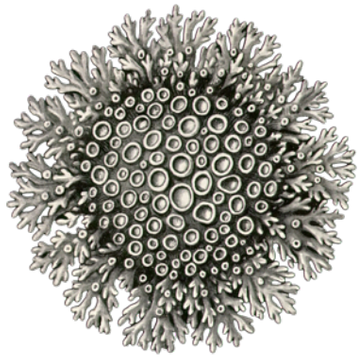
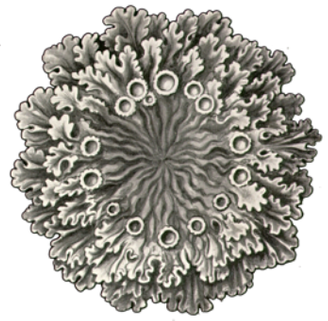
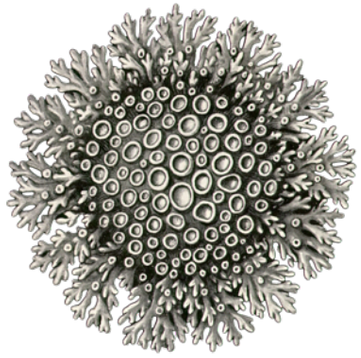


Lichen Puzzles™

multiplication & subtraction

Lichen drawings by Ernst Haeckel
Art Forms of Nature (1904)





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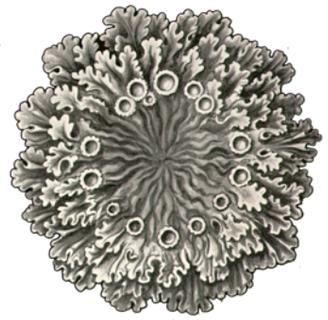


Fungus and algae grow together and help each other. It's called lichen - the algae provides energy and the fungus provides protection. When creatures help each other like the algae and fungus, we call it a symbiotic relationship. Symbiotic sets have the property that *every* number can be created exactly *once* using the *other* numbers in the set. Here we are going to work with multiplication and subtraction. Is {1,2,3,6} symbiotic? Let's see...

1 = 3-2
2 = 3-1
3 = 6-3
6 = 2x3

No. 3 = 6-3 does not work because 3 needs to be created using other numbers - not itself.

Is {2,3,4,5,9,12} symbiotic? Let's see...

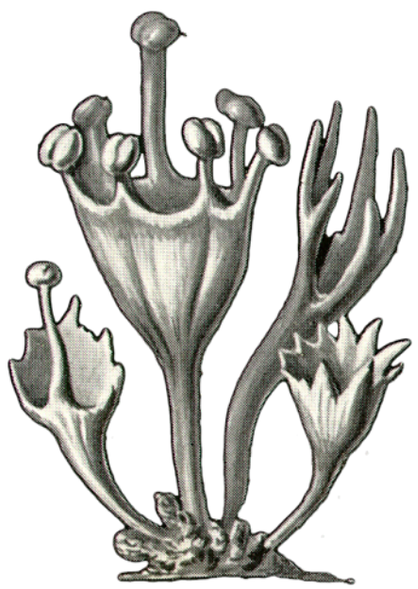
2 = 5-3
3 = 5-2 = 12-9
4 = 9-5
5 = 9-4
9 = 12-3
12 = 3x4

No. This time 3 can be created twice. We want each number to be created exactly once.

4 = 9-5 is the only way to create 4.
4 = 2x2 is not legitimate.
No duplicates!

12 = 3x4 is the only way to create 12.
12 = 2x2x3 is not legitimate.
Multiply only two numbers!

Half of the sets on the right are symbiotic and half are impostors. Find the 3 impostors.



7, 9, 16

3, 4, 9, 12, 27

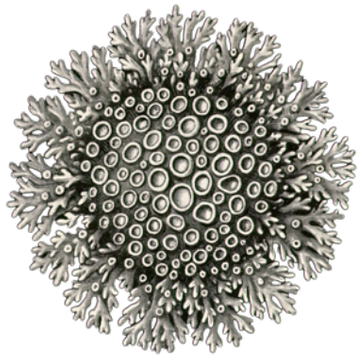
3, 5, 8, 16, 24, 72

3, 5, 7, 8, 15, 21, 24

1, 3, 8, 16, 21, 23, 24

1, 2, 10, 13, 23, 25, 26

Computational thanks to Charles Greathouse IV



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multiplication & subtraction

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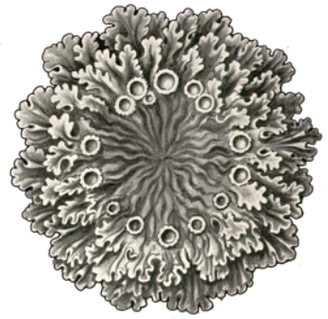


These are all symbiotic sets. You can add a number at the end of each symbiotic set to create a new symbiotic set. What is the smallest such number?

3, 7, 11, 18, 21, 33, ☐

1, 3, 6, 8, 10, 12, 15, 16, 24, ☐

Here, the smallest number cannot be 30 because then there would be two ways to make 24:

24 = 3x8
24 = 30-6

2, 4, 5, 14, 15, 16, 20, ☐

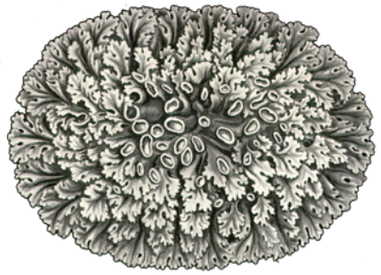
3, 5, 7, 13, 14, 15, 16, 21, ☐

1, 3, 5, 10, 12, 14, 15, 30, 36, ☐

3, 4, 5, 6, 8, 10, 18, 20, ☐

4, 6, 9, 11, 13, 18, 24, ☐

Computational thanks to Charles Greathouse IV



Lichen Puzzles™

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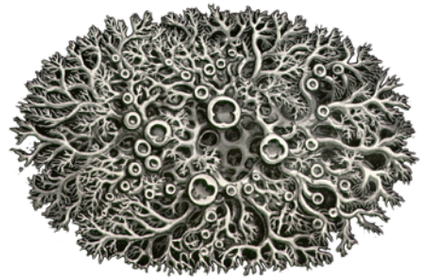


Find the missing numbers in these symbiotic sets.

