies Council
Aims

CPAC opportunities – practical endorsement

Apparatus and techniques practical skills

How to design and adapt...

Required practical 12: Investigation into the effect of a named environmental factor on the distribution of a given species.

Required practical 10: Choice Chambers

Required practical 7: Chromatography

Maximise maths skills opportunities

Other spec content via fieldwork

Synoptic links?

How to design and adapt...

Also Field Studies Council aspirations...

• Environmental awareness
• Benefits of outdoor learning
• ‘Real science’?

My challenge:
Use RP 12 as an example to show you how you can design a rich, synoptic learning experience (even using limited habitats at or near your school).
Requirements

Required practical 12: Investigation into the effect of a named environmental factor on the distribution of a given species.

Apparatus and techniques covered (not full statements).

a. use appropriate apparatus to record a range of quantitative measurements
b. use appropriate instrumentation to record quantitative measurements
h. safely and ethically use organisms to measure: plant or animal distribution
k. use sampling techniques in fieldwork
l. use ICT such as data logger to collect data or use software to process data

Indicative apparatus: tape measures, random number tables, species identification chart, quadrats (could use point quadrat).
## Amount of choice in RP12

<table>
<thead>
<tr>
<th>Increasing independence</th>
<th>Least choice</th>
<th>Some choice</th>
<th>Many choices</th>
<th>Full investigation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Least choice</strong></td>
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<td>Teacher chooses the species and the environmental factor to be investigated.</td>
<td></td>
<td></td>
<td>Teacher allows a limited choice of environmental factors.</td>
<td>Student decides on a question.</td>
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<td>Students use random sampling to investigate the distribution of the species.</td>
<td></td>
<td>Teacher allows a limited choice of environmental factors.</td>
<td>Students use random sampling to investigate the distribution of the species.</td>
<td>Student researches methods for carrying out the experiment then chooses equipment, materials, justifying all choices.</td>
</tr>
<tr>
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### Opportunities to observe and assess different practical competencies for CPAC (see practical handbook)

- Teacher chooses the species and the environmental factor to be investigated.
- Students use random sampling to investigate the distribution of the species.
- Experiments fully specified in terms of equipment and method.
- Teacher allows a limited choice of environmental factors.
- Students use random sampling to investigate the distribution of the species.
- Experiment probably fully specified by teacher.
- Teacher allows a choice of species and environmental factors.
- Students use random sampling to investigate the distribution of the species.
- Outline method provided by teacher.
- Student decides on a question.
- Student researches methods for carrying out the experiment then chooses equipment, materials, justifying all choices.
Investigation into distribution of dandelions in a lawn not treated with herbicide and a lawn treated with herbicide using a point quadrat.

See practical handbook.
Method from student sheet

You are provided with the following:
• point frame (also called a point quadrat or pin frame)
• two tape measures.

You should read these instructions carefully before you start work
1. Before going to the lawn, generate 10 sets of random co-ordinates.
2. Go to the lawn where one site is an herbicide-treated lawn and the other an untreated lawn (your teacher will tell you which area is treated). Make sure you can identify a dandelion plant by the shape of its leaves.
3. Lay out the tapes at right angles and place the point quadrat at the first set of co-ordinates.
4. Use the pointers in the point frame to record the dandelions at this position. Look at the plants hit by the points and attempt to identify them. As each pointer is lowered, you must record any dandelion that is “hit” by the pointer, in the tally chart. Repeat this at the position determined by each set of co-ordinates.

5. Take 100 pointer samples in each site, ie 10 placements of the point quadrat.

6. Carry out the data collection from the two sites. Then add up the total number of dandelion plants in each of the two sites.

\[
\text{\% cover of dandelions} = \left( \frac{\text{no. of dandelion plants hit}}{\text{total no. of pointersamples}} \right) \times 100
\]

For each of the stages of the suggested method how can we improve or modify the procedure to cover as many skills as possible?
Stage 1

1. Before going to the lawn, generate 10 sets of random co-ordinates.

**Ideas to improve or modify?**

- Random number tables.
- Use random number button on calculator.
- Use `=randbetween(1,99)` on spreadsheet.
- Use phone numbers (middle two digits).

What happens if two co-ordinates are the same?

Also discuss:
- Different numbers of co-ordinates/sample size?
- How can we estimate minimum sample size?
Cumulative mean method – estimating minimum sample size

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Cumulative mean method – estimating minimum sample size

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Cumulative Mean

Sample size (no. of quadrats)
Cumulative mean method – estimating minimum sample size

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**Graph:**
- Cumulative Mean
- Sample size (no. of quadrats)
### Cumulative mean method – estimating minimum sample size

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Sample size (no. of quadrats)
### Cumulative mean method – estimating minimum sample size

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**Diagram:**
- **Cumulative Mean:**
- **Sample size (no. of quadrats):**
### Cumulative mean method – estimating minimum sample size

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- Cumulative mean method – estimating minimum sample size

- Sample size (no. of quadrats)
Cumulative mean method – estimating minimum sample size

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Also Note:

Maths skills covered
- MS 0.2 (appropriate no. of d.p.s)
- MS 0.4 (estimate results…)
- MS 1.2 (arithmetic means)
- MS 1.3 (construct, interpret graphs)

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When cumulative mean stabilises no need to put down further quadrats?

eg minimum no. of quadrats = 10?
2. Go to the lawn where one site is an herbicide-treated lawn and the other an untreated lawn (your teacher will tell you which area is treated). Make sure you can identify a dandelion plant by the shape of its leaves.

**Ideas to improve or modify?**

- Different comparisons: light/shade, trampled/untrampled, mown/grazed, tall/short grass, sloping/flat.
- Different plants: yarrow, daisy, clover, thistle, plaintain, lesser celandine, nettle (?) etc. Identification skills.
Task: Identification of playing field plants

Match these plants to the correct letters:

- Lesser Celandine
- Dandelion
- White Clover
- Thistle
- Nettle
- Ribwort Plantain
- Yarrow
- Daisy
- Red Clover.

Task: Identification of playing field plants

How many did you get?

