Tasks and Solutions for

Bebras International Challenge on Informatics and Computational Thinking

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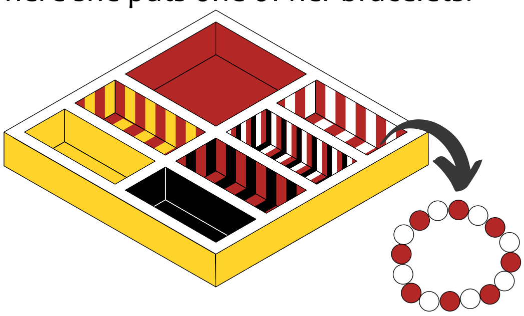
PreEcolier Level (Class 1 & 2)

T1. Organizing bracelets

Victoria has a box where she organizes her bracelets.

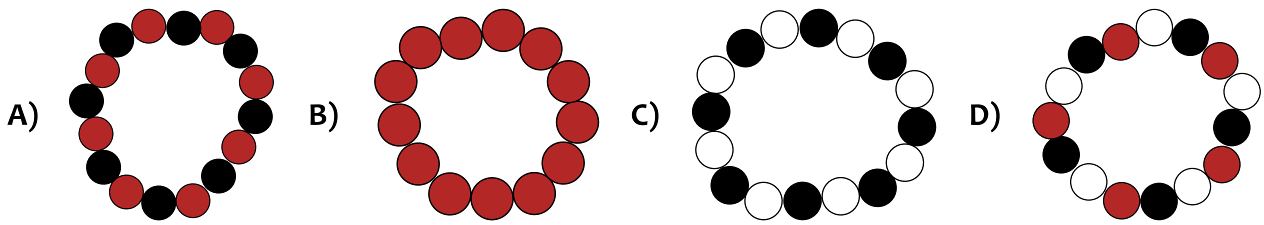
There are seven compartments in this box and Victoria puts each bracelet in a compartment with the same color pattern.

The image below shows where she puts one of her bracelets.



Question / Challenge

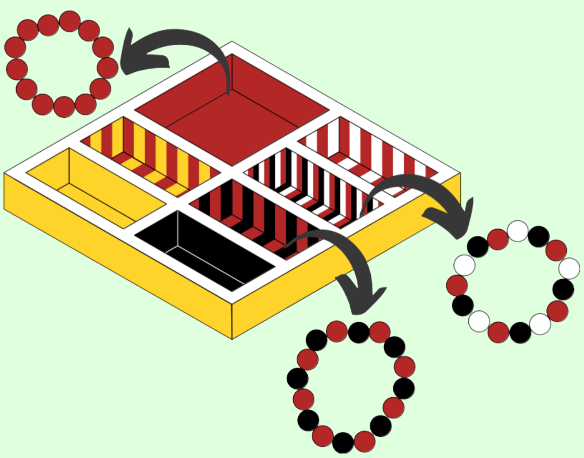
Which of these bracelets does **NOT** match any of the compartments in Victoria's box?



Answer

The correct answer is (C).

The image below shows the compartments where Victoria puts the bracelets from options (A), (B) and (D). Observe that the bracelets and the compartments have the same color pattern.



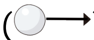
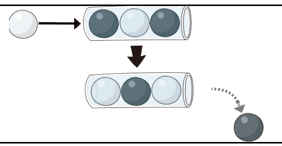
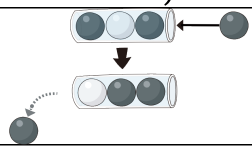
Note there is no compartment with the color pattern black-white in Victoria's box, so there is no compartment for the bracelet in option (C) to match.

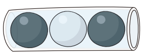
Connection to Informatics

We often have a lot of data to work with when trying to solve a question or problem. Just like in this task, where there are many aspects to the bracelets we could use to put them into the correct boxes. It is important to be able to filter out the data we don't need, so it is easier to find the important data and find a solution. In this task, we only need to look at the colors, it doesn't matter what shape the beads are, how many there are or in what pattern they occur. We don't even need to see the whole bracelet to solve the question, only seeing a part of the images would be enough.

T2. Tube

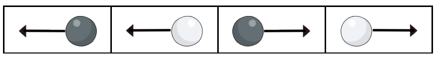
There is a tube () with holes on both sides that can be filled up to 3 balls.
The following images show what happens when three balls are in the tube and we try to put a fourth ball in it:

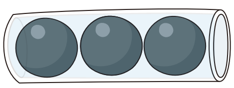
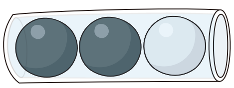
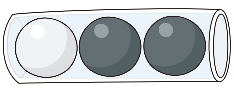
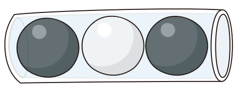
from the left ()	from the right ()
	

This tube is now filled as follows: 

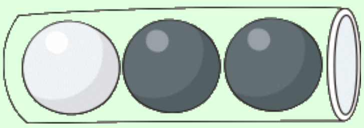
Question / Challenge

How would this tube look like after putting 4 balls in the following order?

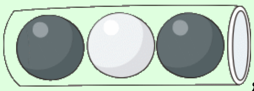
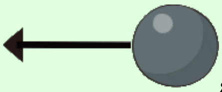
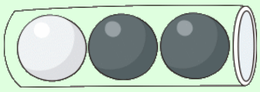


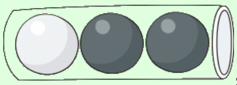
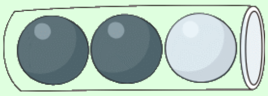
A)  B)  C)  D) 

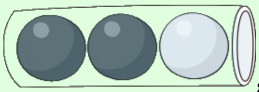
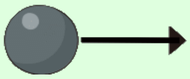
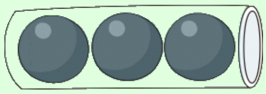
Answer

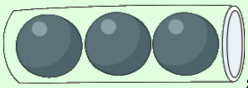
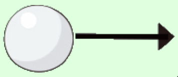
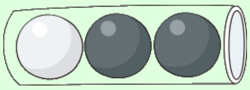
The correct answer is C) 

To solve the task we need to check the direction of putting the next ball and follow the steps:

In state , after putting , it becomes 

In state , after putting , it becomes 

In state , after putting , it becomes 

In state , after putting , it becomes 

Connection to Informatics

In this Task, the tube functions similarly to a deque (double-ended queue), a data structure that allows data to be pushed or popped from both sides. This data structure facilitates efficient data creation completion based on priority or order.

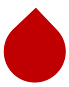
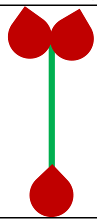
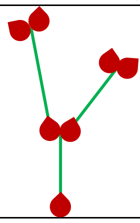
In the context of this Task, we have a deque variant that only allows data insertion (represented by the tube). The Task also shows an example of data structure where we cannot store information, because we have a limited capacity (observe that the tube can be filled with up to 3 balls).

Consequently, if we need to exceed the amount of data, we will lose information, as well as the tube "loses" balls when we try to put a fourth ball in it. This represents an important aspect of data storage in Informatics: capacity constraints.

Deques find application in parallel computing for Work Stealing, a method of scheduling the processing of computer programs designed to be multi-threaded tasks. Work Stealing can be used effectively in parallel computing using multiple multicores and threads.

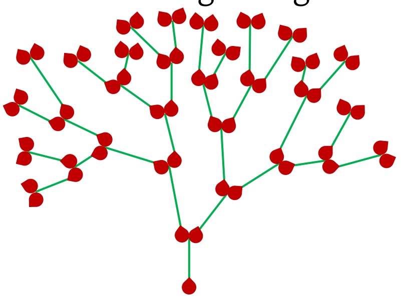
T3. Miracle Flower

At sunrise, one stem grows from each new bud of a miracle flower. The stem continues to grow throughout the day. At sunset, the stem branches into two new miracle flower buds and stops growing. This continues day after day and the miracle flower becomes more and more magnificent.

New bud before sunrise	Miracle Flower after sunset (first day)	Miracle Flower after sunset (second day)
		

Question / Challenge

How many days has this miracle flower been growing?



A) 5 days **B)** 11 days **C)** 16 days **D)** 32 days

Answer

5 days (correct answer, height of the binary tree): At the end of each day, a stem with two new buds has grown out of each bud of the miracle flower. You only have to follow one branch, e.g. the rightmost one, to count the days of growth.

11 days (wrong answer, total number of buds and stems for one branch)

16 days (wrong answer, number of outer stems)

32 days (wrong answer, number of outer buds)

Connection to Informatics

Miracle flowers grow according to a single rule. The rule simply states that a **bud** forms a stem and **two new buds.** In this way, the rule is self-contained and the miracle flower can theoretically continue to grow indefinitely. Such self-contained rules are called recursive rules in computer science.

In programming, a recursive function is a function that calls itself. So, the function calls itself, the new instance of the same function starts and it calls itself, the new instance... and so on. It is important that there is a termination condition, that is, the function should call itself only if some condition is fulfilled. In this case, after a certain number of calls to itself, the process will stop when the condition will not be fulfilled anymore.

An example from mathematics is the factorial function "n!": *n! = n * (n-1)! if n > 1, and 1! = 1.*

If you enter the number 4 for n, you get 24 as the result.

4!=4*3!=4*(3*2!)=4*(3*(2*1!))=4*(3*(2*1))=4*(3*2)=4*6=24

Recursive programs can be very clear and easy to read. However, due to the many function calls, they are usually slower at runtime than iterative programs and require a lot of memory.

Recursive programs can also be used to create very natural-looking graphics called *fractals*, for example "Pythagoras trees".

Another example of recursion is the image of the French beaver. On his T-shirt you can see the image of the French beaver wearing a T-shirt with the image of the French beaver, and so on. The picture contains itself.