1, 2, 5, 8, 11, 15, 19, 20, 22, ☐, 55

1, 2, 7, 10, 11, ☐, 18, 20, 36, 40, 72, 77

1, ☐, ☐, 7, 9, 10, 14

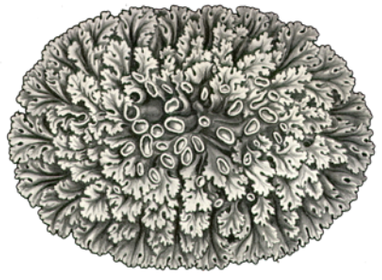
3, 5, 7, ☐, 15, 21

2, 4, 7, 13, ☐, 22, 26

1, 3, 5, 7, 9, 11, 13, ☐, ☐, 33, 39, 55

1, 3, ☐, ☐, 8, 14, 18, 42, 54

Computational thanks to Charles Greathouse IV



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multiplication & subtraction

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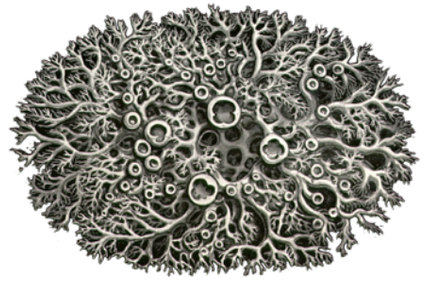


These sets are not symbiotic, but choose a single number to squish and they will be.

4, 5, 7, 17, 24, 28

4, 5, 6, 7, 19, 20, 21, 22, 23, 28, 42

2, 3, 4, 7, 9, 10, 15, 16, 21, 22, 25, 27

3, 9, 10, 11, 15, 16, 17, 18, 27, 30

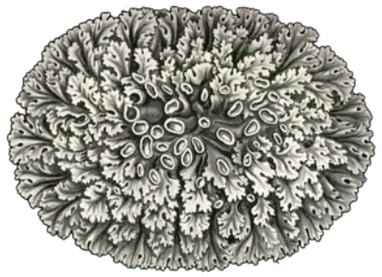
2, 5, 6, 10, 13, 18, 20, 26, 36

1, 2, 10, 12, 13, 15, 20, 25, 26

4, 6, 18, 20, 24, 44, 80

1, 2, 3, 6, 10, 12, 17, 20, 24

Computational thanks to Charles Greathouse IV



Lichen Puzzles™

multiplication & subtraction

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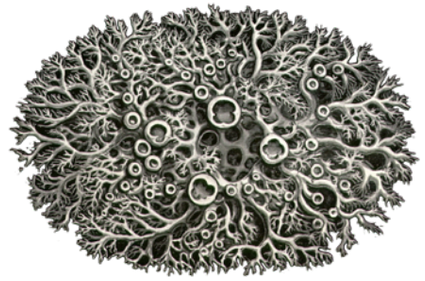


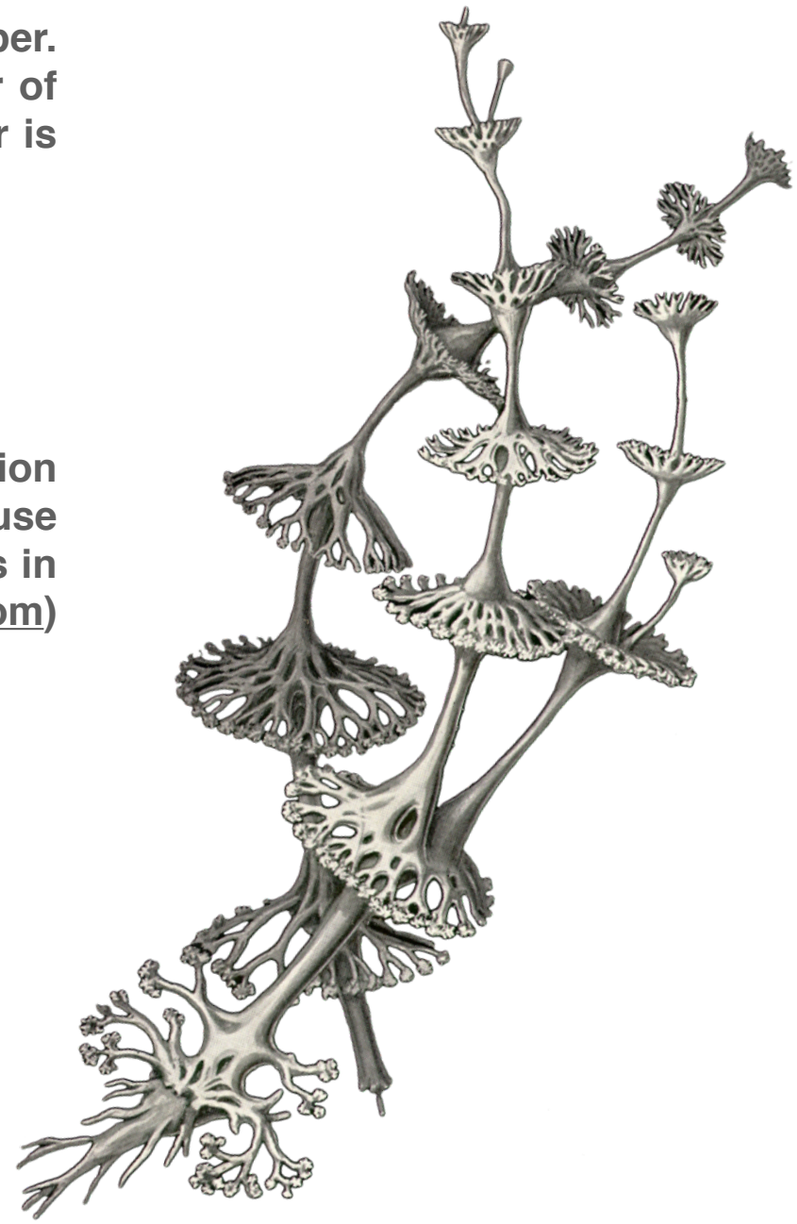
Find a symbiotic set with the fewest numbers.

Find the symbiotic set with the smallest biggest number.

Symbiotic sets can actually allow more than one way to create a number. What's important is that all numbers can be created in the same number of ways. Below I was trying to make a symbiotic set in which each number is created in three ways. Did I succeed?

1, 2, 3, 5, 6, 9, 10, 12, 20, 24, 36, 40, 45, 50, 60

$100 reward for the first person to find a symbiotic set (using multiplication and subtraction) with each number being created twice. Charles Greathouse IV has not been able to find such a set. He has searched all possible sets in which the largest number is less than 40. Email me (gord@mathpickle.com) to claim the reward or commiserate.



