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BEAR ISLAND – THE JELLY BEAR EVOLUTION GAME

INTRODUCTION

The Jelly Bear Evolution Game allows students to explore the following concepts:

- polymorphism, in this case variation in a phenotypic feature (bear colour)
- action of selection pressures
- adaptation of populations through natural selection
- genetic drift through chance occurrences
- variation in the environment leading to balanced polymorphism and possibly allopatric speciation

The game should be played as an exercise in reinforcement and expansion of understanding of these concepts after the basic content of evolution by natural selection has been introduced.

Key terms such as:

- species, population, phenotype, genotype, mutation, allele, natural selection, selection pressure and polymorphism

could be established with a homework exercise asking students to match these words and definitions, or to source definitions from a text book, before the game.

A follow up worksheet which includes research and discussion questions is supplied, along with the associated answers.

Common student misconceptions to watch out for are:

- not appreciating that evolution means a change in the relative frequency of alleles of a gene in a population
- not realising that this change over time can be reversible (eg change to a higher frequency of melanic forms of *Biston betularia* moths in industrial areas followed by a reversal to spotted forms when air pollution reduced).
- not discriminating between natural selection acting to better adapt populations for a particular environment, versus genetic drift as a random cause of change in the population
- not realising that selection pressures work mainly by killing the less well-adapted morphs in a population (or by reducing their reproductive output).
- not linking density-dependent and density-independent factors that regulate population size (encountered in the ecology section of the specification) with the selection pressures that affect evolution.

TEACHER PREPARATION

- **For use with the sample materials –** Collect resources per group of five students – supply of jelly bears* or printed bears from the sheet provided, printed map, 1 set of printed cards, new, disposable plastic cups for use as 'Bear banks'.

OR

- **For use with the student-generated materials –** Supply of jelly bears* or printed bears from the sheet provided, A3 or A2 paper, coloured pens, A4 coloured card cut into eighths or copies of the playing card template, new, disposable plastic cups for use as 'Bear banks'.

- If using jelly bears, all players should wash their hands before play. If there is a likelihood of students eating their bears at the end of the game, a classroom that is not used as a laboratory should be used and players should only handle their own colour bears.

* *Haribo Gold Bears come in five different colours: green, red, orange, yellow and white and come in 160g packets or plastic tubs of 600 bears.*

STUDENT PREPARATION

Sample materials can be used if time is short, but students benefit from thinking about how different habitats might affect bear survival (map production) and thinking of their own selection scenarios (playing cards).

See the next page for details of student preparation to be carried out before the game can begin.

NUMBER OF PLAYERS

4 or 5 players per map.

SETTING UP THE GAME

Place the map in the centre of the table so that all players can sit around the map. Place the playing cards face down next to the map in easy reach of all players.

GAME INSTRUCTIONS

Full game instructions are provided on the Student Instruction page.

ACTIVITY INSTRUCTIONS

Creating a map:

Divide students into groups of four or five. Each group draws a map onto A2* paper, to include different habitats and natural resources such as rivers, forests, desert and mountains.

A sample map of Bear Island is provided but students would benefit from creating their own and thinking about how different habitats might affect bear survival. Maps can be laminated so they can be wiped clean of any stickiness from the bears after the game and re-used another time.

* *Students could use two sheets of A3 paper, or flipchart paper if A2 paper is not available.*

Playing cards:

Coloured cards (from an A4 sheet cut into 8 or using the playing card template provided) can be filled in by students with instructions detailing the action of a selection pressure.
For example:

- Red bears in open country (non-forest) get Red Bear Fever. 50% die.
- Only green bears survive mass panther attacks in forest. 1 in 3 other colour forest bears get eaten.
- Student questions to be prepared for during and after the game might include the numerical impact of selection, ie how many offspring of a given species survive and for how long, and the frequency with which new mutations occur.

Selection pressures to be invented should include differing ability to obtain food and other resources, susceptibility to disease and predation and the effects of abiotic factors like temperature change and landslides. New mutations giving a selective advantage to some bears should be included, as should selection pressures introduced by humans like hunting, road-kill and development.

The sample playing cards provided can be used if time is short but students benefit from thinking of their own selection scenarios.

Note: A deliberately light-hearted approach is taken in the cards so that the game is fun and not taken too seriously, but be sensitive to recently bereaved or depressed students who might find the repeated references to bears dying or being killed upsetting.