Ecolier Level (Class 3&4)

T1. Online Class

Teacher Ava conducts an online class from her home.
On her computer screen, Ava can see that there are 9 students who have joined her class: Emma, Maya, Bella, Lee, Raul, Hannah, Diana, Alice, and James.
Each of the 9 students is using a different computer in the school library.

Because the students are sitting next to each other in the library, Ava can also see on her screen who each student is sitting next to. Therefore she knows that all the students are sitting side by side in the library.

Question / Challenge

Which of the 9 students is sitting in the middle (5th position)?

A) Diana **B)** Raul **C)** Bella **D)** Hannah

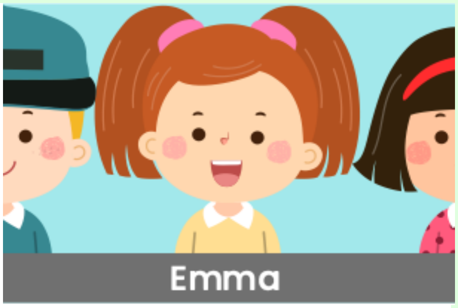
Answer

Answer: E. Hannah

Based on the what can be seen on the computer screen, we know who each student sits next to.

From the view below, we know that James is sitting next to Emma.

From the view below, we know that Emma is sitting between James and Diana.



Using the same method with the rest of the views, we can see all 9 students in this order:

The one who sits in the middle is the one at the 5th position from left, or the 5th position from right.

That person is Hannah.

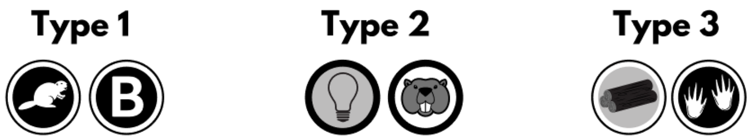
Connection to Informatics

This task presents an example in which streaming software for an online class arranged the students as separate tiles in an arbitrary way. We are asked to find the correct order to discover who is sitting in the middle.

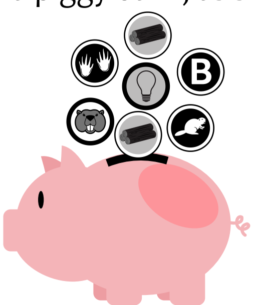
The data structure of the students arrangement is called ‘doubly linked list’. In a doubly linked list each node of the list contains the element, a reference to the previous node, and a reference to the next node. In this task, each screen (node) shows the child (element of the list) and references for the child on the right and on the left of the child in the center of the screen. This task includes an exercise in traversing a list, starting from either end.

T2. Saving Beavercoins

There are three types of Beavercoins in Beaverland.
The following images show the Beavercoins from both sides.



Ana keeps her seven Beavercoins in a piggy bank, as shown below.



Question / Challenge

Which of these are Ana’s Beavercoins?

A) 

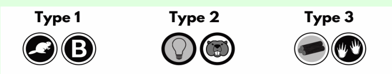
C) 

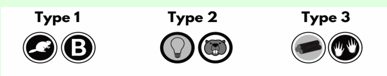
B) 

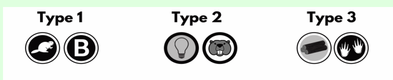
D) 

Answer

The correct answer is (C).

The images 

represent the same type of Beavercoin. The same condition applies to 

, as well as 

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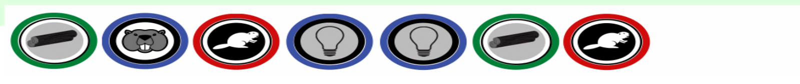
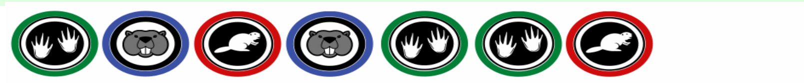
Ana has 2 Beavercoins of type 1 (circled in red), 2 Beavercoins of type 2 (circled in blue), and 3 Beaver coins of type 3 (circled in green), shown in the following image.

Option (A) shows 1 Beavercoin of type 1, 3 Beavercoins of type 2, and 3 Beavercoins of type 3.

Option (B) shows 2 Beavercoins of type 1, 3 Beavercoins of type 2, and 2 Beavercoins of type 3.



Option (C) shows 2 Beavercoins of type 1, 2 Beavercoins of type 2, and 3 Beavercoins of type 3. Then this is the correct answer.



Option (D) shows 2 Beavercoins of type 1, 1 Beavercoin of type 2, and 4 Beavercoins of type 3.

Connection to Informatics

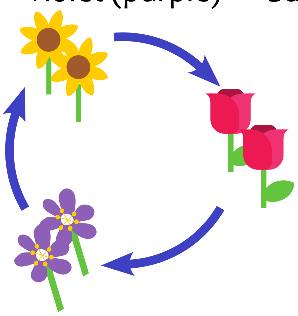
"Sets" are structures made up of different elements, regardless the order in which they are written. For example, the sets {1,2,3} and {2,1,3} are the same. Also, observe that the sets formed by the coins in the answer options are all the same, and they can be represented in 2 x 2 x 2 = 8 different ways. The following images show two examples:

"Multisets" are structures that can be considered a generalization of the concept of "sets", in which repeated elements are allowed. They are very important in Computer Science regarding data representation. In this case, the repeated elements of a multiset are considered equal through an equivalence relation, which is a relation established between these elements that shows something they have in common in some aspect. We say that elements related in this way belong to the same equivalence class. In mathematics, for example, it is possible to create an equivalence class of all the numbers that have a certain remainder when divided by a given number.

Regarding to the Task, the equivalence relationship shown is "representing the same coin". For example, the black side of the coin with a white beaver and the black side with the letter B are equivalent in terms of representing the type 1 coin (we do not have to observe both sides of a coin to determine its type, observing only one is enough). Additionally, all of Ana's Beavercoins represent a multiset in which there are 2 Beavercoins of type 1, 2 Beavercoins of type 2, and 3 Beavercoins of type 3.

T3. Magic Garden

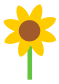
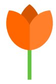
In the Magic Garden, a wonderful transformation occurs every night. Each flower can change its color based on a magical rule: If a flower is next to at least one flower of the same type, it will transform into the next type in the magical sequence. The sequence of transformation is:
Sunflower (yellow) → Rose (red) → Violet (purple) → Sunflower (yellow).



On first day, the garden had a row of flowers in this order:
Sunflower, Sunflower, Rose, Violet, Rose.

Question / Challenge

In the morning of Day 5, the Magic Garden had a remarkable transformation, with one type of flower covering the entire garden. Which flower has prevailed and filled the garden with its color?

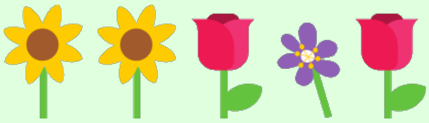
A) Sunflower    **B)** Rose    **C)** Violet    **D)** Tulip 

Answer

The correct answer is B (Rose).

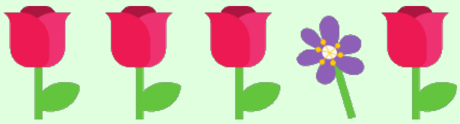
Following the sequence of transformations dictated by the magical rule, and considering the initial arrangement and changes over the days, all flowers in the garden turned into Roses by the end of Day 4. This unique occurrence showcases the power of sequential changes and patterns in nature.

At the beginning the Magic Garden looks like this:



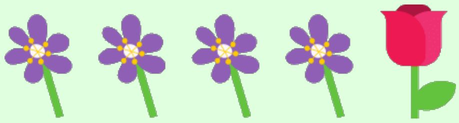
Sunflowers are the only ones that are next to each other, so they are the only ones to transform into the next flower, which is Rose.

In the morning of day 2, the Magic Garden looks like this:



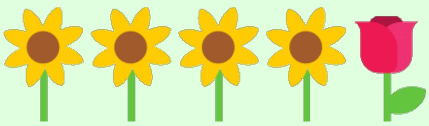
Now, there are three Roses together, which transform into the next flower type.

In the morning of day 3, the Magic Garden looks like this:

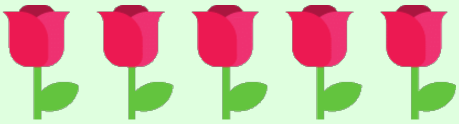


The four Violets are now together.

In the morning of day 4 Violets are transformed to Sunflowers:



Finally, the last day the four Sunflowers transform into Roses. In the morning of day 5, the Magic Garden is completely covered by Roses:



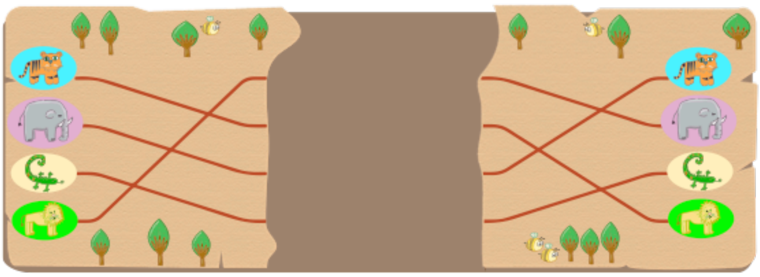
Connection to Informatics

This task illustrates the concept of sequential processing and conditional transformations by following an algorithm execution. Each flower color changes based on its neighbors: this set of predefined rules mirrors the way data can be processed and altered in sequences within computational systems. By following the steps of the algorithm, the garden changes colors.

Benjamin Level (Class 5&6)

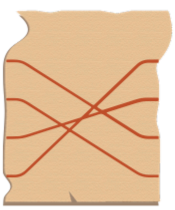
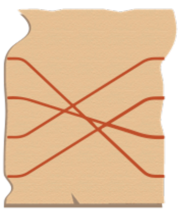
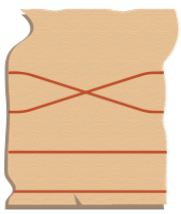
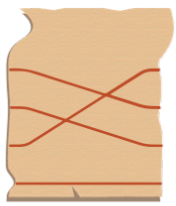
T1. Map it Out

Four animals set out on a journey. A map showing their journey was created, showing for each animal, a line going from its initial location to its final location. However, the middle section of the map went missing.