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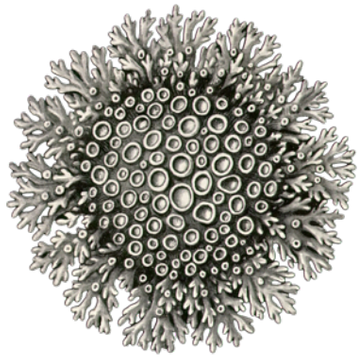
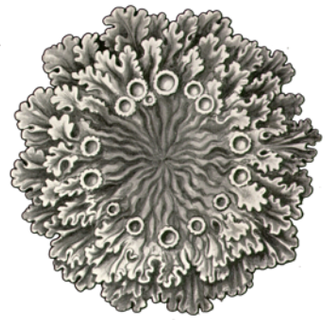


Answers to page 2

Lichen Puzzles™

multiplication & subtraction

Lichen drawings by Ernst Haeckel
Art Forms of Nature (1904)



http://youtu.be/D8wXJ0tZUx4

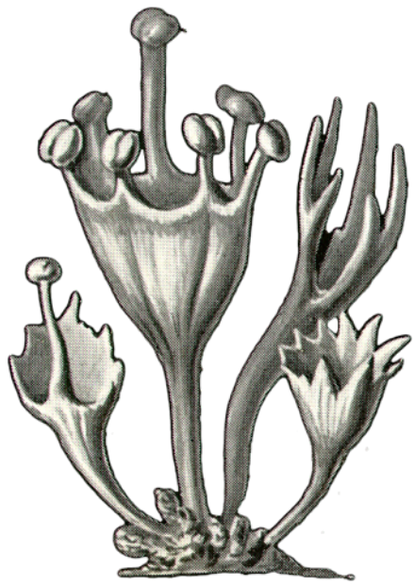
Fungus and algae grow together and help each other. It's called lichen - the algae provides energy and the fungus provides protection. When creatures help each other like the algae and fungus, we call it a symbiotic relationship. Symbiotic sets have the property that every number can be created *once* using the *other* numbers in the set. Here we are going to work with multiplication and subtraction. Is {1,2,3,6} symbiotic? Let's see...

1 = 3-2
2 = 3-1
3 = 6-3 ← No. 3 = 6-3 does not work because 3 needs to be created using other numbers - not itself.
6 = 2x3

Is {2,3,4,5,9,12} symbiotic? Let's see...

2 = 5-3
3 = 5-2 = 12-9 ← No. This time 3 can be created twice. We want each number to be created exactly once.
4 = 9-5 ← 4 = 9-5 is the only way to create 4. 4 = 2x2 is not legitimate. No duplicates!
5 = 9-4
9 = 12-3
12 = 3x4 ← 12 = 3x4 is the only way to create 12. 12 = 2x2x3 is not legitimate. Multiply only two numbers!

Half of the sets on the right are symbiotic and half are impostors. Find the 3 impostors.



7, 9, 16

3, 4, 9, 12, 27

3, 5, 8, 16, 24, 72

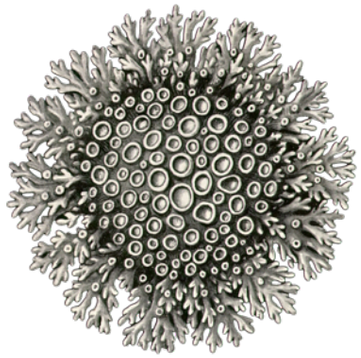
3, 5, 7, 8, 15, 21, 24

1, 3, 8, 16, 21, 23, 24

1, 2, 10, 13, 23, 25, 26

Computational thanks to Charles Greathouse IV

Answers to page 3



Lichen Puzzles™

multiplication & subtraction

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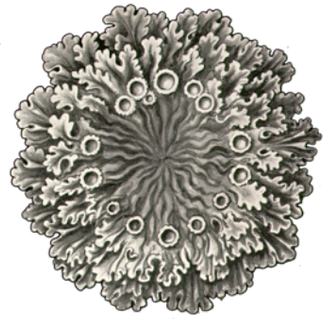


These are all symbiotic sets. You can add a number at the end of each symbiotic set to create a new symbiotic set. What is the smallest such number?

3, 7, 11, 18, 21, 33, **54**

1, 3, 6, 8, 10, 12, 15, 16, 24, **45**

Here, the smallest number cannot be 30 because then there would be two ways to make 24:

24 = 3x8
24 = 30-6

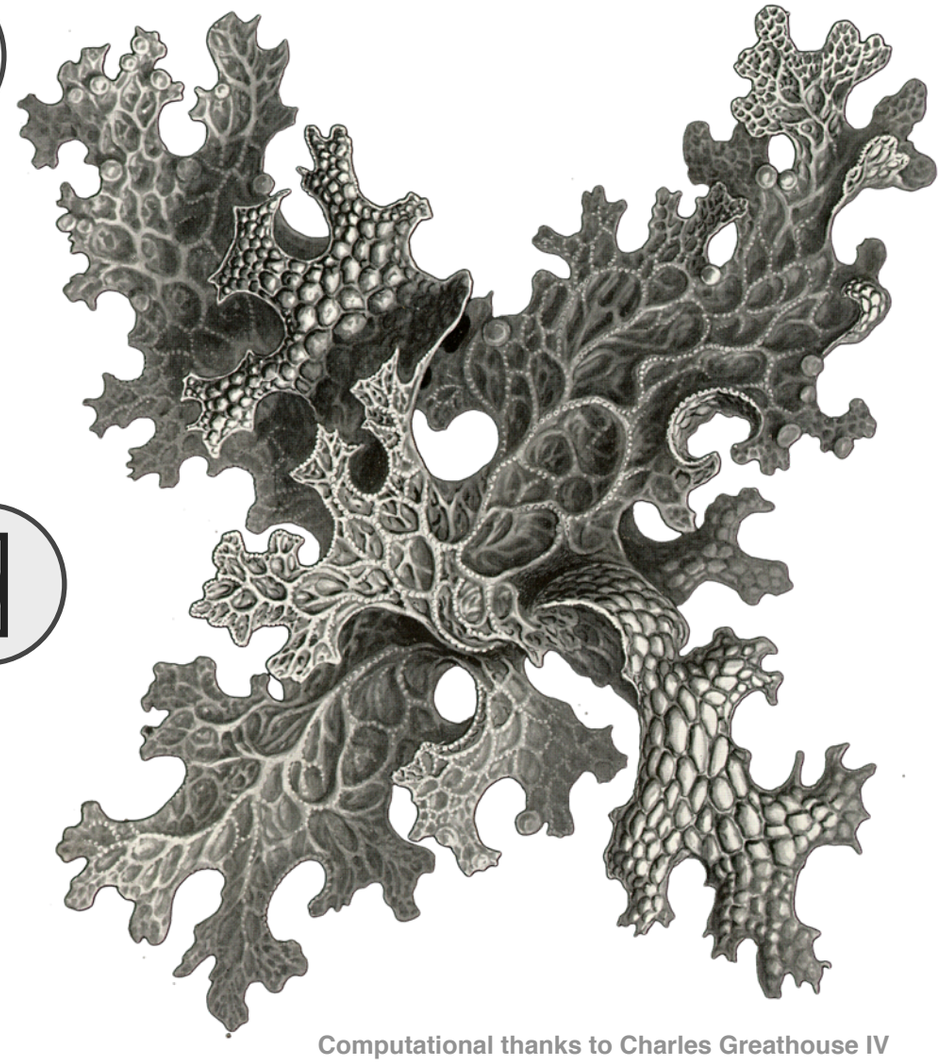
2, 4, 5, 14, 15, 16, 20, **28**

3, 5, 7, 13, 14, 15, 16, 21, **39**

1, 3, 5, 10, 12, 14, 15, 30, 36, **60**

3, 4, 5, 6, 8, 10, 18, 20, **32**

4, 6, 9, 11, 13, 18, 24, **36**



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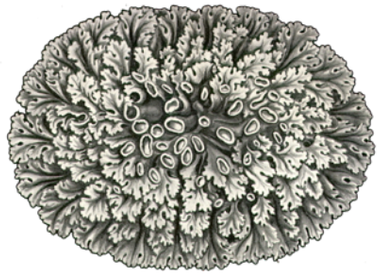
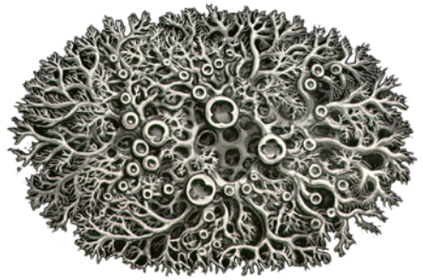


Answers to page 4

Lichen Puzzles™

multiplication & subtraction

Lichen drawings by Ernst Haeckel
Art Forms of Nature (1904)



Find the missing numbers in these symbiotic sets.

1, 2, 5, 8, 11, 15, 19, 20, 22, 38, 55

1, 2, 7, 10, 11, 14, 18, 20, 36, 40, 72, 77

1, 2, 4, 7, 9, 10, 14

3, 5, 7, 12, 15, 21

2, 4, 7, 13, 20, 22, 26

1, 3, 5, 7, 9, 11, 13, 14, 21, 33, 39, 55

1, 3, 4, 6, 8, 14, 18, 42, 54

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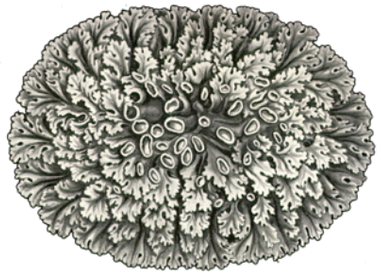
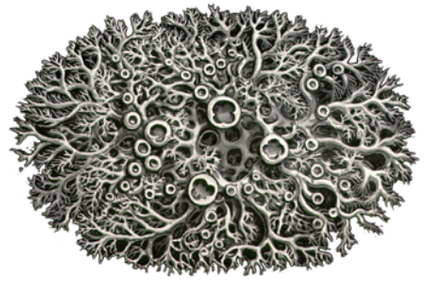


Answers to page 5

Lichen Puzzles™

multiplication & subtraction

Lichen drawings by Ernst Haeckel
Art Forms of Nature (1904)



These sets are not symbiotic, but choose a single number to squish and they will be.

4, 5, 7, 17, 24, 28

4, 5, 6, 7, 19, 20, 21, 22, 23, 28, 42

2, 3, 4, 7, 9, 10, 15, 16, 21, 22, 25, 27

3, 9, 10, 11, 15, 16, 17, 18, 27, 30

2, 5, 6, 10, 13, 18, 20, 26, 36

1, 2, 10, 12, 13, 15, 20, 25, 26

4, 6, 18, 20, 24, 44, 80

1, 2, 3, 6, 10, 12, 17, 20, 24

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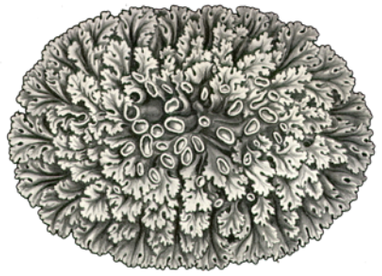
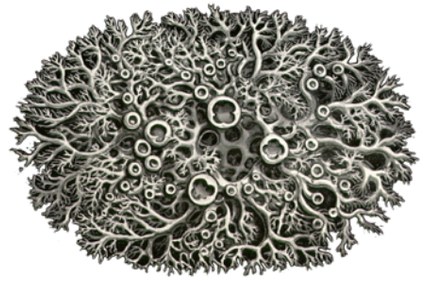


Answers to page 6

Lichen Puzzles™

multiplication & subtraction

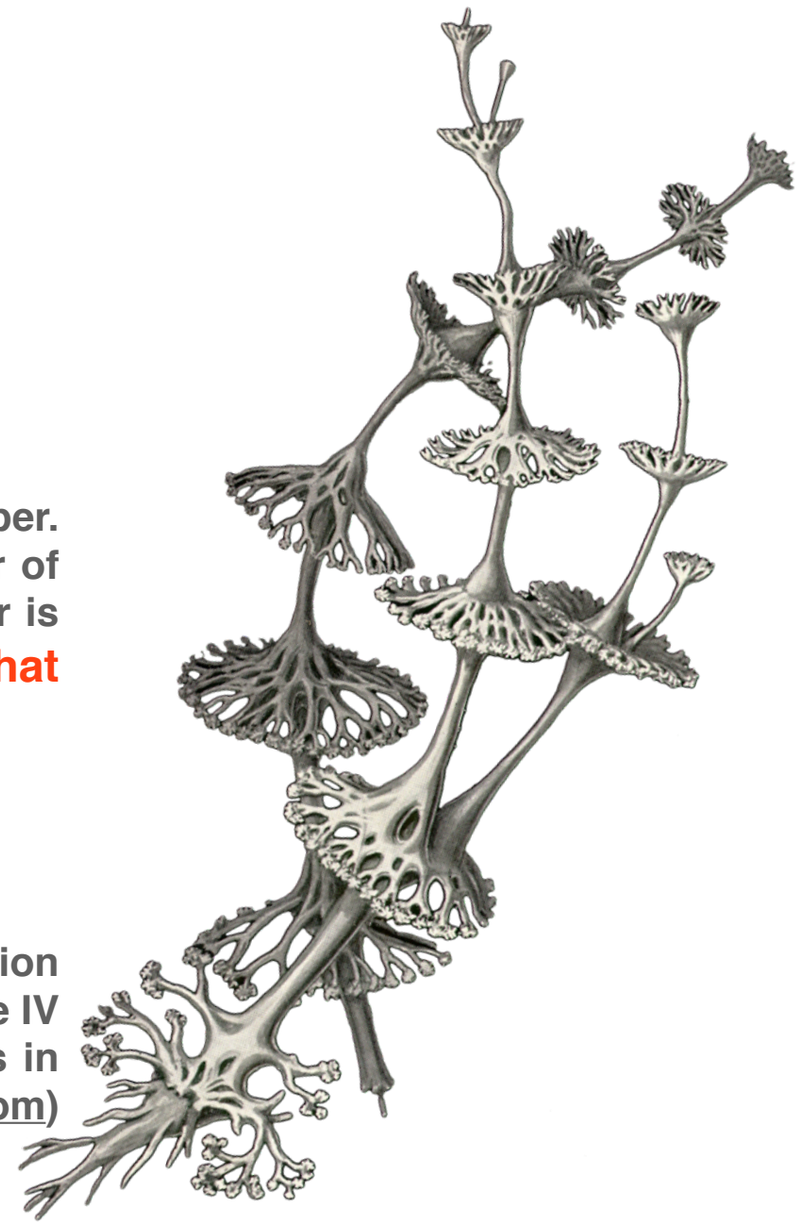
Lichen drawings by Ernst Haeckel
Art Forms of Nature (1904)