Other links:
- 3.4.5 Species and taxonomy
- Apparatus and Techniques ‘e’: produce scientific drawing (see Practical Handbook)
- Maths skill MS 0.3 use ratios, fractions and % (inc use scales for measuring = drawing scale lines)

field-studies-council.org/publications/fold-out-charts.aspx#Plants
3. Lay out the tapes at right angles and place the point quadrat at the first set of co-ordinates.

**Ideas to improve or modify?**

- Use transects – random vs non-random sampling.
- Frame quadrats vs point quadrat (see later).

**Question – write a definition for:**
1. random sampling
2. non-random sampling.
MS 1.5 Understand the principles of sampling as applied to scientific data.

Random sampling = Unbiased subset of whole population.
Types of sampling

Positions at which samples are taken or the strategy for sampling are chosen by the investigator according to the question being investigated and some assumptions about the system being investigated.

Non-random sampling = transect (belt)
Types of sampling

Positions at which samples are taken or the strategy for sampling are chosen by the investigator according to the question being investigated and some assumptions about the system being investigated.

Non-random sampling = transect (belt)

Path
Types of sampling
Stratified sampling
Stratified sampling (random)
4. Use the pointers in the point frame, record the dandelions at this position.

Look at the plants hit by the points and attempt to identify them. As each pointer is lowered, you must record any dandelion that is “hit” by the pointer, in the tally chart. Repeat this at the position determined by each set of co-ordinates.

**Ideas to improve or modify?**

- Frequency or % cover?
- Frame quadrat vs point quadrat.
Choosing quadrat types

**Question:** what determines ‘size’ of frame quadrat used?

- Size of organism?
- How common/dispersed/patchy?
- Size of whole sample area?
Choosing quadrat types

Quadrat sampling game:

![Image of students conducting quadrat sampling](image-url)
Choosing quadrat types

Quadrat sampling game
- Place cardboard shapes randomly on the ground.
- Use different quadrat types in turn to estimate abundance of the cardboard shapes (=plants).
- Complete the results column.
- Consider the advantages and disadvantages of each type of quadrat.

<table>
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<th>Description</th>
<th>Result</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Density</td>
<td>Individuals per unit area (eg count individuals)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% cover</td>
<td>Proportion of area covered by a species</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>% frequency</td>
<td>Presence/absence of a species at points/in squares</td>
<td>100 square:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. 100 square gridded frame quadrat</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Point frame quadrat</td>
<td>Point quadrat:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative abundance</td>
<td>Into categories (ACFOR)</td>
<td>Circle...</td>
<td>A C F O R</td>
<td></td>
</tr>
</tbody>
</table>
Choosing quadrat types

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Description</th>
<th>Result</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (open quadrat)</td>
<td>Individuals per unit area (eg count individuals)</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% cover (open quadrat)</td>
<td>Proportion of area covered by a species</td>
<td>65%</td>
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<td>% frequency</td>
<td>Presence/absence of a species at points/in squares</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>1. 100 square gridded frame</td>
<td>100 square:</td>
<td>58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Point frame quadrat</td>
<td>Point quadrat:</td>
<td>38</td>
<td></td>
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<td>Relative abundance</td>
<td>Into categories (ACFOR)</td>
<td>Circle...</td>
<td></td>
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<tr>
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Choosing quadrat types

### Calculating area of quadrats

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<th>Result</th>
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<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Density</strong> (open quadrat)</td>
<td>Individuals per unit area (e.g., count individuals)</td>
<td>7</td>
<td>Accurate if all individuals identified.</td>
<td>Difficult to identify ‘individual’ specimens.</td>
</tr>
<tr>
<td>% cover (open quadrat)</td>
<td>Proportion of area covered by a species</td>
<td>65%</td>
<td>Quick and easy.</td>
<td>Subjective. Misses underlying vegetation.</td>
</tr>
<tr>
<td>% frequency</td>
<td>Presence/absence of a species at points/in squares</td>
<td>100 square: 58</td>
<td>Objective.</td>
<td>Overestimate (esp. of small species). Time consuming.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Point quadrat: 38</td>
<td>Objective: see underlying vegetation.</td>
<td>Time consuming. Pin head small (not representative unless large sample size).</td>
</tr>
<tr>
<td>Relative abundance</td>
<td>Into categories (ACFOR)</td>
<td>Circle... A C F O R</td>
<td>Quick. Easy comparison of different species/types/sizes.</td>
<td>Less precise as based on subjective estimates. Can’t do stats (semi-quantitative).</td>
</tr>
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</table>
Calculating quadrat areas

MS 0.1 Recognise and make use of appropriate units in calculations

Students may be tested on their ability to convert between units

For example, to calculate area of a 0.5 m by 0.5 m quadrat for ecological analysis:

- could calculate the area of the quadrat in m$^2$ as 0.5 x 0.5 = 0.25 m$^2$
- issues can arise if use 1 m = 100 cm to convert this area into centimetres.

Question: What is the area stated as cm$^2$?

- Misconception can be that if 1 m is 100 cm then 0.25 m$^2$ is 25 cm$^2$.
- **But** 0.5 m = 50 cm so the correct area is 50 x 50 = 2500 cm$^2$.
- The difference in these answers is a factor of 100 and can lead to massive calculation errors.
Stages 5-6

5. Take 100 pointer samples in each site, ie 10 placements of the point quadrat.
6. Carry out the data collection from the two sites. Then add up the total number of dandelion plants in each of the two sites.

\[
\text{% cover of dandelions} = \left( \frac{\text{no. of dandelion plants hit}}{\text{total no. of pointer samples}} \right) \times 100
\]

Ideas to improve or modify?

- Sample size? (See earlier).
- How to decide number of samples? (See earlier).
- Type of quadrats (see earlier).

Question: How could we increase sample size without more placements of point quadrat?
5. Take 100 pointer samples in each site, ie 10 placements of the point quadrat.
6. Carry out the data collection from the two sites. Then add up the total number of dandelion plants in each of the two sites.

\[ \text{% frequency of dandelions} = \left( \frac{\text{no. of dandelion plants hit}}{\text{total no. of pointer samples}} \right) \times 100 \]

**Ideas to improve or modify?**

- Sample size? (See earlier).
- How to decide number of samples? (See earlier).
- Type of quadrats (see earlier).

**Question:** Is there a possible error in wording in stage 6?
Summary

We have looked at:

• RP12 method as suggested in the practical handbook activity
• how to adapt it and set in context of developing practical and maths skills.