SAMPLE PLAYING CARDS

Cut along the dotted lines

BEAR ISLAND

Red bears outside of the forest get Red Bear Fever. 50% die.

BEAR ISLAND

Only Green bears survive mass panther attacks in forest. Other colour forest bears get eaten.

BEAR ISLAND

Bears of any colour in or alongside the Paddington River get washed away in a flash flood.

BEAR ISLAND

Global warming means only light coloured bears (White, Yellow or Orange) survive in the desert. Other desert bears dehydrate and die.

BEAR ISLAND

Red bears in the Red Mountains are well-camouflaged and avoid yeti attacks. All Green, White and Yellow bears die. Half of the Orange bears here survive.

BEAR ISLAND

White bears in the Ice Mountains get buried in an avalanche and die. Other coloured bears are seen and rescued.

BEAR ISLAND

Roosevelt river bears find a salmon run. Add 1 cub now to each bear feeding in the Roosevelt river.

BEAR ISLAND

All bears on the muddy marsh get sucked down by quicksand and disappear.

BEAR ISLAND

A mutation in Orange bears lets them digest and eat Bitterberries. Add 1 cub now to each Orange bear feeding in the Berry Patches.

BEAR ISLAND

A freak shoal of fish hits the Fishing Piers resulting in a feeding frenzy for any bears there. Add 1 cub now to each bear feeding on the Fishing Piers.

Cut along the dotted lines

BEAR ISLAND

Pollution in the Pooh River kills any bear within a 2cm distance of its banks.

BEAR ISLAND

Sea levels rise due to human pollution. All bears within 1cm of the coast get swept to sea and drown.

BEAR ISLAND

Yellow bears get a mutation giving them resistance to Bear Flu. They survive the winter epidemic but 1 in 3 other bears die.

BEAR ISLAND

Human poachers go from Blue Harbour up the Roosevelt River, across to the bend of the Paddington river and up to the ice mountains. They kill every second bear they see.

BEAR ISLAND

A virus wipes out the bears' food plants in the forest north of the red mountains. Bears at the Eastern Edge of the forest migrate south, all other bears here starve.

BEAR ISLAND

Bears hate overcrowding. Any two bears within 1cm of each other fight and kill each other.

BEAR ISLAND

Red and Orange bears overheat in a heat wave. They go mad, jump in the nearest river or sea, and float away never to be seen again...

BEAR ISLAND

Marsh, forest and riverside bears get bitten by ticks and infected with a disease which kills 1 in 2 of them.

BEAR ISLAND

Summer mosquito attacks enrage bears within 2cm of the rivers. 1 in 3 die from Bearlaria disease and 1 in 2 do not reproduce next time due to less time spent feeding.

BEAR ISLAND

Marsh bears avoid summer mosquito attacks by wallowing in mud. Next reproduction event all marsh bears get twins.

Cut along the dotted lines

BEAR ISLAND

Green bears have an allele conferring resistance to Bearlaria disease. Keep this card to show all Green bears survive Bearlaria incidents.

BEAR ISLAND

Yellow bears to the East of the Paddington River learn to raid the nests of ground-nesting birds for eggs. Extra nutrition means they get twin cubs next time they reproduce.

BEAR ISLAND

A long snowy winter means thinner hibernating bears do not survive till Spring. 1 in 3 bears who have never used fish, eggs or honey as a food source die.

BEAR ISLAND

Bears fishing in the tributaries of the Paddington river around the muddy marsh get attacked by piranhas and die.

BEAR ISLAND

Red forest bears double their fitness (get twin cubs when they reproduce) by exploiting new food source in forests.

BEAR ISLAND

White bears in the forest north of the red mountains find honey trees, feast and get fat. They have twins when they reproduce.

BEAR ISLAND

In fights over delicious termite mounds on the grassy slopes, red bears kill green bears, orange bears kill yellow bears and white bears run away to the mountains.