Find a symbiotic set with the fewest numbers. Five is the fewest (see below).

Find the symbiotic set with the smallest biggest number.
The smallest biggest number is 12. There are six solutions:

- 3, 4, 5, 7, 12
- 1, 3, 4, 8, 12
- 3, 4, 5, 8, 12
- 3, 4, 5, 9, 12
- 3, 4, 8, 9, 12
- 2, 3, 6, 7, 10, 12



Symbiotic sets can actually allow more than one way to create a number. What's important is that all numbers can be created in the same number of ways. Below I was trying to make a symbiotic set in which each number is created in three ways. Did I succeed? No - there are many numbers that fall short...

- 1, 2, 3, 5, 6, 9, 10, 12, 20, 24, 36, 40, 45, 50, 60

$100 reward for the first person to find a symbiotic set (using multiplication and subtraction) with each number being made twice. Charles Greathouse IV has not been able to find such a set. He has searched all possible sets in which the largest number is less than 40. Email me (gord@mathpickle.com) to claim the reward or commiserate.

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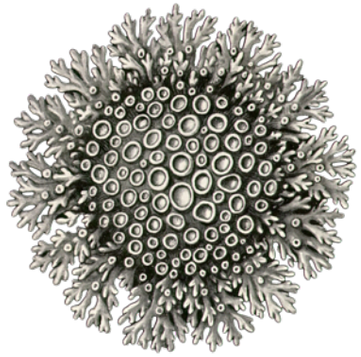

Lichen Puzzles™

multiplication & subtraction

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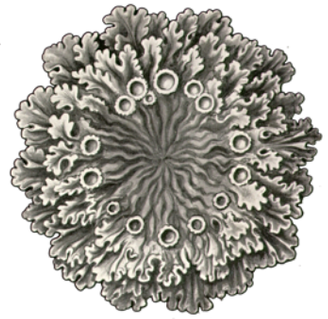

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1 = 3-2
2 = 3-1
3 = 6-3
6 = 2x3

No. 3 = 6-3 does not work because 3 needs to be created using other numbers - not itself.

Is {2,3,4,5,9,12} symbiotic? Let's see...

2 = 5-3
3 = 5-2 = 12-9
4 = 9-5
5 = 9-4
9 = 12-3
12 = 3x4

No. This time 3 can be created twice. We want each number to be created exactly once.

4 = 9-5 is the only way to create 4.
4 = 2x2 is not legitimate.
No duplicates!

12 = 3x4 is the only way to create 12.
12 = 2x2x3 is not legitimate.
Multiply only two numbers!

Half of the sets on the right are symbiotic and half are impostors. Find the 3 impostors.

8, 9, 17

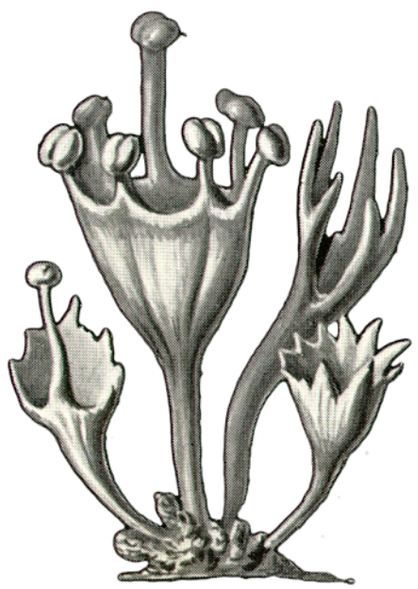
3, 5, 7, 8, 15

4, 5, 9, 11, 20

3, 7, 10, 11, 21

2, 5, 8, 13, 15, 16

1, 2, 4, 7, 8, 12, 14



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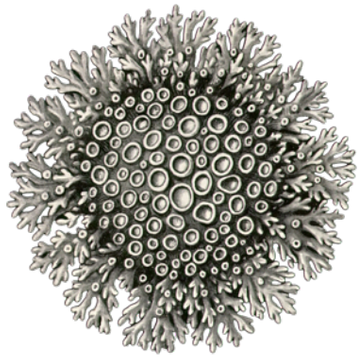
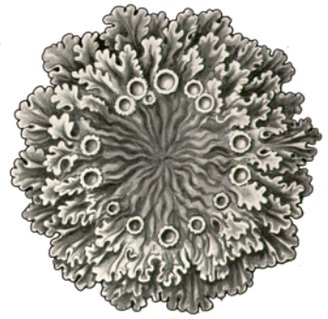


Lichen Puzzles™



multiplication & subtraction

Lichen drawings by Ernst Haeckel
Art Forms of Nature (1904)

These are all symbiotic sets. You can add a number at the end of each symbiotic set to create a new symbiotic set. What is the smallest such number?