For the Apparatus and Techniques - AT k (fieldwork sampling):

• investigate the distribution of organisms in a named habitat using randomly placed frame quadrats, or a belt transect
• use both percentage cover and frequency as measures of abundance of a sessile species.
Maths Skills have included aspects of:

- MS 1.5 understand the principles of sampling as applied to scientific data
- MS 0.1 recognise and make use of appropriate units in calculations
- MS 0.3 use ratios, fractions and %
- MS 0.2 (appropriate no. of d.p.s)
- MS 0.4 (estimate results…)
- MS 1.2 (arithmetic means)
- MS 1.3 (construct, interpret graphs).
Required practical 12: developing extended sessions

Task: using the map below of an imaginary field site with a range of habitats, write down a list of other fieldwork investigation titles that would:
1. cover some or all of the apparatus and techniques listed for RP12
2. cover the relevant areas of the specification.
Required practical 12: developing extended sessions

Apparatus and techniques covered (not full statements):

a. use appropriate apparatus to record a range of quantitative measurements
b. use appropriate instrumentation to record quantitative measurements
h. safely and ethically use organisms to measure: plant or animal distribution.

Students could:
use the mark-release-recapture method to investigate the abundance of a motile species.
k. use sampling techniques in fieldwork.

**Students could:**
- investigate the distribution of organisms in a named habitat using randomly placed frame quadrats, or a belt transect
- use both percentage cover and frequency as measures of abundance of a sessile species.

i. use ICT such as data logger to collect data or use software to process data.
Directly relevant specification content:

3.7 Genetics, populations, evolution and ecosystems (A-level only)
Populations of different species live in communities. Competition occurs within and between these populations for the means of survival. Within a single community, one population is affected by other populations, the biotic factors, in its environment. Populations within communities are also affected by, and in turn affect, the abiotic (physicochemical) factors in an ecosystem.

3.7.4 Populations in ecosystems
Investigation into changes in the abundance of species X between stream/pond, mown/grazed (untreated), treated/untreated (mown).

Investigation into changes in the abundance of species X with distance from woodland/stream edge/hedge/building.

Investigation into abundance of species X (e.g., Pleurococcus/moss) on tree trunks/gravestones with changing aspect.

Investigation into abundance of species X in different areas of a stream (pool v riffle/deep v shallow, with velocity).
  - Collect leaf samples if studying plants/algae to use in RP7: Chromatography.
  - Note: in any of these investigations – could record the size of species X instead or as well as abundance. Size = length, height, leaf area etc..
  - Collect organisms (e.g., woodlice) to use in RP10: Choice Chambers.

Collect organisms (e.g., woodlice) to use in RP10: Choice Chambers.
Also...

- M-R-R on snails on wall/woodlice under dead logs/snails in pond.
  - Collect organisms (eg woodlice) to use in RP10: Choice Chambers.
Field session one

- Initial activities to explore how to plan sampling (sample size, sampling type, quadrat type).
- Use keys. Biological drawing of plant leaves (in situ) – AT e.
- Decisions about measuring other environmental variables.
- Carry out whole class investigation using method agreed by class (random sampling of plants in two areas).
- Could record all plant species (not just sp. X).
- Could measure leaf/plant size of one species (use calipers?)
- Collect leaf samples for RP7.
- Collect and mark organisms as part of m-r-m investigation. Keep sample for RP10.
Required practical 12: Lesson plan for fieldwork sessions

**Classroom follow up:**
- analysis of data (maths skills): species diversity, using statistics
- construct and interpreting graphs etc
- evaluation of techniques.

**Discussion:**
- relevant specification content
- planning for session two.
Field session two:
• carry out individual/small group investigations based around RP12 title
• allows for further higher level CPAC opportunities esp CPAC 2 and CPAC 5.

Classroom follow up:
• analysis of data
• evaluation
• poster/presentation.
Required practical 12: developing extended sessions

Are we covering the required apparatus and techniques suggested for RP12?

a. use appropriate apparatus to record a range of quantitative measurements
b. use appropriate instrumentation to record quantitative measurements
h. safely and ethically use organisms to measure: plant or animal distribution
k. use sampling techniques in fieldwork
i. use ICT such as data logger to collect data or use software to process data.

- Uprooting plants, avoid trampling, returning animals, turning back rocks
- Quadrats, probes, dataloggers, calipers
- Spreadsheets, graphs, stats software, ID apps, ArcGIS
## Required practical 12: developing extended sessions

<table>
<thead>
<tr>
<th>Common practical assessment criteria</th>
<th>CPAC 1: Follows written procedures</th>
<th>CPAC 2: Applies investigative approaches and methods when using instruments and equipment</th>
<th>CPAC 3: Safely uses a range of practical equipment and materials</th>
<th>CPAC 4: Makes and records observations</th>
<th>CPAC 5: Researches, references and reports</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPAC 1: Follows written procedures</td>
<td>(a) Correctly follows instructions to carry out the experimental techniques or procedures.</td>
<td>a) Correctly uses appropriate instrumentation, apparatus and materials (including ICT) to carry out investigative activities, experimental techniques and procedures with minimal assistance or prompting.</td>
<td>a) Identifies hazards and assesses risks associated with these hazards, making safety adjustments as necessary, when carrying out experimental techniques and procedures in the lab or field.</td>
<td>(a) Makes accurate observations relevant to the experimental or investigative procedure.</td>
<td>(a) Uses appropriate software and/or tools to process data, carry out research and report findings.</td>
</tr>
<tr>
<td>CPAC 2: Applies investigative approaches and methods when using instruments and equipment</td>
<td>(b) Carries out techniques or procedures methodically, in sequence and in combination, identifying practical issues and making adjustments when necessary.</td>
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<td>(b) Uses appropriate safety equipment and approaches to minimise risks with minimal prompting.</td>
<td>(b) Obtains accurate, precise and sufficient data for experimental and investigative procedures and records this methodically using appropriate units and conventions.</td>
<td>(b) Sources of information are cited demonstrating that research has taken place, supporting planning and conclusions.</td>
</tr>
<tr>
<td>CPAC 3: Safely uses a range of practical equipment and materials</td>
<td>(c) Identifies and controls significant quantitative variables where applicable, and plans approaches to take account of variables that cannot readily be controlled.</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPAC 4: Makes and records observations</td>
<td>(d) Selects appropriate equipment and measurement strategies in order to ensure suitably accurate results.</td>
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<td></td>
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</tr>
<tr>
<td>CPAC 5: Researches, references and reports</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>
Using the AQA suggested practical we can cover:

- MS 1.5 Understand the principles of sampling as applied to scientific data.
- MS 0.1 Recognise and make use of appropriate units in calculations.
- MS 0.3 Use ratios, fractions and %.
- MS 0.2 (appropriate no. of d.p.s).
- MS 0.4 (estimate results…).
- MS 1.2 (arithmetic means).
- MS 1.3 Construct, interpret graphs.
If we expand fieldwork sessions we can also cover:

- MS 1.6 Understand the terms, mean, median and mode.
- MS 1.7 Use a scatter diagram to identify a correlation between two variables.
- MS 1.9 Select and use a statistical test.
- MS 1.10 Understand measures of dispersion, including standard deviation and range.
- MS 1.3 Construct, interpret bar charts and histograms (including SE bars).
- MS 1.11 Identify uncertainties in measurements.
- MS 2.3 Substitute numerical values into algebraic equations (e.g., Simpson’s Index of Diversity).
Species richness (R) =

Measure of number of species in a particular area or habitat.
Simpson’s Index of Diversity

Species richness (R) =
Measure of number of species in a particular area or habitat.

Species diversity (D) =
Measure of number and relative abundance of species in a particular area or habitat.
Simpson’s Index of Diversity

Area one
Species Richness (R) = 4

Higher Diversity
= ecological equilibrium

Area two
Species Richness (R) = 4

Lower Diversity
= ecological stress
Simpson’s Index of Diversity

\[ D = 1 - (\Sigma \ (n/N)^2) \]

n = number of individuals of a species
N = Total number of individuals of all species
\( \Sigma \) = sum of

Maximum D = 1. Minimum D = 0.
More diverse an area, D value closer to 1.
Simpson’s Index of Diversity

Example....

D = 1 − (Σ (n/N)²)

<table>
<thead>
<tr>
<th>Species</th>
<th>Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>32</td>
</tr>
<tr>
<td>B</td>
<td>78</td>
</tr>
<tr>
<td>C</td>
<td>86</td>
</tr>
</tbody>
</table>

N = Total No. of individuals

N = 32 + 78 + 86 = 196
Simpson’s Index of Diversity

Example....

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Next Step.... \((n/N)^2\) for each species:

\[
\begin{align*}
\frac{32}{196} &= 0.1632653^2 = 0.0266555 \\
\frac{78}{196} &= 0.3979592^2 = 0.1583715 \\
\frac{86}{196} &= 0.4387755^2 = 0.1925394 \\
\end{align*}
\]

Σ \((n/N)^2\) = 0.3775664

Finally... \(1 - (\Sigma \ (n/N)^2)\) = 1 - 0.3775664 = 0.6224336

= 0.62

MS 0.2 Recognise and use expressions in decimal and standard form.
MS 1.11 Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined.
Leaf size investigation

Sample data
Leaf length (mm) of *Plantago lanceolata* in two contrasting areas of grassland.

<table>
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<tr>
<th>Area 1: mown</th>
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</table>

What maths skills can be tested here?
- M0.2 Recognise and use expressions in decimal and standard form.
- M1.1 Use an appropriate number of significant figures.
- M1.2 Find arithmetic means.
- M1.3 Construct and interpret frequency tables and diagrams, bar charts and histograms.
- M1.6 Understand the terms mean, median and mode.
- M1.10 Understand measures of dispersion, including standard deviation and range.
- M1.9 Select and use a statistical test.
- M1.11 Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined.
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Mean

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Mean 35.800 57.175

What maths skills can be tested here?
- M0.2 Recognise and use expressions in decimal and standard form.
- M1.1 Use an appropriate number of significant figures.
- **M1.2 Find arithmetic means.**
- M1.3 Construct and interpret frequency tables and diagrams, bar charts and histograms.
- M1.6 Understand the terms mean, median and mode.
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What maths skills can be tested here?

M0.2 Recognise and use expressions in decimal and standard form.

Decimal places and significant figures
Students are expected to record raw data to the same number of decimal places (rather than the same number of significant figures).

For example, in this table all values are to 2 decimal places but they do not have the same number of significant figures.

Note: in exams may be asked to record answer(s) to a particular number of decimal places or to a particular number of significant figures.
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What maths skills can be tested here?

M0.2 Recognise and use expressions in decimal and standard form.

Processed data can be recorded to up to one decimal place more than the raw data.

For example, calculated mean for this example could be recorded as 57.175 mm or 57.18 mm.
# Leaf size investigation

## Sample data
Leaf length (mm) of *Plantago lanceolata* in two contrasting areas of grassland.

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<td>48.15</td>
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<tr>
<td>27.55</td>
<td>30.90</td>
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<td>35.10</td>
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<td>25.90</td>
<td>49.90</td>
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<tr>
<td>44.75</td>
<td>39.85</td>
</tr>
</tbody>
</table>

**Mean**  
35.80  57.18

## What maths skills can be tested here?

- **M0.2** Recognise and use expressions in decimal and standard form.
- **M1.1** Use an appropriate number of significant figures.
- **M1.2** Find arithmetic means.
- **M1.3** Construct and interpret frequency tables and diagrams, bar charts and histograms.
- **M1.6** Understand the terms mean, median and mode.
- **M1.9** Select and use a statistical test.
- **M1.10** Understand measures of dispersion, including standard deviation and range.
- **M1.11** Identify uncertainties in measurements and use simple techniques to determine uncertainty when data are combined.
Stats – why bother?
- to test whether sample data is significant = good
- …or could values have arisen by chance?
- …how much confidence do you have in your data?

- Especially if samples are small.

- Especially if any patterns or trends in data are unclear (is something going on or not?)

- Stats means prizes (can come up in exams).
MS 1.9 Select and use a statistical test

Statistics – flowchart

- Formulae that you can put **sample** data into to test its **significance**.
- Different tests for different types of sample data.
- Learners must be able to choose correct test for their data.
Leaf size investigation

Sample data
Leaf length (mm) of *Plantago lanceolata* in two contrasting areas of grassland.