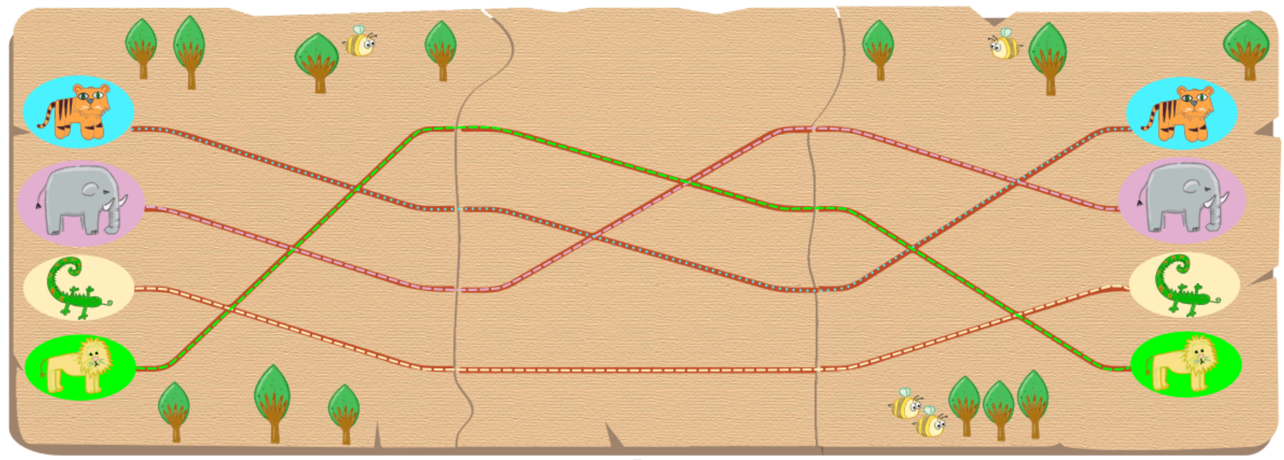
Question / Challenge

Which of these could be the missing portion of the map?

A)  B)  C)  D) 

Answer

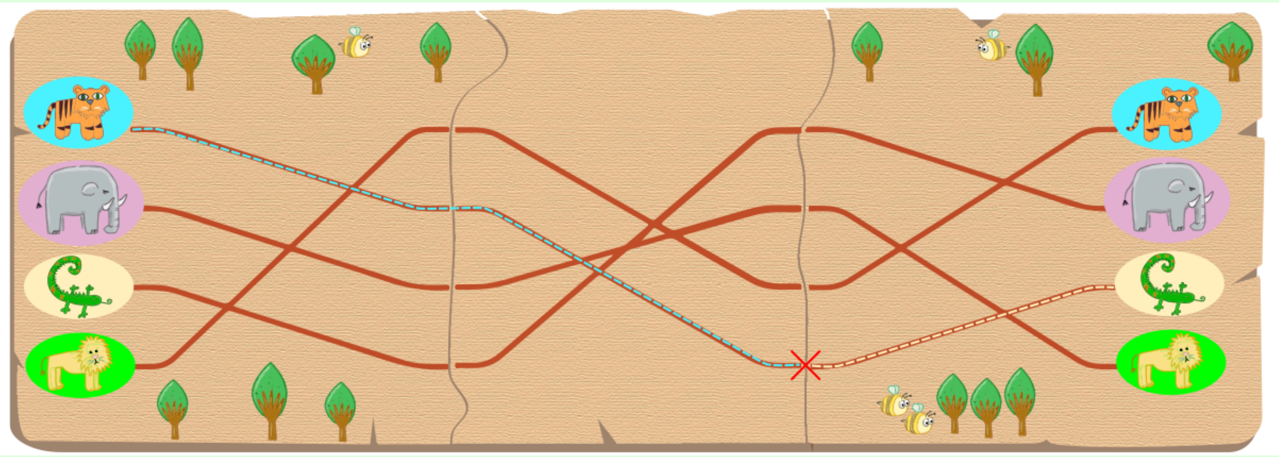
The correct answer is D.



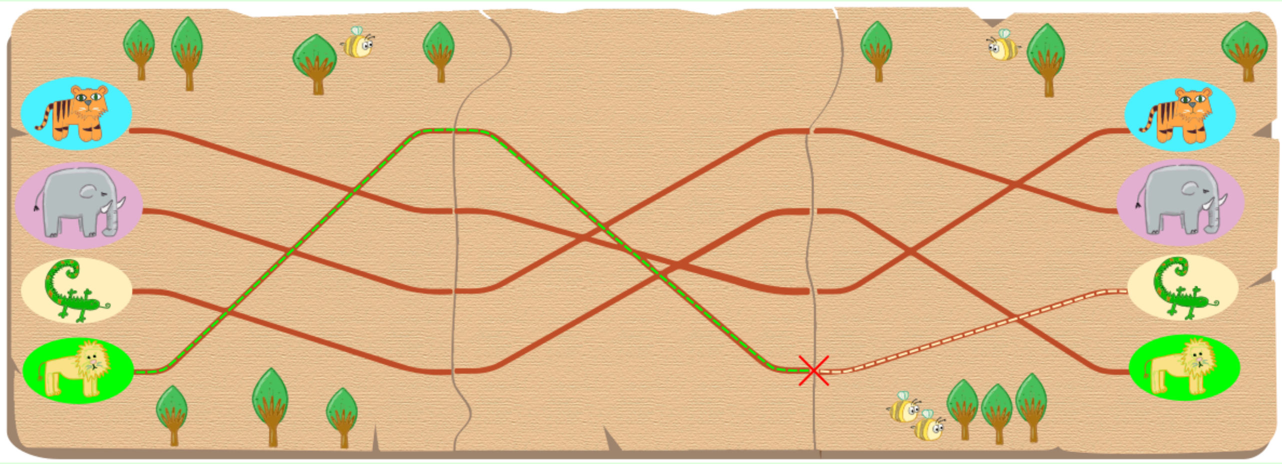
D

Considering the other options (why are they wrong):

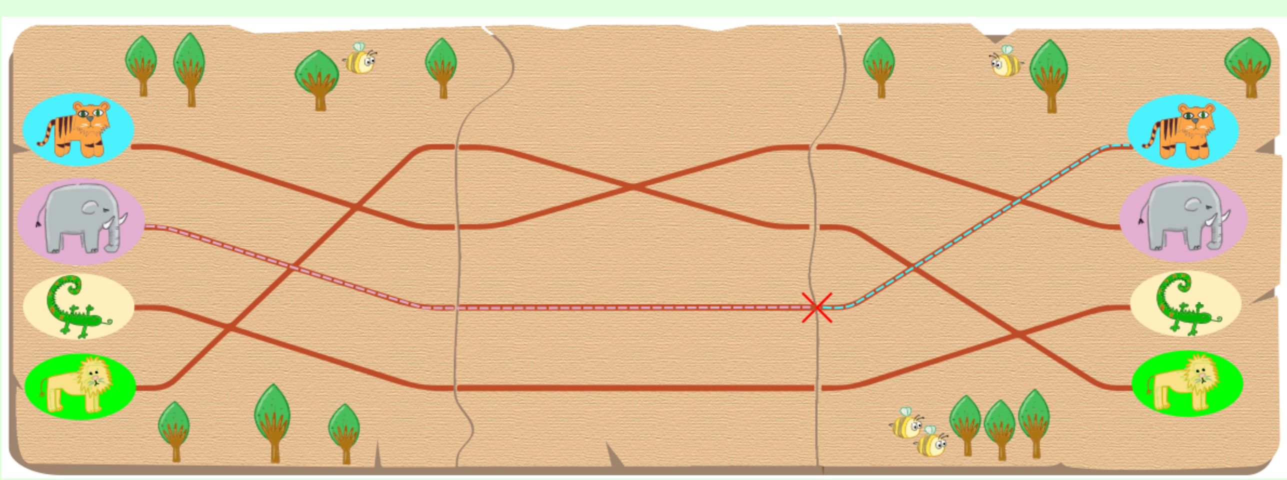
(A) Tiger ends up in the lizard's place.



(B) Lion ends up in the lizard's place.



(C) Elephant ends up in the tiger's place.



Connection to Informatics

Computers have greatly assisted humans in solving various problems. To be solved by a computer, we first need to model the problem into a form understandable by the computer. One way is by using a model called a graph. A graph is a way to represent relationships between objects. A graph consists of two main parts:

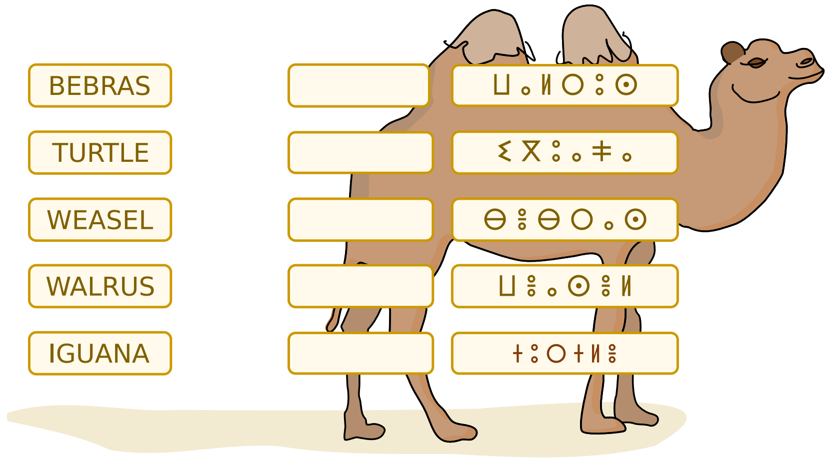
1. Nodes (or Vertices): These are the objects we want to connect. In this task, the nodes are the starting positions of each animal.
2. Edges: These are the lines that connect the nodes. In this task, the lines connecting the starting and ending positions of the animals are the edges.