BEAR ISLAND

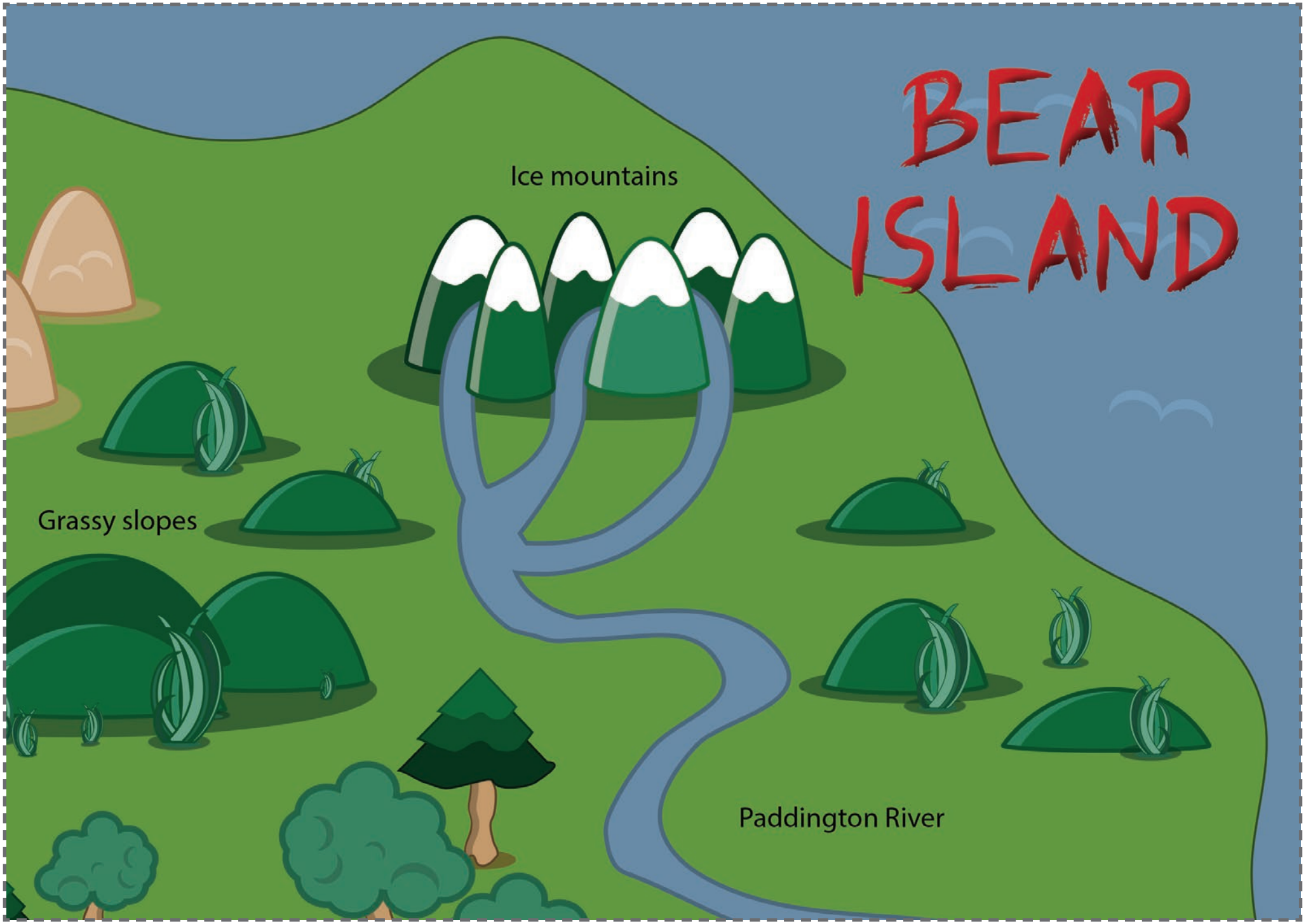
Predation by Giant Sea Eagles kills 1 in 2 bear cubs within 5cm of the coast.