3, 4, 5, 6, 10, 13, 18, ☐

2, 4, 5, 8, 11, 15, 18, 20, ☐

3, 4, 5, 6, 7, 12, 14, 20, ☐

2, 3, 6, 7, 10, 11, 19, 20, 21, ☐

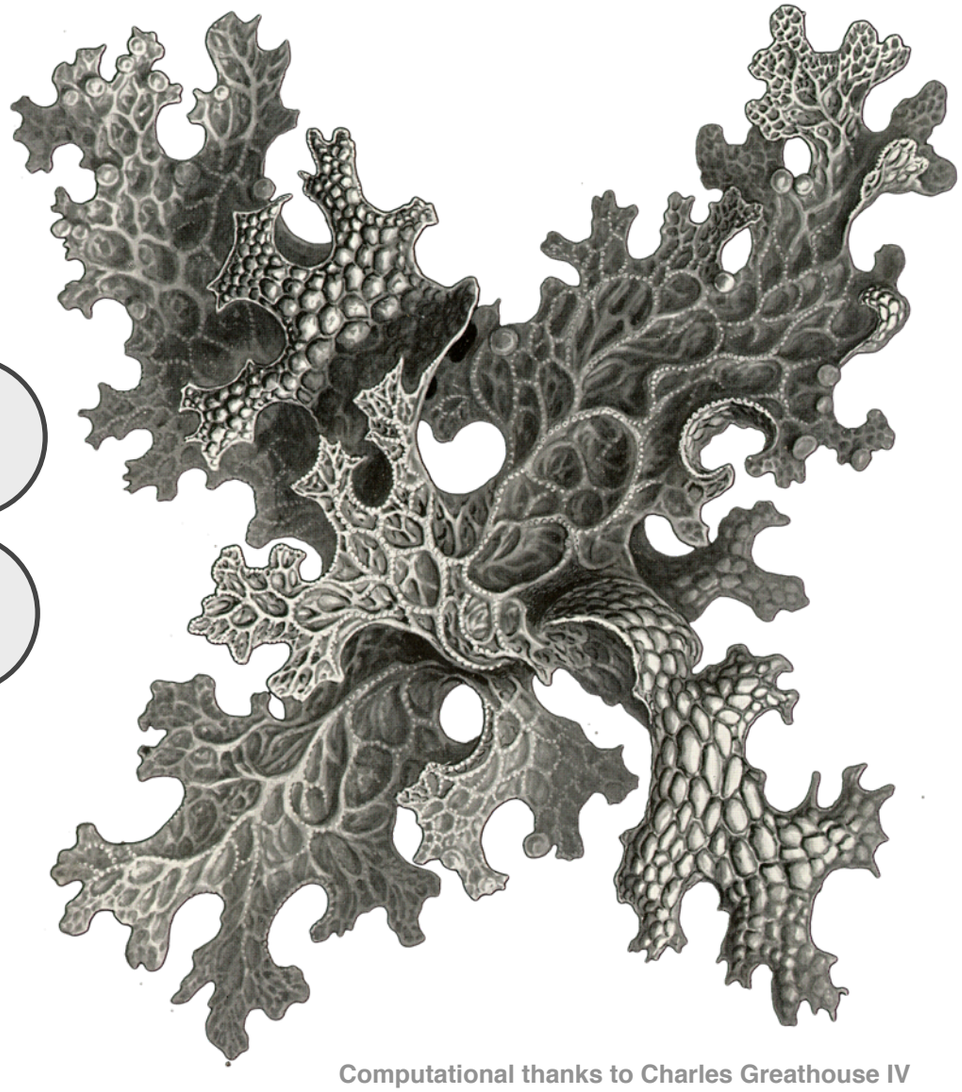
1, 2, 5, 8, 11, 15, 19, 20, 22, ☐

3, 4, 7, 8, 9, 16, 24, ☐

1, 3, 8, 13, 15, 16, 24, ☐

Here, the smallest number cannot be 22 because then there would be two ways to make 20:

$20 = 4 \times 5$
$20 = 22 - 2$



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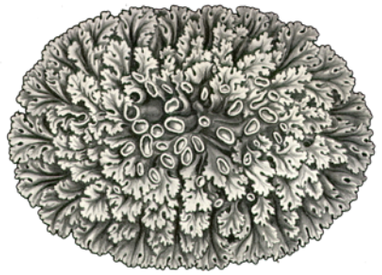

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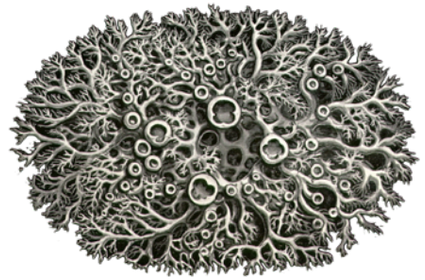
Lichen drawings by Ernst Haeckel
Art Forms of Nature (1904)



Find the missing numbers in these symbiotic sets.