<table>
<thead>
<tr>
<th>Area 1: mown</th>
<th>Area 2: unmown</th>
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</thead>
<tbody>
<tr>
<td>30.55</td>
<td>60.00</td>
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<tr>
<td>41.60</td>
<td>104.60</td>
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<td>40.00</td>
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<tr>
<td>44.75</td>
<td>39.85</td>
</tr>
</tbody>
</table>

Mean 35.80 57.18

Which stats test will be used here?

- Student’s t-test (MS 1.9).
- Also need standard deviation (MS 1.10).
- Also draw histograms (MS 1.3).
MS 1.9 Select and use a statistical test

Teaching stats: handy hints

- Don’t ‘over-teach’.
- Ensure differentiation for range of maths ability.
- Peer teaching?
- Calculators vs manual vs spreadsheets?
- Don’t get bogged down in ‘number crunching’.
- Don’t lose sight of ‘why’.
- Teach Spearman’s first? Easier?
3.7 Genetics, populations, evolution and ecosystems (A-level only)

Populations of different species live in communities. Competition occurs within and between these populations for the means of survival. Within a single community, one population is affected by other populations, the biotic factors, in its environment. Populations within communities are also affected by, and in turn affect, the abiotic (physicochemical) factors in an ecosystem.

3.7.4 Populations in ecosystems


Also… 3.4.5 Species and taxonomy

How do we make wider synoptic links?
Plants – Synoptic Links

Distribution and abundance of plants
Plants – Synoptic Links

- Light
  - Distribution and abundance of plants
  - Plants need
Plants – Synoptic Links

Distribution and abundance of plants

Light

Water

Plants need Light

Plants need Water
Plants – Synoptic Links

- Light
- Water
- Nutrients

Distribution and abundance of plants

Plants need:
- Light
- Water
- Nutrients
Plants – Synoptic Links

Distribution and abundance of plants

Photosynthesis

Light

Water

Nutrients

Plants need

for

Plants need

Plants need

Nutrients for Photosynthesis
Plants – Synoptic Links

Distribution and abundance of plants

- Light
  - for Photosynthesis
- Water
  - plants need
- Nutrients
  - plants need

Photosynthesis

Plants – Synoptic Links

Distribution and abundance of plants

Photosynthesis

Light

Water

Nutrients

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Plants – Synoptic Links

- Photosynthesis
- Light
- Water
- Transport

Distribution and abundance of plants

- Nutrients
- Plants need for photosynthesis
- Affects the transport of nutrients
- Plants need water for photosynthesis

Light for photosynthesis
Plants – Synoptic Links

Photosynthesis

Light

Water

Transport

Nutrients

Distribution and abundance of plants

Plants need

Light affects the

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Nutrients plants need

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Transport

Distribution and abundance of plants

Plants need

Water

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Light

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Photosynthesis
Plants – Synoptic Links

Photosynthesis

Light

Transport

Nutrients

Distribution and abundance of plants

Water

Support

Light affects the plants, and for photosynthesis, so plants need water and their transport for support.
Plants – Synoptic Links

Distribution and abundance of plants

Photosynthesis

Light

Transport

Water

Support

Turgor pressure

Nutrients

Plants need

Light affects the plants need

Photosynthesis

Transport

and their

Support

depends on

Water

Plants need

Nutrients

Plants need

Nutrients

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Plants – Synoptic Links

**Distribution and abundance of plants**

*Light*

*Water*

*Cells*

*Transport*

*Support*

*Photosynthesis*

*Plants need*

*Nutrients*

*Plants need*

*Water*

*Can enter and leave*

*Support depends on*

*Turgor pressure*

*Plants need*

*Transport*

*for*

*and their*

*Light affects the*

*Plants need*

*for Photosynthesis so affects the Transport*

*Cells*

*Plants need*

*Can enter and leave Cells depends on Turgor pressure*
Plants – Synoptic Links

- **Distribution and abundance of plants**
  - **Nutrients**
  - **Photosynthesis**
    - Light
  - **Water**
    - Cells
      - Osmosis
        - Turgor pressure
  - **Transport**
    - and their
      - depends on
    - for
      - can enter and leave
  - for
    - and
  - so
    - affects the
      - plants need
  - plants need

Photosynthesis

Water

Transport

Support

Cells

Osmosis

Turgor pressure

Cells

Nutrients

Distribution and abundance of plants

Light

Transport

Support

Nutrients

Distribution and abundance of plants

Light

Photosynthesis

Water

Cells

Osmosis

Turgor pressure

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Plants – Synoptic Links

- **Distribution and abundance of plants**
- **Photosynthesis**
  - Light affects the plants need for photosynthesis.
  - Water is used in photosynthesis.
- **Light**
  - Affects the plants need for light.
- **Water**
  - Plants need water for photosynthesis.
  - Water can enter and leave cells through osmosis.
- **Nutrients**
  - Plants need nutrients for distribution and abundance.
- **Transport**
  - For and and their depends on turgor pressure.
- **Support**
  - Turgor pressure depends on cells.
Plants – Synoptic Links

Photosynthesis

Light

Transport

Water

Cells

Support

Nutrients

Distribution and abundance of plants

Plants need Nutrients

Plants need Water

Water can enter and leave Cells through Osmosis affecting Turgor pressure and their depends on

Light affects the plants need for and

Photosynthesis so for and

Transport for and their

Support and their
Plants – Synoptic Links

Distribution and abundance of plants

Photosynthesis

Light

Transport

Water

Cells

Osmosis

Support

Turgor pressure

A lack of water can affect the distribution of plants in many ways

Plants need

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A lack of water can affect the distribution of plants in many ways

Transport

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A lack of water can affect the distribution of plants in many ways. Plants need water for photosynthesis, which affects the transport of nutrients and their support through turgor pressure. Waterlogging can disrupt osmosis, affecting cells. Nutrients are also required for distribution and abundance of plants.
Plants – Synoptic Links

**Distribution and abundance of plants**

- **Photosynthesis**
  - **Light**
  - **Water**
  - **Cells**
  - **Support**
  - **Osmosis**
  - **Turgor pressure**

**Plants need**
- **Light**
- **Water**
- **Nutrients**
- **Transport**

A lack of water can affect the distribution of plants in many ways.