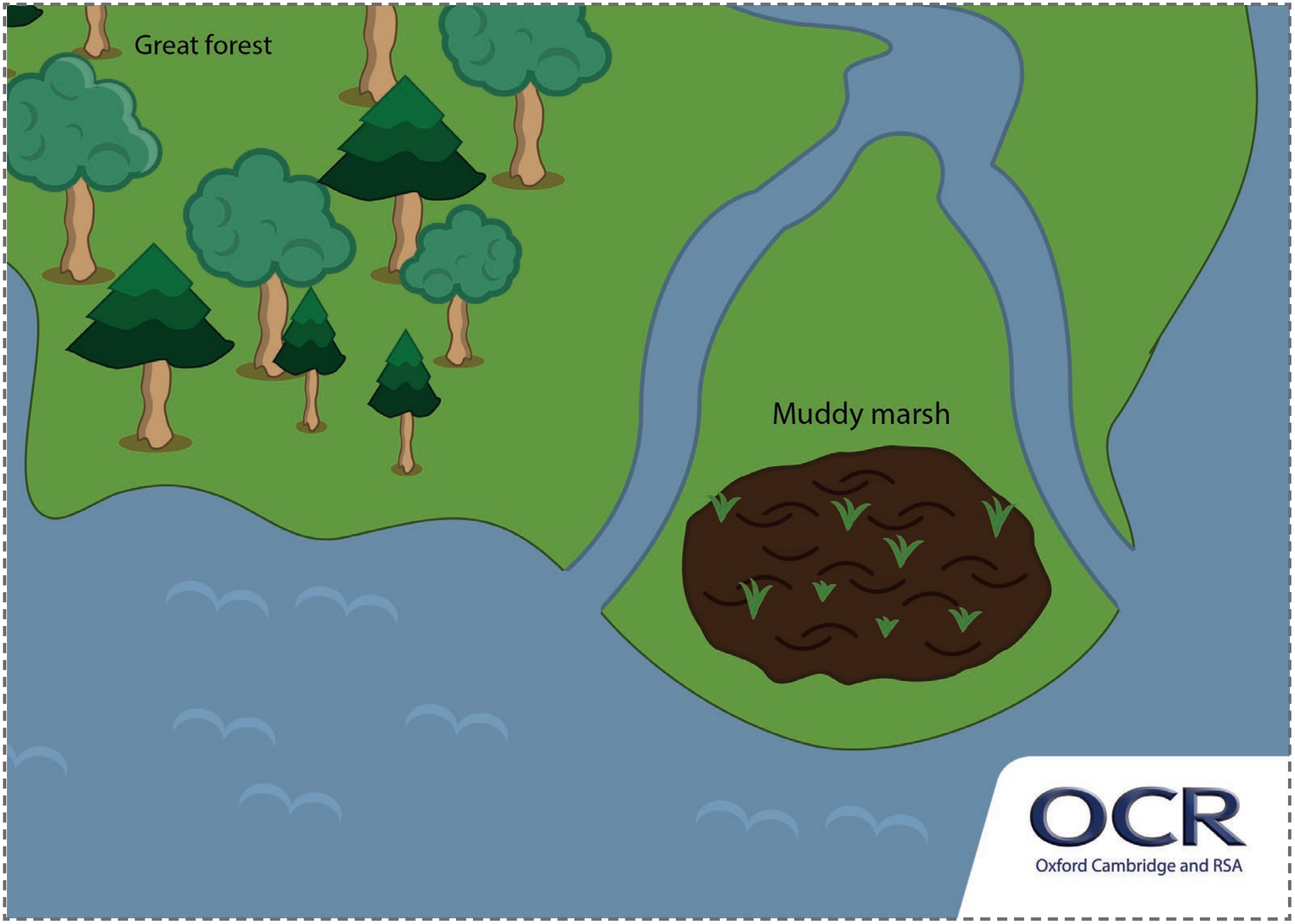
BEAR ISLAND

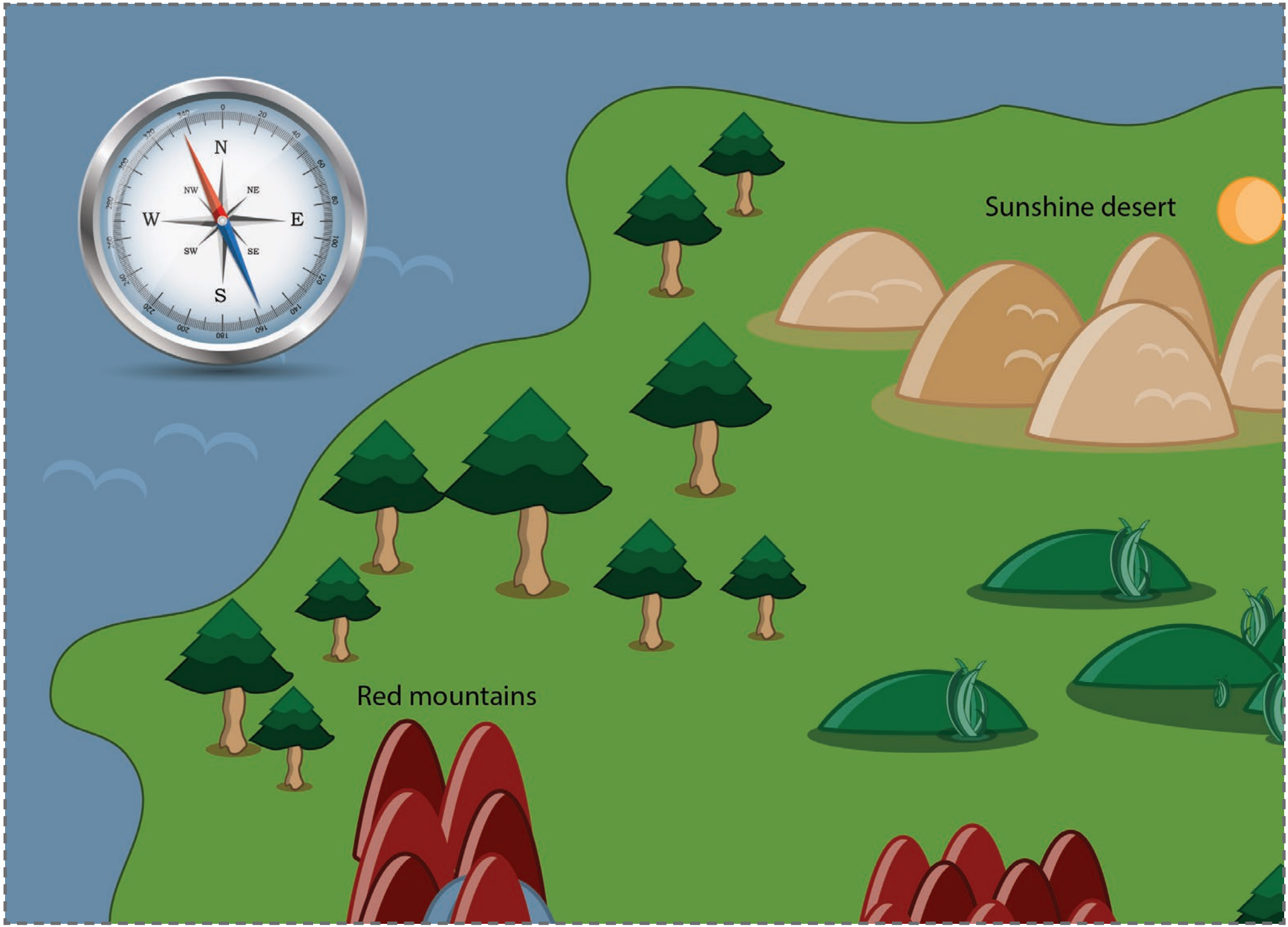
Mountain lions kill 1 in 4 bear cubs in the mountains, except white cubs which are well-camouflaged.