2, 4, 7, 10, 13, 15, 16, 19, ☐

2, 3, 8, 9, 14, 15, ☐, 26, 27, 28, 33, 39, 72

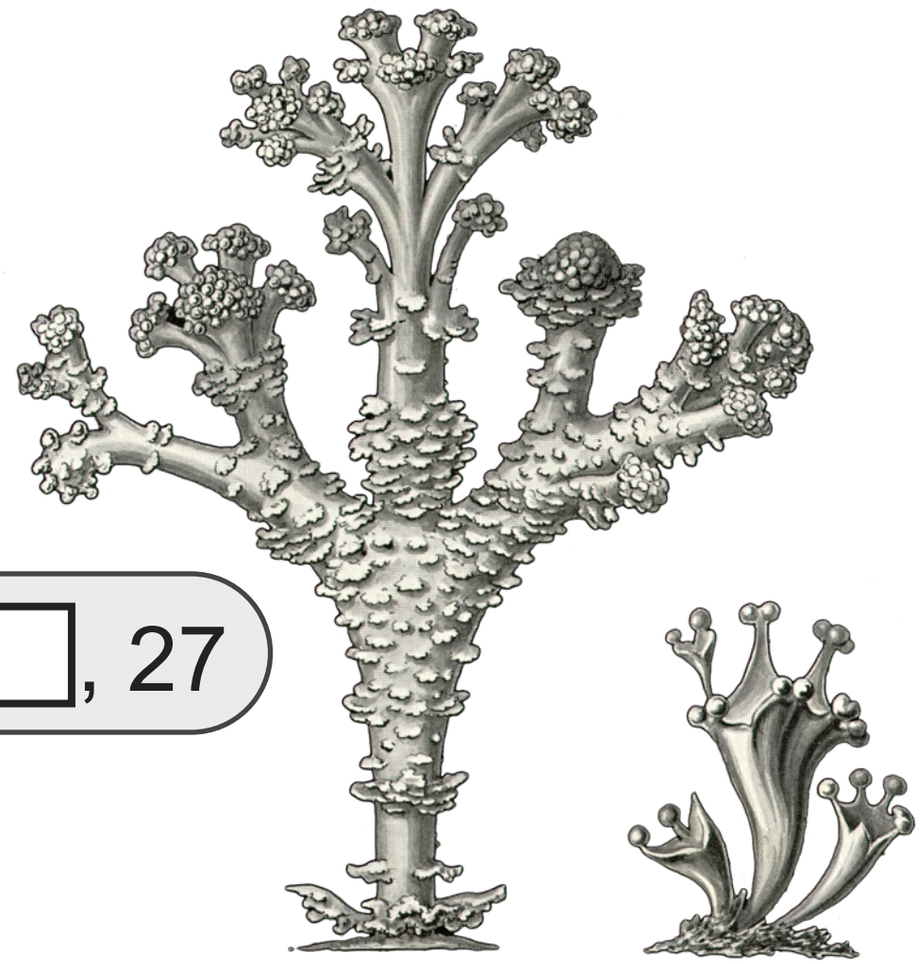
1, ☐, 6, 8, 11, 15, 16, 18, 24

☐, ☐, 14, 18, 24

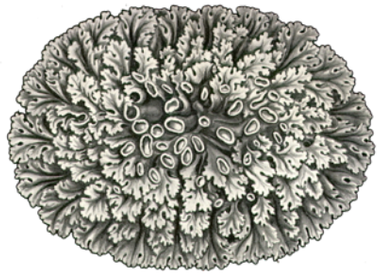
3, 7, 10, 11, ☐, 77

1, 3, 7, 9, 11, 15, 17, 19, 21, 23, ☐, 27

4, 5, 15, ☐, ☐, 100



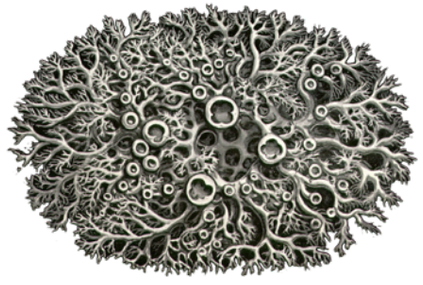
Computational thanks to Charles Greathouse IV



Lichen Puzzles™

multiplication & subtraction

Lichen drawings by Ernst Haeckel
Art Forms of Nature (1904)



These sets are not symbiotic, but squish the right number and they will be.

3, 5, 8, 16, 21, 24

2, 5, 10, 13, 18, 20, 45, 65

3, 4, 5, 6, 7, 10, 16, 21, 48

1, 2, 8, 14, 16, 20, 28

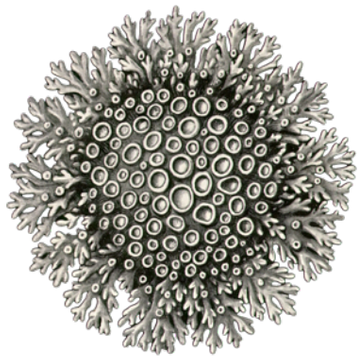
1, 2, 6, 8, 11, 12, 20, 22, 88

2, 7, 10, 12, 14, 17, 24, 34

1, 3, 8, 9, 12, 20, 23, 24, 60

2, 3, 4, 9, 10, 12, 18, 23, 27

Computational thanks to Charles Greathouse IV

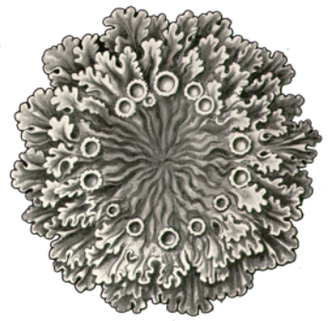


Answers to page 12

Lichen Puzzles™

multiplication & subtraction

Lichen drawings by Ernst Haeckel
Art Forms of Nature (1904)



http://youtu.be/D8wXJ0tZUx4

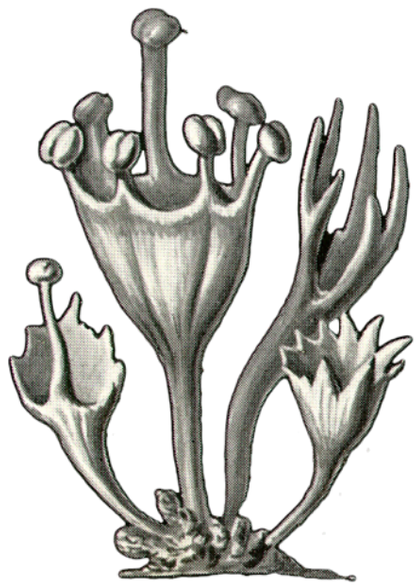
Symbiotic sets have the property that every number can be created *once* using the *other* numbers in the set. Here we are going to work with multiplication and subtraction. Is {1,2,3,6} symbiotic? Let's see...

1 = 3-2
2 = 3-1
3 = 6-3 ← No. 3 = 6-3 does not work because 3 needs to be created using other numbers - not itself.
6 = 2x3

Is {2,3,4,5,9,12} symbiotic? Let's see...

2 = 5-3
3 = 5-2 = 12-9 ← No. This time 3 can be created twice. We want each number to be created exactly once.
4 = 9-5 ← 4 = 9-5 is the only way to create 4. 4 = 2x2 is not legitimate. No duplicates!
5 = 9-4
9 = 12-3
12 = 3x4 ← 12 = 3x4 is the only way to create 12. 12 = 2x2x3 is not legitimate. Multiply only two numbers!

Half of the sets on the right are symbiotic and half are impostors. Find the 3 impostors.



8, 9, 17

3, 5, 7, 8, 15

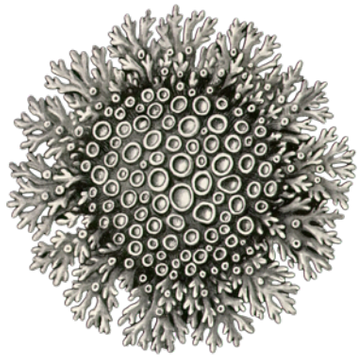
4, 5, 9, 11, 20

3, 7, 10, 11, 21

2, 5, 8, 13, 15, 16

1, 2, 4, 7, 8, 12, 14

Computational thanks to Charles Greathouse IV

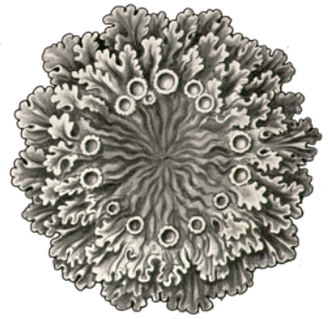


Answers to page 13

Lichen Puzzles™

multiplication & subtraction

Lichen drawings by Ernst Haeckel
Art Forms of Nature (1904)



These are all symbiotic sets. You can add a number at the end of each symbiotic set to create a new symbiotic set. What is the smallest such number?