One type of graph is a bipartite graph. A bipartite graph is a type of graph where its nodes (or vertices) can be divided into two groups (sets) in such a way that no two nodes in the same group are directly connected by an edge. This means that each edge only connects nodes from one group to nodes in the other group. In this problem, the two groups referred to are the group of nodes representing the starting positions of the animals and the group of nodes representing the ending positions of the animals.

Bipartite graphs are applied in many ways. For example, if there are 10 students in your school, and each student likes one or more sports activities, then we can depict the relationship between students and their preferred sports activities. By using a bipartite graph, we can easily visualize the relationship between two different groups, such as individuals with their preferences or students with their choices, helping us understand how the preferences or choices of one group are connected to another group.

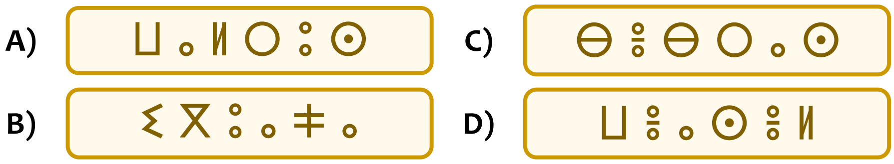
T2. Tifinagh

Tim knows the Tifinagh alphabet, which is used by some Tuareg Berber, who are living in northern Africa. Tim uses the Tifinagh alphabet as code. Tim maps the same Tifinagh symbol to the same letter. Tim codes five words: BEBRAS, TURTLE, WEASEL, WALRUS, and IGUANA.



Question / Challenge

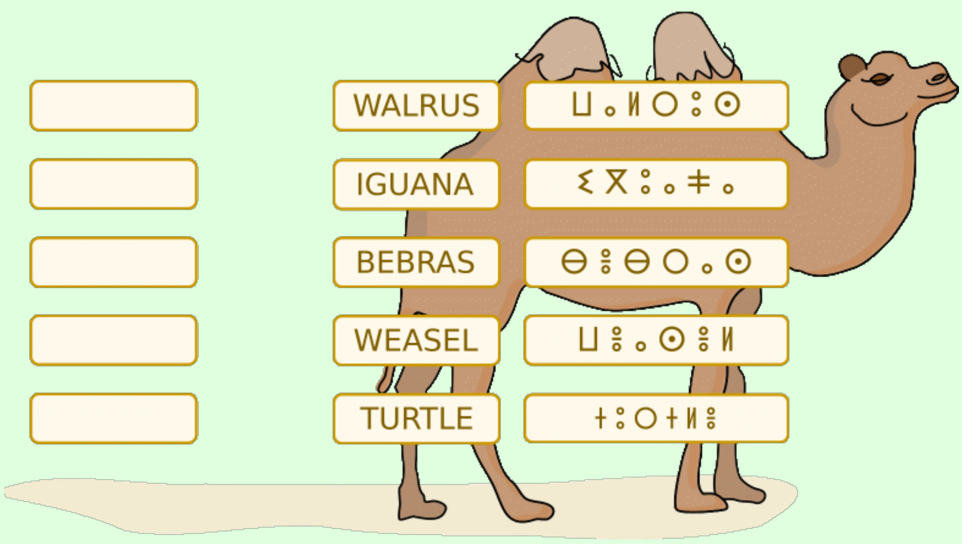
Which is the Tifinagh-code for BEBRAS?



Answer

The correct answer is C.

The first attempt is to check whether the number of letters can help. But no, all words contain 6 letters. We therefore look to the pattern of letters which can be: doubles or triples of the same letter, same letter at beginning and end of the word, same letters in different positions, etc. The direction of letters (from left to right or from right to left) must also be considered as part of the pattern. The first assumption is that the direction is from left to right, we will work with this assumption and check against it at the end.



Here is the detailed explanation how to find the solution:

You see that WEASEL and WALRUS begin with the same letter and you find two with the same pattern (and you have learned that W must be). You cannot yet assign them as you need to know which is which.

You also see that BEBRAS has the same letter in the first and third position. So you check and find this pattern in the code texts, and since only one of the code words has this pattern, you can assign BEBRAS to . You also have learnt the meaning of the letters in the word BEBRAS. Interesting are A (which is coded) and E (which is coded) because these letters are used in the other words.

You look for other patterns and find that both WEASEL and WALRUS start with the same letter.

And yes, there are two code words that begin with the same letter. Which is which? The position of the A and E help you assigning both words.

TURTLE has the same letter in the first and fourth position, allowing it to be assigned to the code word (as only one code word has this pattern).

IGUANA has the same letter in the fourth and last position, and again only one code word has this pattern, so it can be assigned.

We have assigned all clear text words to code words, so the assumption of the direction (left to right or right to left) seems to be correct. Nevertheless, and to be absolutely certain, the patterns are tested on the pattern of WEASEL and WALRUS: No two code words have the same letter on the right-hand side.

Connection to Informatics

When information is written down, it is represented as a sequence of symbols of an alphabet. Many languages – such as English – use an alphabet of 26 symbols, called letters. The (current) computers use an alphabet of 2 symbols, called 0 and 1.

In this Bebras-Task, the same words are represented in different alphabets. Why do we use different alphabets? It would be so much easier if we would all use the same alphabet!

We have different needs for alphabets, here are some examples:

- Computers must be built in a way that can be produced and transported easily, the solution is the binary alphabet using 0 and 1 only.
- Some people cannot see and so they cannot read the books, the solution is the braille alphabet that they can read using their fingertips.

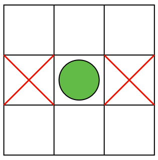
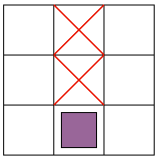
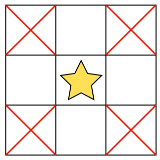
- Sometimes, the information must be kept secret, this can be a recipe of making the best cheese, a military secret or the password to a bank account. The solution for this need started with using different directions of writing, changing the sequence of the letters and also included inventing new alphabets where only the selected few knew how to interpret the symbols correctly.

This area is evolving with the current technology and within computer science a new science has emerged, called *cryptology*.

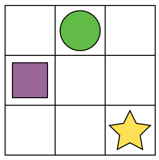
The Bebras-Task is very simply transforming letter by letter from one alphabet to another. Pattern recognition (and pattern matching) is used to solve the task, which is a nice illustration how this powerful technique can be used to understand unknown writing. Pattern recognition not only helped in understanding the ancient Egyptian hieroglyphs, but also is used to understand the information stored in the DNA.

T3. Symbol game

Ana is playing a game where she places a circle, square, triangle, and star on a 3x3 grid, according to the following rules.

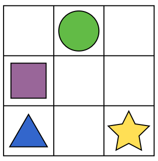
Rule	No symbol can be in the same row as the circle.	No symbol can be in the same column as the square.	No symbol can be in the same diagonal as the star.
Example			

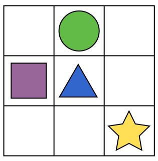
Ana has already placed the circle, square, and star on the grid as shown.

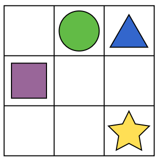


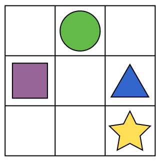
Question / Challenge

What could the grid look like after Ana places her triangle?

A) 

B) 

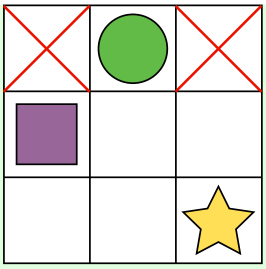
C) 

D) 

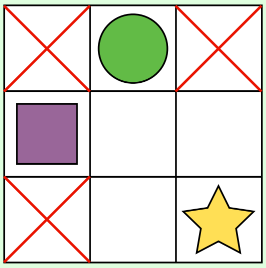
Answer

The answer is option D.

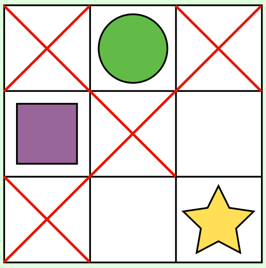
We follow the rules for each symbol separately. Since the circle is in the top row, the triangle cannot be placed in the top row.



Since the square is in the left column, the triangle also cannot be placed in the left column.



Since the star is in the bottom-right corner, the triangle also cannot be placed along this diagonal.



Therefore, there are only two possible positions for the triangle. The only option with the triangle in one of these positions is option D.

Connection to Informatics

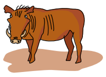
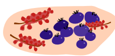
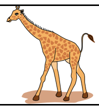
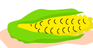
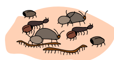
In this challenge, we need to apply specific rules and constraints when placing symbols on the grid, which requires evaluating conditions such as the type of symbol present in a cell and its position relative to other cells. These rules act as logical conditions that determine whether an action, such as placing a new symbol, is valid or not.

In computer science, conditional structures such as if statements allow a program to make decisions based on certain conditions or specific criteria.