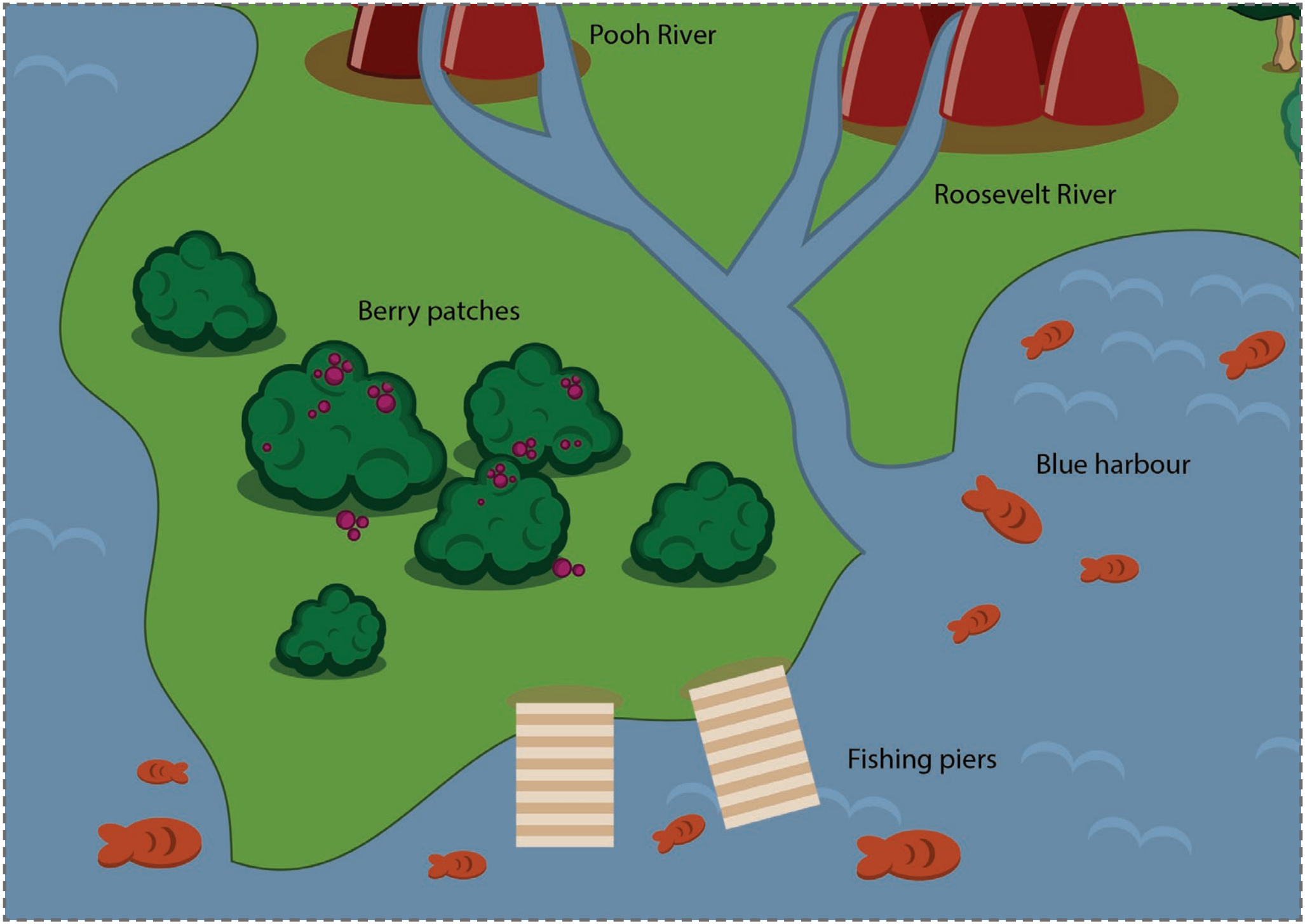
BEAR ISLAND

1 in 5 bears in the desert and forests get bitten by venomous snakes and die.








Pooh River
Roosevelt River
Berry patches
Blue harbour
Fishing piers

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STUDENT WORKSHEET

1. **Selection pressures** are also the factors that regulate population size. List the various factors that killed the bears under the headings biotic and abiotic.

Biotic	Abiotic

2. An allele has a selective advantage when .....

..... Since an allele is defined as .....

..... there must always exist another allele at the same gene locus which gives a selective disadvantage. Alleles of a gene arise by the process of .....

RESEARCH AND DISCUSSION QUESTIONS

1. Different selection pressures in different environments such as the Galapagos islands can result in allopatric speciation. Explain what is meant by this with reference to either ground finches or tortoises.

2. Selection pressures can alter over time, for example the level of soot and sulphur dioxide pollution in industrial towns in England between 1850 and 1970. How did the rise and fall in industrial pollution affect the frequency of the allele for melanism (black wings) in the peppered moth, *Biston betularia*?

3. The jelly bears represented a polymorphic species with five colour variants. Can you name two other species with more than three colour forms? (Hint – consider domestic animals and plants.)

4. (Internet access required). Find as many different pictures of the snail *Cepaea nemoralis* as you can and find out why it has so many colour variants. This can be answered on one level in terms of the underlying genes that affect shell colour and on another level in terms of why so much variation is tolerated or useful to the snail species.