**Waterlogging**
- leads to **Anaerobic conditions**

**Transport**
- **Support**
- **Nutrients**

**Nutrients**
- for **Photosynthesis**
- affects the **distribution** of plants in many ways

**Photosynthesis**
- for **Light**
- affects the **distribution** of plants in many ways

**Light**
- for **Water**
- affects the **distribution** of plants in many ways

**Water**
- for **Transport**
- plants need
- through **Osmosis**
- can enter and leave cells

**Cells**
- affects **Turgor pressure**
- depends on

**Support**
- for **Transport**
- and their

**Nutrients**
- for **Photosynthesis**
- affects the **distribution** of plants in many ways

**Distribution and abundance of plants**

- **Waterlogging**
- leads to **Anaerobic conditions**

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Plants – Synoptic Links

Photosynthesis

Light

Water

Transport

Support

Osmosis

Cells

Transport

Nutrients

Distribution and abundance of plants

Water

A lack of water can affect the distribution of plants in many ways

Nutrients

Waterlogging

Anaerobic conditions

A lack of water can affect the distribution of plants in many ways

Transport

Support

Transport

A lack of water can affect the distribution of plants in many ways
Plants – Synoptic Links

Distribution and abundance of plants

Photosynthesis

Light

Water

Transport

Support

Nutrients

Waterlogging

Cells

Osmosis

Anaerobic conditions

Respiration

for

and

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plants need

plants need

water

Water can enter and leave cells through osmosis affecting turgor pressure.

A lack of water can affect the distribution of plants in many ways.
Plants – Synoptic Links

**Distribution and abundance of plants**

- **Light**
- **Water**
- **Nutrients**
- **Photosynthesis**
- **Transport**
- **Support**
- **Waterlogging**
- **Cells**
- **Osmosis**
- **Anaerobic conditions**
- **Oxygen**
- **Plant roots**

A lack of water can affect the distribution of plants in many ways. A lack of oxygen can affect respiration and for the survival of roots.

**Light** affects the plants need for photosynthesis so it affects the transport and their support. Waterlogging leads to anaerobic conditions affecting the oxygen for respiration and the turgor pressure of cells. Osmosis can enter and leave the cells depending on the pressure. Nutrients are needed for photosynthesis so it affects the transport and their support. Plant roots by respiration for oxygen.
A lack of water can affect the distribution of plants in many ways. Light affects the distribution of plants. Transport and their support depend on turgor pressure. Waterlogging leads to anaerobic conditions affecting respiration. Plant roots have active transport reducing respiration. Oxygen is needed for respiration. Water for photosynthesis is important and affects cells through osmosis. Nutrients are needed for photosynthesis and affects the distribution of plants.
Plants – Synoptic Links

- Distribution and abundance of plants
  - Plants need light, water, and nutrients for Photosynthesis, which affects the distribution of plants in many ways.
  - Transport for and their needs
  - Water for and their needs
  - Light for and their needs
- Support depends on Turgor pressure
- Anaerobic conditions caused by Active transport reducing Respiration, with less Oxygen affecting Osmosis through Cells.
- Waterlogging leads to A lack of water affecting the distribution of plants in many ways.
- Nutrients and the uptake of plants need Active transport for Plant roots by reducing Respiration.
Plants – Synoptic Links

Distribution and abundance of plants

Photosynthesis

Water

Light

Transport

Support

A lack of water can affect the distribution of plants in many ways

Distribution and abundance of plants

Distribution and abundance of plants

Plants need Light

Plants need Water

Plants need Nutrients

So, affects the Transport for and their Cells

Can enter and leave through Osmosis affecting Turgor pressure

A lack of water can affect the distribution of plants in many ways

Plants need Nutrients

Nutrients

and the uptake of

Active transport

Reducing

Plant roots

Decomposers

Respiration

with less Oxygen

Anaerobic conditions

Waterlogging

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SUPPORT

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Active transport

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Plants – Synoptic Links

Distribution and abundance of plants

- Photosynthesis
  - Light
  - Transport

Water

- Cells
  - Osmosis
  - Support
    - Turgor pressure

Nutrients

- Plants need
- Nutrients
- Active transport
  - Plant roots
- Decomposers
- Recycling

Waterlogging

- Anaerobic conditions
- Respiration
- Oxygen
  - Anaerobic respiration

A lack of water can affect the distribution of plants in many ways

- and their
- depends on
- for

Cells

- Osmosis
- can enter and leave through
  - Turgor pressure
- affects
  - Water
  - Light

Light

- affects the
  - Light
- Transport
  - for
- and
- so

Transport

- for

Support

- and their
- depends on
- for

Oxygen

- for
- with less
- by
- by
- so slowing the
- reducing
- and the uptake of
Plants – Synoptic Links

Distribution and abundance of plants

Photosynthesis

Light

Transport

Water

Nutrients

Plants need

for

A lack of water can affect the distribution of plants in many ways

and their

Support

Anaerobic conditions

Osmosis

Waterlogging

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depends on

Turgor pressure

Oxygen

Respiration

Decomposers

Active transport

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A lack of water can affect the distribution of plants in many ways

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Decomposers

Active transport

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with less

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Plants – Synoptic Links

Distribution and abundance of plants

- Photosynthesis
  - Light
- Water
  - Plants need
  - A lack of water can affect the distribution of plants in many ways
- Transport
  - Light
  - Water
- Support
  - Turgor pressure

Nutrients
- Plants need
- which affects the distribution and abundance of plants
- Active transport
  - Reducing
  - Plant roots
- Recycling
  - Decomposers
  - Respiration
  - Anaerobic conditions
  - Waterlogging
  - Osmosis
  - Affecting
  - Oxygen
  - Anaerobic conditions
  - Respiration
  - Decomposers
  - Recycling
  - Turgor pressure
  - Transport
  - Support

Cells
- Plants need
- can enter and leave
- Osmosis
- Turgor pressure

Respiration
- Oxygen
- Decomposers
- Recycling
- Turgor pressure
- Transport
- Support

Decomposers
- Recycling
- Respiration
- Osmosis
- Turgor pressure
- Transport
- Support

Recycling
- Decomposers
- Respiration
- Turgor pressure
- Transport
- Support

Distribution and abundance of plants
- Water
  - Plants need
  - Nutrients
  - Photosynthesis
  - Transport
  - Support

A lack of water can affect the distribution of plants in many ways

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Plants – Synoptic Links

**Distribution and abundance of plants**

- **Water**
  - Plants need water, which affects the transport and support of plants.
  - Waterlogging leads to anaerobic conditions, reducing the uptake of nutrients such as nitrates and the supply of oxygen for respiration and the uptake of nutrients by decomposers.