Cadet Level (Class 7&8)

T1. Exciting Waterhole

Officer Martin is at the waterhole to see what animals are coming to feed. The table shows which animals visit the waterhole and what food they can eat:

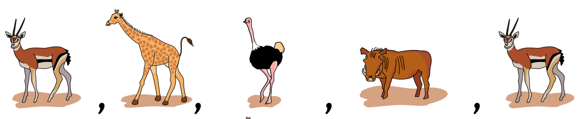
	bush leaves	lucerne	grass	salt	roots	berries	tree leaves	corn	insects
									
									
									
									

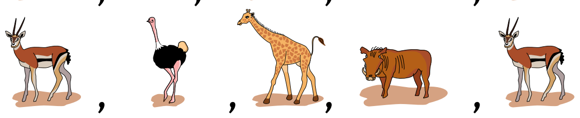
Martin observes five groups of animals that come to eat. The animals in each group are all of the same type. The groups arrive after each other. This is what the different groups ate:

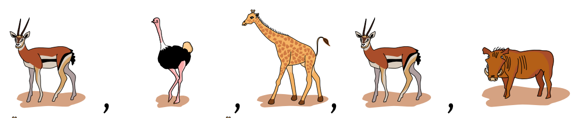
1st Group	The animals ate the lucerne and the salt block.
2nd Group	The animals ate the lucerne and the corn.
3rd Group	The animals did not eat the lucerne.
4th Group	The animals ate the lucerne and the bush leaves.
5th Group	The animals ate the grass and the roots.

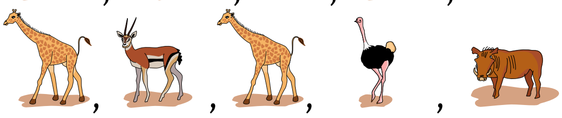
Question / Challenge

In what order did animals arrive at the waterhole?

A) 

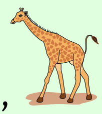
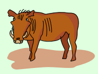
B) 

C) 

D) 

Answer

The correct answer is C)

 Springbok,  Ostrich,  Giraffe,  Springbok,  Warthog

Only animals of the same type arrive together.

Only the springbok uses the salt block. Only the ostrich eats the corn. The giraffe is the only one that does not eat the lucerne but eats the tree leaves. Only the springbok can eat the lucerne and the bush leaves. Only the warthog digs for roots.

Answer A is wrong because the giraffe does not eat lucerne or corn.

Answer B is wrong because the third animal, the warthog does not eat the bush leaves (it is too short) and subsequently, the springbok cannot dig for roots.

Answer D is wrong because already the first animal, the giraffe, does not go for the lucerne or the salt block (it could not bend so much down to the ground)

Connection to Informatics

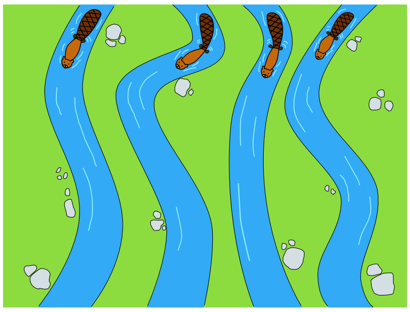
In this task you are not asked to find a solution, you are tasked with verifying multiple solutions and see which one follows the given constraints.

Complex tasks can have various conditions that are combined with AND or OR. Combining "A AND B" means that both conditions have to be true. While "A OR B" means that just one of the conditions has to be satisfied. Restrictions are specified with NOT to indicate that the negation of a condition must be true.

T2. Swimming Competition

Beavers Alex, Benny, Cathy and Diana enjoy swimming competitions and want to see which one of them is the fastest swimmer.
When they swim in a river, the speed of the river is either added to their swimming speed when they swim down the river, or subtracted from their swimming speed when they swim up the river.
However, each beaver is swimming in their own river. The rivers flow with different speeds, which means some beavers may have an unfair advantage if their river is faster when swimming down the river or slower when swimming up the river.
In order to find which one of them is the fastest, they recorded their speeds down the river and up the river and got these result:

Name	Speed down the river	Speed up the river
Alex	5 m/s	3 m/s
Benny	8 m/s	1 m/s
Cathy	7 m/s	3 m/s
Diana	6 m/s	5 m/s



Question / Challenge

Which beaver is the fastest swimmer?

A) Alex **B)** Benny **C)** Cathy **D)** Diana

Answer

The correct answer is D) Diana.

If we note with S_b the beaver's speed and with S_r the river's speed, when swimming down the river, their speed $S_{down} = S_b + S_r$, when swimming up the river, their speed $S_{up} = S_b - S_r$. Which means, if we add the two speeds, we get $S_{down} + S_{up} = 2 * S_b$, so we get two times their real speed. Thus, the beaver with the largest sum is the fastest swimmer.

For Alex, 5+3 = 8 m/s, so Alex's real speed is 8/2 = 4 m/s

For Benny, 8+1 = 9 m/s, so Benny's real speed is 9/2 = 4.5 m/s

For Cathy, 7+3 = 10 m/s, so Cathy's real speed is 10/2 = 5 m/s

For Diana, 6 +5 = 11 m/s, so Diana's real speed is 11/2 = 5.5 m/s

So Diana is the fastest swimmer.

Connection to Informatics

When transferring data via a noisy environment, the real data might be distorted, the same way the rivers' speeds modify their apparent swimming speeds. In order to fix this, the same data is sometimes transmitted over two wires using complementary signals (the same way beavers recorded their speed both down the river and up the river). If the two signals are equally affected by the noise, when the two signals are subtracted the noise is canceled and the real signal is amplified.

This is known as Differential signalling and is used in many technologies we use everyday, such as twisted-pair Ethernet cables or interfaces such as SATA, PCI Express, DDR SDRAM etc.

T3. Time Will Tell

The diamond is hidden in a box that opens only if you type in a secret code. There's a special machine in the box that checks each letter you type to match the secret code. It takes 1 second to check each letter.

If a letter you type doesn't match the secret code, an alarm starts right away. For example, if the first two letters match but the third one doesn't, the alarm starts after 3 seconds.

Every night, the Burglar Beaver tries a different code and writes down how many seconds pass before the alarm sounds. But one night, while running from the guards, he accidentally drops his notes in the mud. Some letters are now covered in mud and can't be read, shown by asterisks (*).

Guess	Number of Seconds Before Alarm
*CORN*DOG***	1
******DOG***	8
*E*VER*Y****	7
VER*Y*	2
BE*B*R*AS***	4
*****R*AS***	9
A*DAM***	5
********M***	10

Despite this accident, the Burglar Beaver says that he can still identify the first 9 letters of the secret code to open the box.

Question / Challenge

What are the first 9 letters of the secret code to open the box?

A) CORNDOGDA **B)** BEAVERDAM **C)** BEBRASEVE **D)** EVERYBEBR

Answer

The correct answer is B) BEAVERDAM.

From the task we know that if the alarm is sounded after *n* seconds, then the Burglar Beaver is guaranteed that the first *n* – 1 letters of his guess are correct and the n^{th} letter is wrong. We illustrate this with an example:

- When the alarm sounds after 3 seconds, here's what happened:
- After 1 second, the first letter of the guessed code has been compared with the first letter of the secret code. The alarm not sounding means that the first letter of his guess is correct.
- After 2 seconds, the second letter has been compared. The alarm not sounding means that the second letter of his guess is also correct.
- After 3 seconds, the third letter has been compared . The alarm sounding means that the third letter of his guess is wrong.

Using this reasoning, we can construct a table to systematically identify the first letters of the secret code. The underlined letters in the "Guess" column refer to those that are guaranteed to be correct.

Guess	Number of Seconds Before Alarm	First 9 Letters of Secret Code
*CORN*DOG***	1	*********
******DOG***	8	******D**
*E*VER*Y****	7	*E*VERD**
VER*Y*	2	*E*VERD**
BE*B*R*AS***	4	BE*VERD**

Guess	Number of Seconds Before Alarm	First 9 Letters of Secret Code
*****R*AS***	9	BE*VERDA*
A*DAM***	5	BEAVERDA*
********M***	10	BEAVERDAM

Connection to Informatics

In computer security, cryptography plays a crucial role in keeping sensitive information safe. This challenge introduces a concept known as side-channel attacks, a sophisticated approach used by hackers. This approach takes advantage of information leaked by the hardware rather than directly targeting a program. A timing attack uses the fact that the amount of time it takes for an algorithm to finish differs depending on the input. In this challenge, we have an algorithm that essentially performs a letter-by-letter comparison for password checking. The number of seconds before it determines that a password is incorrect, provides information about the number of correct characters.

To understand the threat posed by side-channel attacks, consider the following scenario. Suppose that the password is "BEAVERDAM". A hacker can first try one-letter passwords. If the hacker tries "A" or "C", an alert is sounded after 1 second. But, if the hacker tries "B", an alert is sounded after 2 seconds, thereby revealing the first letter of the password. The hacker can continue this strategy and try two-letter passwords, then three-letter passwords, and so on. Assuming that the password consists only of capital letters from the English alphabet, this would mean that, even though there are theoretically over 5.4 trillion possible nine-letter combinations, the password can be correctly guessed after at most 26 × 9 = 234 tries.

Other types of side-channel attacks include power analysis attacks, which rely on patterns in the device voltage while an algorithm is running. Since some computations are more power-hungry than others, tracking power consumption makes it possible to determine the type of computation being performed and thus identify at which step an algorithm currently is. In addition, a cache-based side-channel attack exploits patterns related to accessing the cache, a small section of the computer memory that enables extremely fast retrieval of frequently accessed data.

Defending against side-channel attacks can be really difficult since they are invisible to the user, they do not leave traces, and they use features that are built in the very design of the hardware. For example, the 2018 security vulnerabilities called Spectre and Meltdown, which allowed for cache-based side-channel attacks, affected virtually every Intel processor built after 1995 and forced Intel to redesign its microprocessors.