5. Evaluate the limitations of the Jelly Bear Evolution Game in modelling real events in a population. Some factors to consider include:

   a. What if anything prevented the different colours of bear mating together?

   b. Would each colour breed true?

   c. Were some colours due to dominant alleles and some recessive?

   d. For speciation to occur, what would be needed?

   e. Did the results of your game suggest that all five colours would continue to find a niche and exist, or would you predict that some colours would always go extinct?

ANSWERS TO WORKSHEET

Biotic	Abiotic
predation parasitism disease competition for food poaching by humans	natural disasters eg floods, avalanche, quicksand pollution climate extremes lack of water

An allele has a selective advantage when ... **it makes the organism possessing it more likely to SURVIVE and to REPRODUCE**... Since an allele is defined as ... **an alternative version of a gene** ... there must always exist another allele at the same gene locus which gives a selective disadvantage. Alleles of a gene arise by the process of ...**mutation** ...

RESEARCH AND DISCUSSION QUESTIONS

1. In allopatric speciation one species gets physically separated by a geographic barrier into two or more separate populations. Different selection pressures apply in the different environments. For example, in the Galapagos different islands provided different food sources. Finches with some sizes and shapes of beaks obtained food and survived and reproduced on some islands, but finches with different sizes and shapes of beaks obtained food and survived and reproduced on other islands. Similarly tortoises with different shell shapes and neck lengths were able to obtain food at different heights on different islands.

   Over time **differences in allele frequency** build up in the separated populations. **Genetic drift** (chance changes in the composition of the population) can contribute to this, as well as **natural selection**. Speciation has happened when the genetic changes are so large that if members of the separated populations are brought together they can no longer successfully breed to give fertile offspring. They are now **reproductively isolated**.

2. As the industrial towns got more polluted with sulphur dioxide and coal soot in Victorian times, the allele for black wings (melanism) rose from under 1% to nearly 100% of the moth populations in these places. (Conversely, the allele for wild-type peppered wings fell from around 100% to nearly 0%). The situation reversed itself as manufacturing industry fell and particularly after the Clean Air Acts of 1954. The frequency of the melanic allele fell back again to near 1%.

3. Cats – tabby, ginger, black, tortoiseshell, Siamese pointed pattern, dilute colours (blue, cream), white.
   Dogs – black, brown, golden, white, black and white patches, brown and white patches, black and white spots.
   Horses – black, brown, bay, piebald, skewbald, chestnut, roan, palomino, grey, dun.
   Other examples include cattle, goats, chickens, domestic ducks, fancy rats and mice, corn snakes.

   Many wild species show occasional melanic and albino forms as well as the wild-type. An internet image search for melanic and albino animals will show how common this polymorphism is in mammals, birds and reptiles.

4. Pictures should show three basic background shell colours: yellow, brown and pink, These may be plain in colour or there may be striping. The variation in colour is due to an interplay of alleles for the shell colour gene and the striping gene. The continued existence of so many variants (balanced polymorphism) is thought to be due to natural selection in different habitats. For example in beech woodlands brown and pink snails survive thrush predation better than other colours. In long grass yellow striped variants survive best. As well as predation, thermoregulation may be a factor, as dark shells heat up faster allowing the snail to emerge to forage faster in cold weather/locations.

5a. If the jelly bears were a polymorphic species the five bear colours could mate together. This factor was ignored in the game in order to avoid introducing complex rules of inheritance to predict the colours of the offspring. Also, if reproduction gave mixed offspring, one human player would not be identifying with the fortunes of one colour of bear to see how well it was adapted and survived.

5b. It is likely that the colours would not all breed true, as in the domestic animals listed in Q3 this does not occur. Only homozygous dominant parents breed true, eg two black cats (BB x BB).

5c. To get 5 colours of bears there would probably be a dominance hierarchy like C (same colour all over) > cs (Siamese restriction) > c (albino) in cats, plus some epistasis or genetic interaction with a second locus (eg D/d for diluting effect, such as red diluting to orange and yellow diluting to white). Perhaps some alleles were co-dominant (red and yellow together giving orange for example).

5d. For speciation to occur, geographic isolation of the different habitats would be needed. If there was no migration in or out of areas such as forests and mountains, specialised adaptation to these habitats could accumulate and over a long time genetic differences to other populations build up to give reproductive isolation.

5e. In trials of the game, some colours tended to go extinct as starting populations were so small. In real life, a balanced polymorphism like that of Cepaea nemoralis might occur.

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