- **Nutrients**
  - Plants need nutrients, which affects the uptake and supply of oxygen for respiration and the uptake of nutrients by decomposers.

- **Light**
  - A lack of water can affect the distribution of plants in many ways.
  - Waterlogging leads to anaerobic conditions, affecting the uptake of nutrients such as nitrates and the supply of oxygen for respiration and the uptake of nutrients by decomposers.

- **Transport**
  - Water and their support depend on turgor pressure.

- **Support**
  - Waterlogging leads to anaerobic conditions, affecting the uptake of nutrients such as nitrates and the supply of oxygen for respiration and the uptake of nutrients by decomposers.

**Photosynthesis**

- Plants need light for photosynthesis, affecting the distribution and abundance of plants.

**Osmosis**

- A lack of water can affect the distribution of plants in many ways.

**Respiration**

- Waterlogging affects the uptake of nutrients such as nitrates and the supply of oxygen for respiration and the uptake of nutrients by decomposers.

**Decomposers**

- Waterlogging affects the uptake of nutrients such as nitrates and the supply of oxygen for respiration and the uptake of nutrients by decomposers.

**Anaerobic conditions**

- Waterlogging affects the uptake of nutrients such as nitrates and the supply of oxygen for respiration and the uptake of nutrients by decomposers.
Plants – Synoptic Links

Distribution and abundance of plants

- Photosynthesis
- Light
- Water
- Cells
- Support

Nutrients
- Synthesis of amino acids and proteins
- Nitrates
- such as
- plants need
- which affects the
- and the uptake of
- and supply of
- reducing
- Active transport
- Plant roots
- Decomposers
- Recycling
- Respiration
- Oxygen
- Anaerobic conditions
- Waterlogging
- Water
- A lack of water can affect the distribution of plants in many ways

Transport
- for
- so
- and their
- and
- can enter and leave
- through
- depending on
- Turgor pressure

Light
- for
- so
- and
- affects the
- plants need
- affects the
- plants need
- can enter and leave
- affects

A lack of water can affect the distribution of plants in many ways.
Plants – Synoptic Links

**Synthesis of amino acids and proteins**
- Nitrates
- Phosphates
- Nutrients
  - Active transport
  - Recycling
  - Decomposers
  - Respiration

**Photosynthesis**
- Light
- Transport
- Supports
  - Turgor pressure

**Water**
- Plants need
- Nutrients
- for Photosynthesis
- and their Transport
- and their Support
- depending on Turgor pressure

**Osmosis**
- A lack of water can affect the distribution of plants in many ways

**Nutrients**
- such as Nitrates

**Respiration**
- by which affects the uptake of Nutrients
- and the supply of Nutrients

**Decomposers**
- reducing and the uptake of Nutrients
- so slowing the Anaerobic conditions

**Anaerobic conditions**
- leads to Waterlogging

**Waterlogging**
- can enter and leave Cells
- through Osmosis
- affecting with less Oxygen

**Oxygen**
- for Respiration

**Cells**
- for Water

**Support**
- depends on Turgor pressure
A lack of water can affect the distribution of plants in many ways. Light affects the distribution and abundance of plants, which affects the transport of water to the cells, and their support depends on turgor pressure. Waterlogging leads to anaerobic conditions affecting respiration and the uptake of nitrates, such as phosphates and DNA and ATP for the synthesis of amino acids and proteins. Nutrients and the uptake of active transport by plant roots can enter and leave cells through osmosis, affecting the distribution and abundance of plants. Decomposers by recycling and the supply of nutrients affects the distribution and abundance of plants.
Plants – Synoptic Links

Distribution and abundance of plants

DNA and ATP

Photosynthesis

Transport

Support

A lack of water can affect the distribution of plants in many ways

Water

Waterlogging

Osmosis

Anaerobic conditions

Respiration

Decomposers

Extracellular digestion

Nutrients

Phosphates

Nitrates

Light

Cells

Oxygen

Transport

for

support

and their

depends on

through

affecting

for

can enter and leave

but

affects the

and

plants need

for

so

so slowing the

by

by

with less

for

supply of

Active transport

reducing

Plant roots

Synthesis of amino acids and proteins

for use in

which are released by

which affects the

such as

and

and

uptake of

for

Synthesis of amino acids and proteins

for the

Plants need

Water

for Photosynthesis

so

for

A lack of water can affect the distribution of plants in many ways

Cells

Osmosis

A lack of water can affect the distribution of plants in many ways

Oxygen

Respiration

Decomposers

Extracellular digestion

Nutrients

Phosphates

Nitrates

Active transport

reducing

Plant roots

Synthesis of amino acids and proteins

for use in

which are released by

which affects the

such as

and

and

uptake of

for

Synthesis of amino acids and proteins

for the

Plants need

Water

for Photosynthesis

so

for

A lack of water can affect the distribution of plants in many ways

Cells

Osmosis

A lack of water can affect the distribution of plants in many ways

Oxygen

Respiration

Decomposers

Extracellular digestion

Nutrients

Phosphates

Nitrates

Active transport

reducing

Plant roots

Synthesis of amino acids and proteins

for use in

which are released by

which affects the

such as

and

and

uptake of

for

Synthesis of amino acids and proteins

for the

Plants need

Water

for Photosynthesis

so
Plants – Synoptic Links

Distribution and abundance of plants

- Plants need Light for Photosynthesis which affects the Transport so plants need Water and their support depends on Turgor pressure.
- A lack of water can affect the distribution of plants in many ways so Waterlogging leads to Anaerobic conditions which affects Respiration and the uptake of Nutrients such as Nitrates and the supply of Phosphates for use in Synthesis of amino acids and proteins.
- Enzymes which are released by Extracellular digestion affects the Transport for and their support.
- Recyling which affects the active transport reducing the uptake of Nitrates.
- Active transport reducing the uptake of Nitrates.
- Decomposers by Respiration for the synthesis of Nitrates.
Plants – Synoptic Links

- Distribution and abundance of plants
  - Light
  - Water
  - Cells
  - Osmosis
  - Waterlogging
  - Anaerobic conditions
  - Turgor pressure
  - Decomposers
  - Respiration
  - Oxygen
  - Support
  - Transport
  - Photosynthesis
  - Extracellular digestion
  - Enzymes
  - Phosphates
  - pH
  - DNA and ATP
  - Synthesis of amino acids and proteins

- Plants need water for photosynthesis, transport, and support. A lack of water can affect the distribution of plants in many ways.