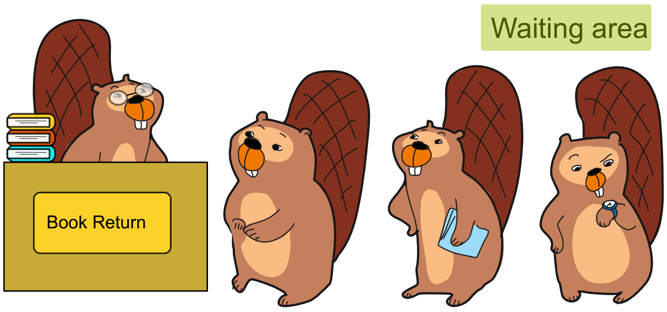
Junior Level (Class 9&10)

T1. Returning the books

In Hardwood Village, beavers love to read books. At the library, there is usually a long queue of beavers waiting to return their books. Since all the beavers are friendly, the library manager has decided to introduce a new rule about the order in which the beavers return their books. The rule is:

"The beaver with the fewest books goes first."

Beavers come to return books at different times, and no matter what time the beaver comes to the library, the beaver in the queue with the fewest books will return them first. The librarian processes one book return per minute. When she has processed all the books that a beaver has returned, the beaver currently in the queue with the fewest books will come to her.



One morning, 5 beavers come to the library to return their books. The time of arrival and the number of books per beaver are shown in the table below:

Name	Time of arrival	Number of books
Ana	9.00	4
Beti	9.02	6
Cene	9.03	2
Darja	9.05	4
Emil	9.11	1

Ana arrives as the library opens, so her books are immediately processed upon her arrival.

Question / Challenge

In which order will the beavers return their books to the librarian?

A) Ana, Beti, Cene, Darja, Emil
B) Ana, Cene, Beti, Darja, Emil
C) Ana, Cene, Darja, Beti, Emil
D) Emil, Cene, Ana, Darja, Beti

Answer

The correct answer is C: Ana, Cene, Darja, Beti, Emil.

Ana is the first to arrive at the library. As she is the only one in the queue, she can return the book immediately. As she returns 4 books, she finishes at 9.04.

At 9.04 there are 2 beavers in the queue: Beti arrived at 9.02 with 6 books and Cene arrived at 9.03 with 2 books. As Cene only has two books, he is the next to return them. Cene finishes returning books at 9.06.

At 9.06 there are 2 beavers in the queue: Beti with 6 books and Darja, who arrived at 9.05 with 4 books. As Darja has fewer books to return than Beti, she is next. Darja finishes returning the books at 9.10.

At 9.10 only Beti is in line, so she returns the books at 9.16. At 9.16 only Emil, who arrived at 9.11, is in the queue with 1 book to return, so he finishes returning his book at 9.17.

Answer A would have been correct if the basis of processing is only the time of arrival.

Answer B is wrong because in this order, Beti returns the books before Darja, even though Darja arrived at the library with fewer books than Beti when the first beaver in the queue was called to the librarian.

Answer D would have been correct if only the number of books is taken into account.

Connection to Informatics

Behind this task is the operation of the scheduler. A scheduler is a program that determines the order in which processes access the central processing unit (CPU) - which processes run, when, and for how long. There are a number of different scheduler concepts, such as:

First Come First Serve (FCFS) - The process that is first in the queue is executed first, processes are executed in their entirety.

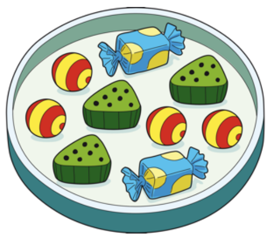
Priority Scheduling - The process with the highest priority is executed first (the process is executed in its entirety).

Round Robin - Processes take turns running for a certain amount of time. If the process is not yet fully executed, it returns to the queue, and a new process is selected to run.

Shortest Job First (SJF) - The process in the queue with the shortest estimated duration is executed first (the process is executed in its entirety). In our case, we used the Shortest Job First algorithm to solve the task.

T2. Candies

Gabija has 9 candies and wants to treat her friends:



- Andrius will take half of all remaining round stripped candies  (rounding down, for example 2.5 rounds to 2).
- Benas will take one candy of each different shape, if at least two candies of that shape are left.
- Marija will take 2 green dotted candies. 

Question / Challenge

What is the order in which Gabija should treat her friends so that she has the most candies left?

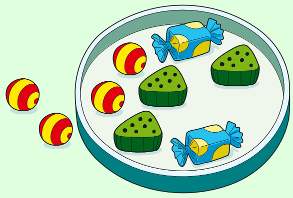
A) Andrius, Benas, Marija **B)** Marija, Benas, Andrius
C) Benas, Andrius, Marija **D)** Marija, Andrius, Benas

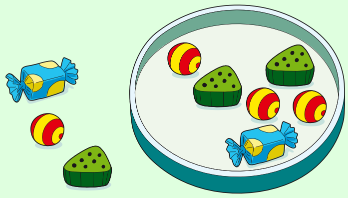
Answer

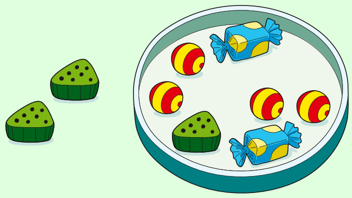
The correct answer is B: Marija, Benas, Andrius

There are six possible scenarios for the order in which the kids can take candies.

For example, for the first kid we can choose between these three options:

Andrius: 

Benas: 

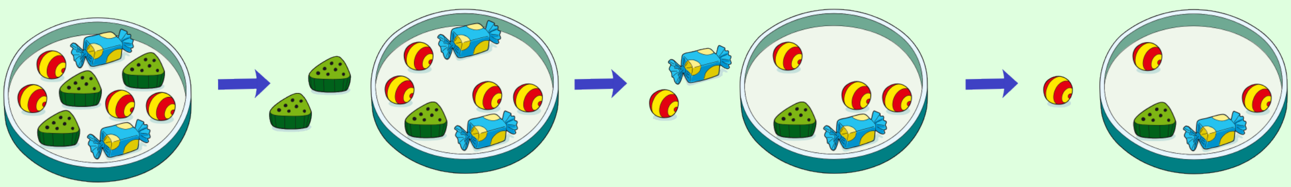
Marija: 

But we don't need to analyze each of the 6 possible scenario, as we can observe that Marija will consistently take 2 candies in all scenarios, because Andrius doesn't take green candies and Benas will only take 1 at most.

But, in the other hand, the number of candies Benas takes depends solely on Marija's turn; if he goes before her, he will take 3 candies (one of each), but if he goes after her, he will take only 2 (no green candies). Therefore, Benas should follow Marija's turn.

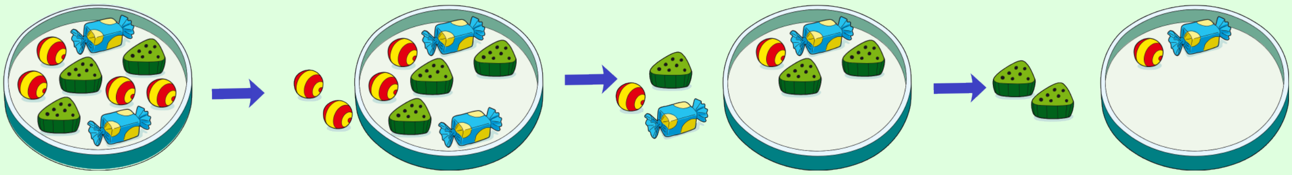
Also, Andrius will take two candies if he goes before Benas, but only one if he goes after him.

Hence, the optimal order is Marija first, followed by Benas, and finally Andrius. It means order B is the correct answer. In this scenario 4 candies will be left:

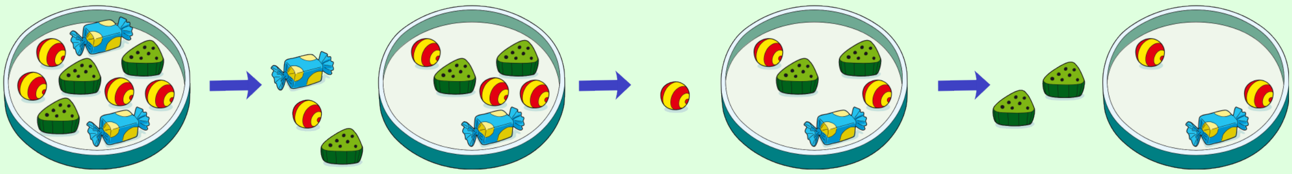


In the other options A, C and D scenarios, less candies will be left in the end.

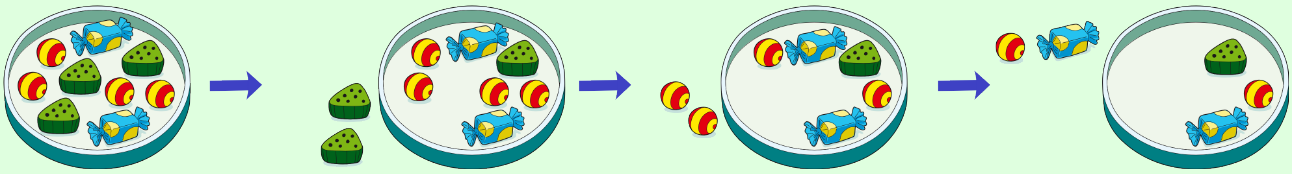
For example, in Option A, only 2 candies remain:



In Options C 3 candies will be left,



and in option D 3 candies will be left too.



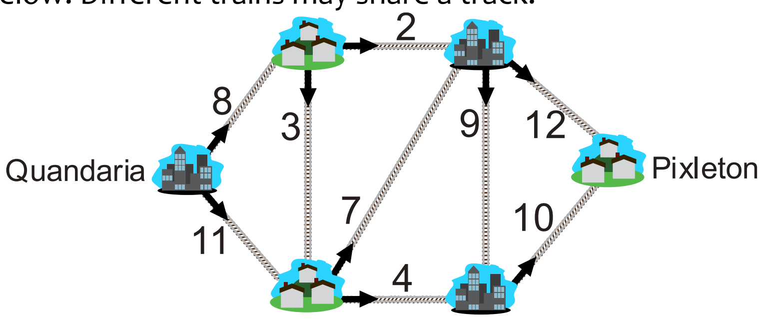
Connection to Informatics

This task depicts a classical optimization problem. One agent, Gabija, wants to maximize the number of elements (candies) that are available after a set of fixed operations. Gabija can decide the order the operations will be performed, which in turn will impact the number of elements left. Informatics can help us solve this kind of problems by devising algorithms that can optimize the outcome of a set of operations by simulating the final outcome.

Optimization algorithms are used, for example, in transportation and logistics, where computers can help optimize routes for delivery trucks, reducing delivery times and fuel consumption. Another example of optimization algorithms can be found in healthcare systems, where such algorithms can be used to schedule resource allocation in hospitals in an optimal way to improve service delivery and reduce patient wait times.

T3. Railway Network

In the land of Bebravia, neighboring settlements are linked by a network of railway tracks. For each track, there is a limited number of trains that can travel along it each day, indicated on the diagram below. Different trains may share a track.



Quandaria offered to send materials to Pixleton. In this direction, trains must always follow the arrows.

Question / Challenge

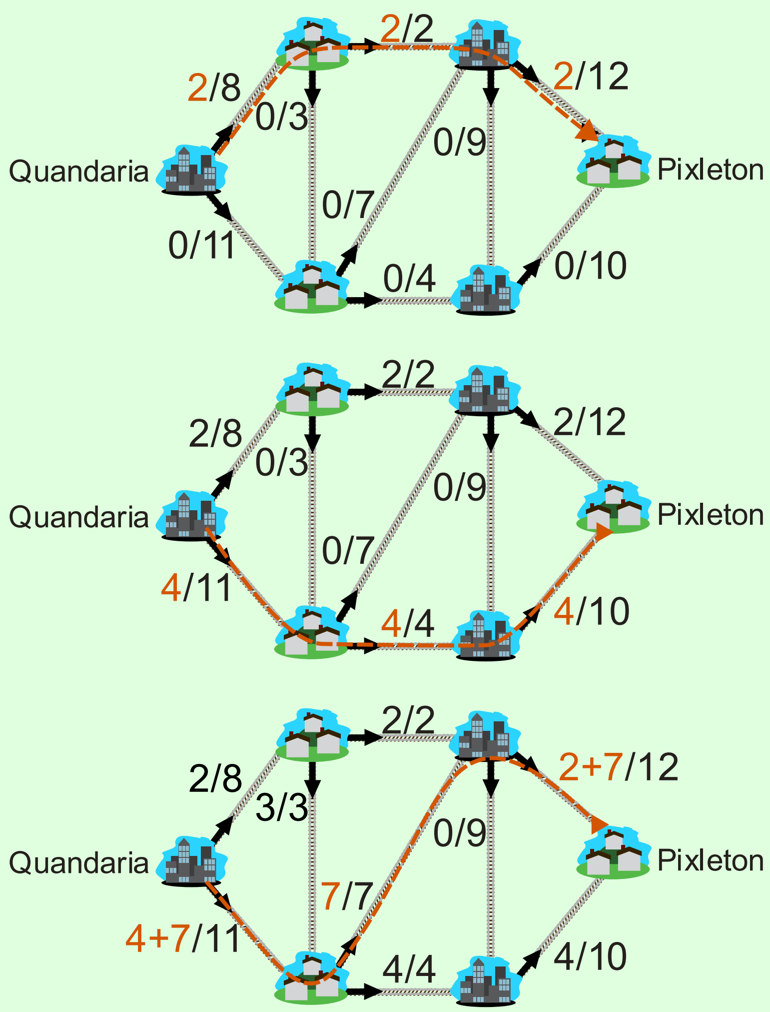
What is the maximum number of trains that can depart from Quandaria and arrive at Pixleton every day?

A) 13 **B)** 15 **C)** 19 **D)** 22

Answer

The correct answer is A) 13. The first observation is that Quandaria (Q) cannot send to Pixleton (P) more than 8+11=19 trains, the number of trains which can leave Q. Therefore, answer c) 22 is incorrect.

One way to solve this problem is to find a shortest possible path from Q to P (in this case, of length 3) and determine the largest number of trains it can accommodate. Then we repeat this step on the rest of the network with the remaining number of trains available on each track. The diagrams below show three paths found in this way, with a combined capacity of 2+4+7=13 trains. There are other ways to push 13 trains from Q to P, including some using longer paths.



To check that 13 is the maximum, notice the three tracks in the middle of the network with capacities 2, 7 and 4: all paths go through one of these, so we cannot do better than 2+7+4=13.

Connection to Informatics

The problem in this task is an instance of the maximum flow problem. Problems of this type are like a puzzle game with water flowing through pipes: you have a network of pipes with different capacities, and you want to figure out how much water can flow from a source to a sink.

The maximum flow problem can be solved using various algorithms: Ford-Fulkerson Algorithm, Edmonds-Karp Algorithm, Dinic's Algorithm and many more. The unavoidable tracks in the middle of the network in this task form what is known as a 'minimum cut'.

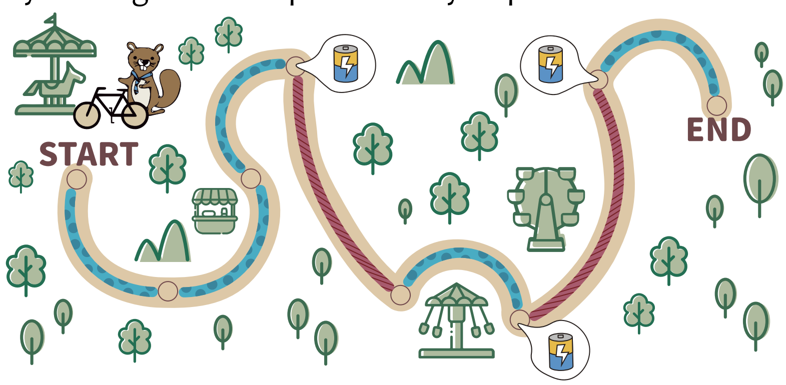
Each of the algorithms above has its advantages and disadvantages in terms of runtime efficiency, ease of implementation, and applicability to different types of networks. The choice of algorithm depends on factors such as the size of the network, the nature of the capacities, and the desired level of optimization.

Maximum flow algorithms are utilized in traffic optimization, distribution systems (e.g. water and electricity), resource allocation, computer networking, and more.

Student Level (Class 11&12)

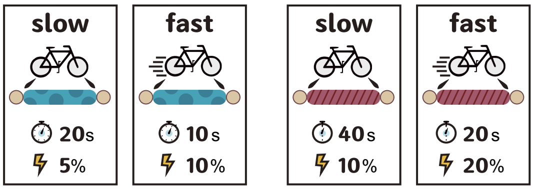
T1. Electric Bike

Realizing that the amusement park is about to close, little Beaver Dean hops on his electric bike and hurries to the exit.
The map below shows the amusement park. There are two types of path sections: a blue section  and a red section . He can change a battery cell  at certain spots and instantly recharge the bike power  by 20 percent.



Dean's bike has two speed modes: slow  and fast . It cannot switch modes during a path section, but can switch modes at the end of a path section.

The following table shows the time and percentage of battery power needed to get through each path section in both modes:



Dean's bike is charged to 20% when he starts, and he has to reach the exit before the power runs out.

Question / Challenge

How many seconds does Dean at least need to reach the exit?

A) 55 **B)** 130 **C)** 150 **D)** 200

Answer

The answer is B) 130.

To complete our mission in the quickest time, we have to use the bike in the fastest possible mode. But, we also have to make sure we don't run out of battery power along the way. We can plan our energy use around the locations of the battery cells, breaking down our strategy into four sections as shown in this table:

Section	Bike mode	Energy used	Energy left	Time
From the start to the first cell	One blue path in fast mode	10	10	10
	Two blue paths in slow mode	2 x 5 = 10	0	2 x 20 = 40
From the first to the second cell	One red path in slow mode	10	10	40
	One blue path in fast mode	10	0	10
From the second to the third cell	One red path in fast mode	20	0	20
From the third cell to the end	One blue path in fast mode	10	10	10

Therefore, it takes at least 10 + 40 + 40 + 10 + 20 + 10 = 130 seconds to reach the exit.

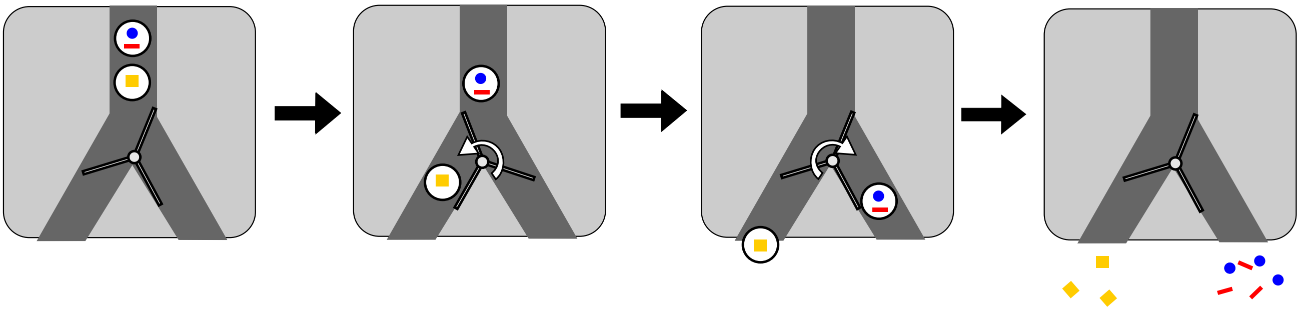
In the first section, we cannot use the fast mode more than once because we would run out of battery before being able to recharge. In the second section, we cannot use the fast mode on the red path as this would also discharge completely the battery before being able to recharge.