- Nutrients such as nitrates are required for the uptake and supply of plants. Active transport reduces the uptake of nutrients by plant roots.

- Decomposers decompose cellulose for recycling and the supply of nutrients.

- Respiration affects the uptake of oxygen for the synthesis of DNA and ATP for use in extracellular digestion using enzymes, which are affected by pH.

- Waterlogging leads to anaerobic conditions, affecting respiration and the uptake of nutrients, which affects the supply of DNA and ATP for the synthesis of amino acids and proteins for active transport.
Plants – Synoptic Links

Distribution and abundance of plants

DNA and ATP
- Synthesis of amino acids and proteins
  - for use in
  - such as Nitrates

Phosphates
- for the uptake of
- and the supply of
- which affects the plants need
  - which affects the phosphates

Nutrients
- and the uptake of
- which affects the
- which affects the

Active transport
- reducing

Decomposers
- by
- by

Respiration
- for

Oxygen

Water
- can enter and leave

Photosynthesis
- so for
- so for

Light
- affects the
- so
- for

Cells
- which affects the
- which affects the
- for

Support
- depends on
- and their

Transport
- for
- and

Waterlogging
- leads to
- affecting
- with less

Osmosis
- affecting

Anaerobic conditions
- for

Turgor pressure
- for

A lack of water can affect the distribution of plants in many ways

Extracellular digestion
- using
- which are released by

Enzymes
- which are affected by
- which affects the
- for

Phosphates
- which affects the

DNA
- for use in

Nutrients

Respiration
- for

Oxygen

Decomposers

Extracellular digestion

Photosynthesis

Light

Transport

Support

Turgor pressure

A lack of water can affect the distribution of plants in many ways
Plants – Synoptic Links

**Distribution and abundance of plants**

- **Photosynthesis**
  - **Light**
  - **Water**
  - **Cells**
  - **Transport**
  - **Support**
  - **Osmosis**
  - **Turgor pressure**
  - **Respiration**
  - **Decomposers**
  - **Active transport**
  - **Recycling**

**Nutrients**
- **Phosphates**
- **Nitrate**

**Support**
- **Turgor pressure**

**DNA and ATP**

**Synthesis of amino acids and proteins**

**Nutrients**
- **Phosphates**
- **Nitrate**

**Active transport**
- **Plant roots**

**Recycling**
- **Decomposers**

**Waterlogging**
- **Anaerobic conditions**

**Extracellular digestion**
- **Enzymes**

**Osmosis**
- **A lack of water can affect the distribution of plants in many ways**

**Transport**
- **for**
- **and**
- **so**

**Support**
- **depends on**

**Photosynthesis**
- **for**
- **and**

**Light**
- **for**

**Water**
- **can enter and leave cells**

**Cells**
- **for**
- **and**

**Turgor pressure**
- **for**
- **and**

**Osmosis**
- **affecting**

**Decomposers**
- **by**

**Respiration**
- **by**

**Phosphates**
- **affect the**

**Nutrients**
- **affect the**

**Photosynthesis**
- **so**

**DNA and ATP**
- **for use in**

**Phosphates**
- **which are released by**

**Extracellular digestion**
- **using**

**Enzymes**
- **which are affected by**

**Distribution and abundance of plants**
- **which affects the**
- **which affects the**

**Support**
- **depends on**

**Active transport**
- **reducing**

**Decomposers**
- **by**

**Respiration**
- **by**

**Phosphates**
- **such as**

**Nitrate**
- **for the**

**Nutrients**
- **and the uptake of**

**Active transport**
- **and supply of**

**Decomposers**
- **so slowing the**

**Respiration**
- **for**

**Phosphates**
- **for**

**Nutrients**
- **for**

**Waterlogging**
- **leads to**

**Anaerobic conditions**
- **with less**

**Oxygen**
- **with less**

**Photosynthesis**
- **so**

**Light**
- **so**

**Water**
- **so**

**Transport**
- **so**

**Support**
- **so**

**Photosynthesis**
- **so**

**Light**
- **so**

**Water**
- **so**

**Transport**
- **so**

**Support**
- **so**

**Photosynthesis**
- **so**

**Light**
- **so**

**Water**
- **so**

**Transport**
- **so**

**Support**
- **so**

**Photosynthesis**
- **so**

**Light**
- **so**

**Water**
- **so**

**Transport**
- **so**

**Support**
- **so**
Review of aims

CPAC opportunities – practical endorsement

Apparatus and techniques practical skills

How to design and adapt…

Maximise maths skills opportunities

Other spec content via fieldwork

Synoptic links?

Required practical 12: Investigation into the effect of a named environmental factor on the distribution of a given species.

Required practical 10: Choice Chambers

Required practical 7: Chromatography

My challenge:

Use RP 12 as an example to show you how you can design a rich, synoptic learning experience (even using limited habitats at or near your school).

Also Field Studies Council aspirations…

Environmental awareness
Benefits of outdoor learning
‘Real science’?
How can the Field Studies Council help?

FSC website age
field-studies-council.org

FSC Biology Fieldwork
http://www.biology-fieldwork.org/

• Residential or day field courses (taught)
• Teacher and professional training
• FSC publications

Other Projects:
• OPAL and outdoor learning – new CPD training
• BES/FSC summer science camp

Visit the FSC/OPAL stall.
How did we do?

• Please rate this session on the Sched Conference app.

• Using the post-its provided, please write:
  • one thing you enjoyed about our session or will take away for your teaching
  • one thing you feel could be improved.
• Stick these on the feedback poster as you leave.
Get in touch

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