Connection to Informatics

Optimization is the process of seeking the best solution to a problem. Under fixed conditions, this involves expressing the problem mathematically and finding the optimal solution through computation or search. Taking the "Electric Bicycle Adventure" game as an example, the map's paths are predetermined, as are the time and energy consumed per path. Under these conditions, seeking to minimize the time spent is essentially the process of searching for the best solution. In the real world, each problem requiring an optimal solution is unique, such as finding the shortest route or minimizing costs, hence there is no single optimization method suitable for all problems. In the scientific domain, numerous algorithms have been developed to find the best solutions, some of which may not guarantee the optimal solution but can help us find results close to it. Optimization is a crucial research topic in the fields of science, engineering, and mathematics, with the rapidly evolving artificial intelligence technology also focusing significantly on this area, such as using AI to identify the most characteristic faces or to determine the best timing for investments.

T2. Pattern Creator

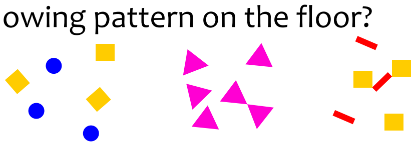
A machine has been created to produce art patterns on a floor when viewed from above. Each ball contains a different pattern shape and follows the direction allowed by gates. Once the ball goes through a gate, the gate automatically switches and sends the next ball in the other direction.

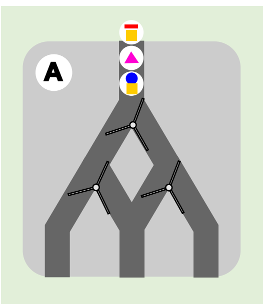


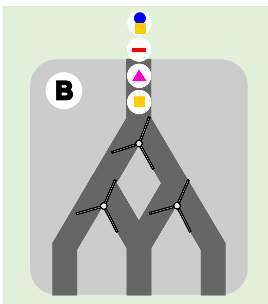
The example shows the gate open on the left, the first ball going left, and the gate switching to send the next ball to the right. This second ball switches the gate back again.
Each ball is labelled with a code representing the shape it will create.
If different balls exit the machine on the same space, the shapes will be distributed on the floor. If two identical balls land on the same space, the result will be the same as if there was only one.

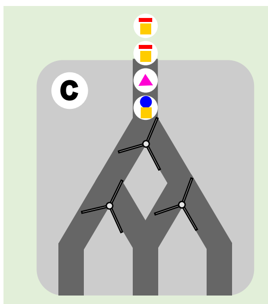
Question / Challenge

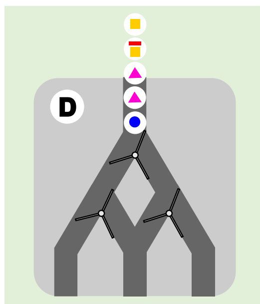
Which balls will create the following pattern on the floor?



A) 

B) 

C) 

D) 

Answer

The correct answer is **D.**

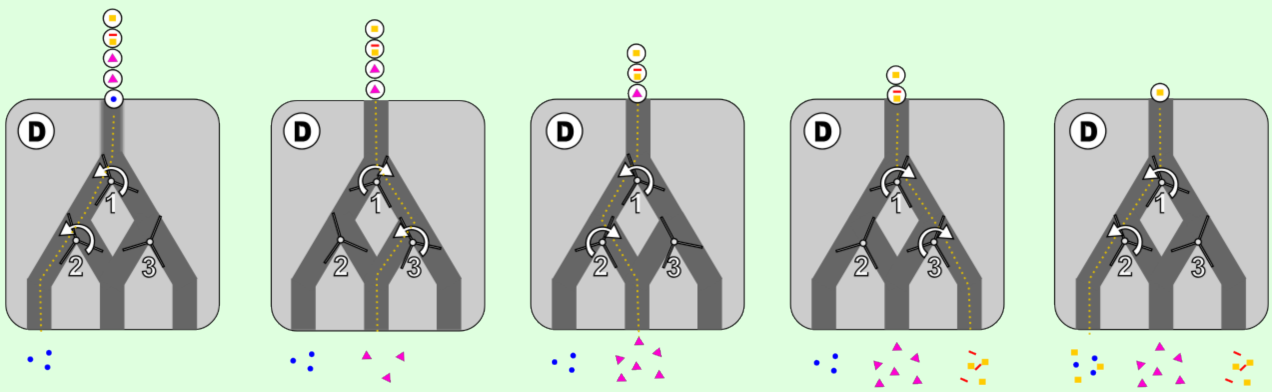
The 1st ball will go down the most left-hand path. This will change the gate 1 and gate 2 to the right.

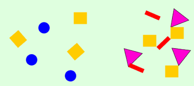
As gate 1 has been changed, the 2nd ball will go to the right, but then left at the gate 3. This will change gate 1 back to left and gate 3 to right.

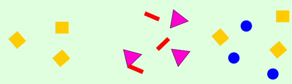
The 3rd ball will be sent left at gate 1 and right at gate 2. This will change gate 1 to right and gate 2 to left.

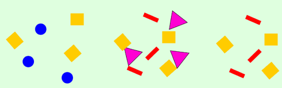
The 4th ball will be sent to the right at gate 1 and will continue right at gate 3. This will change gate 1 and gate 3 to left.

The 5th ball will be sent down the left-hand path.



Answer A is incorrect because it will create this incorrect pattern: 

Answer B is incorrect because it will create this incorrect pattern: 

Answer C is incorrect because it will create this incorrect pattern: 

Connection to Informatics

Computers use very small parts that work like these gates. They are called transistors and a modern computer has billions of them inside to control where the electricity goes. In this task, all the gates were set to the left, but we can see how one gate affects the gates that follow. Transistors in a computer can be set to on or off, just like these gates are set to left or right. Imagine if you could control all the gates independently, wouldn't the task be much easier?

That is how transistors in a computer work. By having an electrical charge or not, it can act like a switch to control a circuit. Transistors can also be used as a memory to store information in a computer, where if there is a charge in the transistor, it represents the digit 1, and if there is no charge it represents the digit 0.

T3. Word Chains

Mr. Castor is teaching his students how to read. To help them learn he creates word chains, which are sequences of words in which exactly one letter in a word is changed in order to create the next word. For example, MUG → MUD → MAD → FAD is a word chain.

Mr. Castor has the following nine words: BOT, SAD, BAT, CAB, COT, BAD, COB, CAT, and SAT. He groups them into three word chains, each with three words, so that each of the nine words is used in one and only one of the word chains.

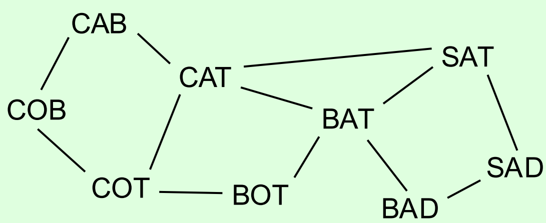
Question / Challenge

None of the following sequences breaks the word chain rules, but one of them makes it impossible to make three word chains without repeating any words. Which option could not be one of Mr. Castor's word chains?

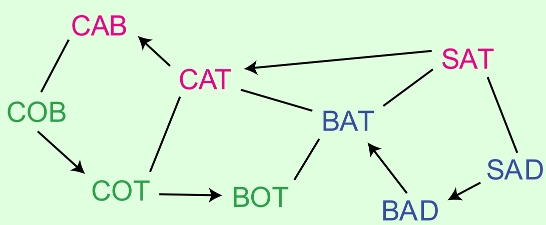
A) SAD → BAD → BAT
B) COT → COB → CAB
C) BAT → CAT → COT
D) CAT → CAB → COB

Answer

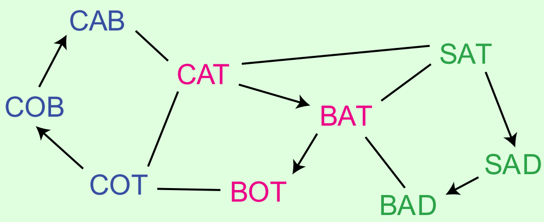
The answer is (C) BAT → CAT → COT. To solve this problem, it is helpful to draw a diagram. In this diagram, two words are connected by a line if they can follow each other in a word chain.



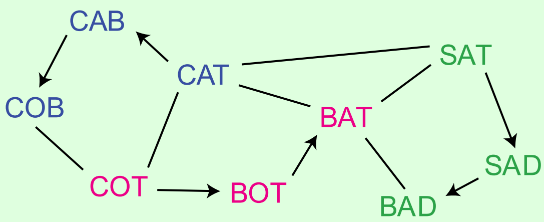
Option A is a possible word chain. In this case, the other two word chains could be SAT → CAT → CAB and COB → COT → BOT, as shown.



Option B is a possible word chain. In this case, the other two word chains could be CAT → BAT → BOT and SAT → SAD → BAD, as shown.



Option D is a possible word chain. In this case, the other two word chains could be COT → BOT → BAT and SAT → SAD → BAD, as shown.



Option C is not a possible word chain because in the diagram, BOT is connected only to BAT and COT. Thus, BOT must be in a word chain with at least one of these words. Since BAT and COT are both in the word chain for Option C, and BOT is not, that leaves no possible word chain for BOT.

Connection to Informatics

In computer science, this type of diagram is called a *graph*, and it is used to show connections. It consists of a set of vertices and a set of edges which each connect a pair of vertices. Here, the vertices represent the words, and there is an edge between two vertices if they can follow each other in a word chain (i.e. if they differ by exactly one letter).

A word chain is found by recording the words along a sequence of connected edges, known as a path, that leads from one word to the next. Since there exists a path between any two vertices in this graph, it is called a *connected graph*. Grouping the nine words into three word chains, each with three words is the same as removing edges of the graph in order to create a *disconnected graph* with three *components*, each with three vertices. In this problem we are checking to see whether or not a given set of three words could be a component of such a disconnected graph.