3, 4, 5, 6, 10, 13, 18, **20**

2, 4, 5, 8, 11, 15, 18, 20, **30**

3, 4, 5, 6, 7, 12, 14, 20, **30**

2, 3, 6, 7, 10, 11, 19, 20, 21, **38**

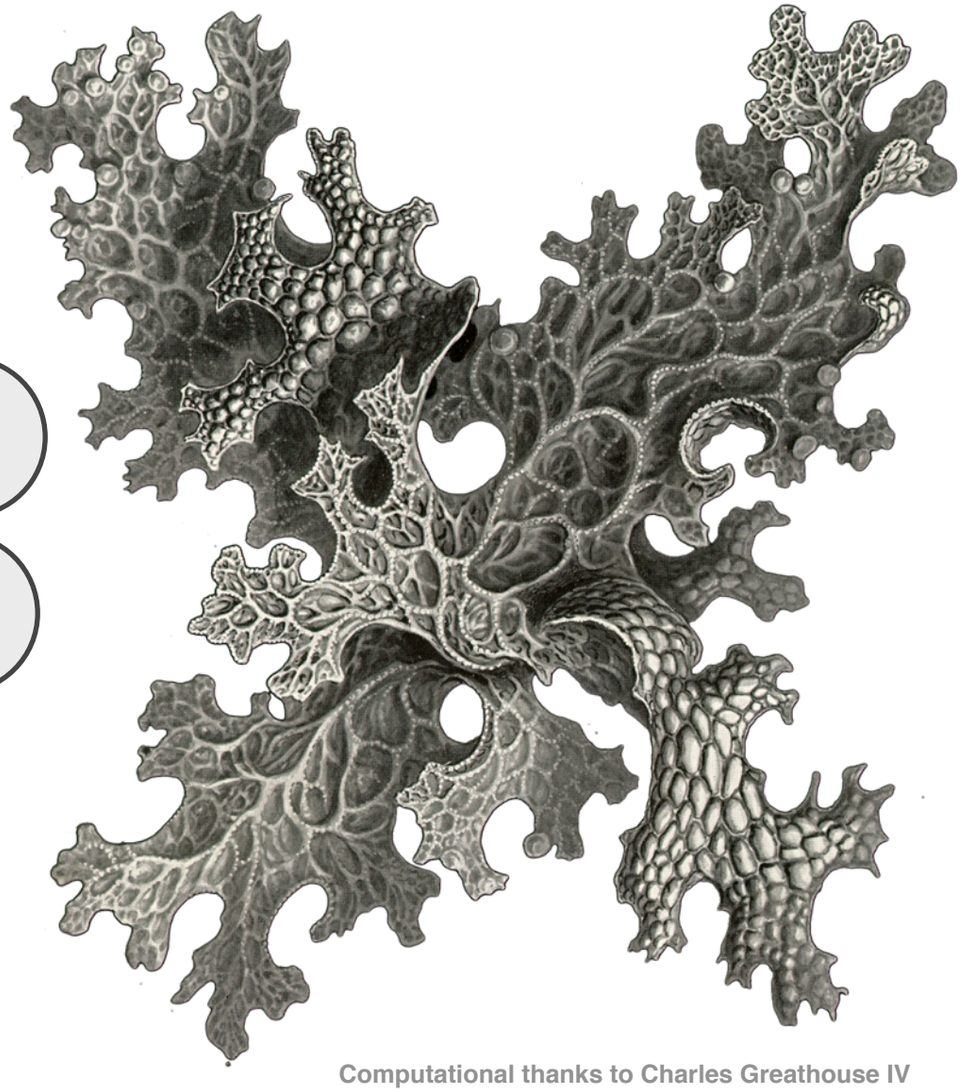
1, 2, 5, 8, 11, 15, 19, 20, 22, **38**

3, 4, 7, 8, 9, 16, 24, **36**

1, 3, 8, 13, 15, 16, 24, **39**

Here, the smallest number cannot be 22 because then there would be two ways to make 20:

20 = 4x5
20 = 22-2



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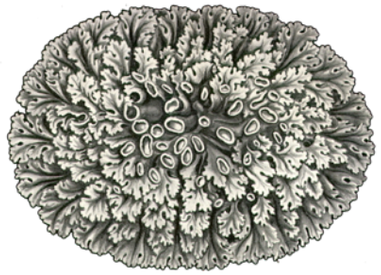
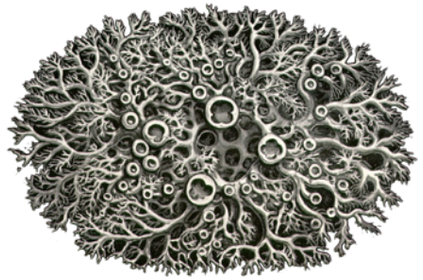


Answers to page 14

Lichen Puzzles™

multiplication & subtraction

Lichen drawings by Ernst Haeckel
Art Forms of Nature (1904)



Find the missing numbers in these symbiotic sets.

2, 4, 7, 10, 13, 15, 16, 19, **26**

2, 3, 8, 9, 14, 15, **23**, 26, 27, 28, 33, 39, 72

1, **4**, 6, 8, 11, 15, 16, 18, 24

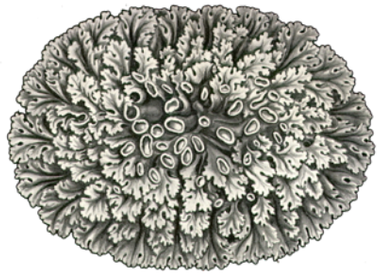
4, **6**, 14, 18, 24

3, 7, 10, 11, **30**, 77

1, 3, 7, 9, 11, 15, 17, 19, 21, 23, **26**, 27

4, 5, 15, **16**, **20**, 100

Computational thanks to Charles Greathouse IV

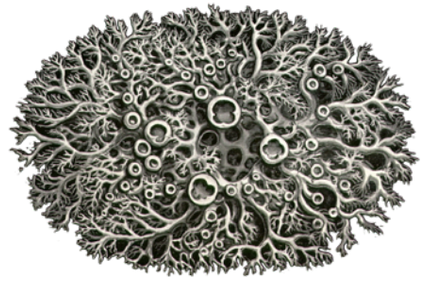


Answers to page 15

Lichen Puzzles™

multiplication & subtraction

Lichen drawings by Ernst Haeckel
Art Forms of Nature (1904)



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3, 5, 8, 16, 21, 24

2, 5, 10, 13, 18, 20, 45, 65

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1, 2, 8, 14, 16, 20, 28

1, 2, 6, 8, 11, 12, 20, 22, 88

2, 7, 10, 12, 14, 17, 24, 34

1, 3, 8, 9, 12, 20, 23, 24, 60

2, 3, 4, 9, 10, 12, 18, 23, 27

Computational thanks to Charles Greathouse IV

Is this a Symbiotic Set?

3, 4, 5, 7, 12, 20, 60

Is this a Symbiotic Set? No

3, 4, 5, 7, 12, 20, 60

Is this a Symbiotic Set? No

3, 4, 5, 7, 12, 20, 60

60 = 5x12 = 3x20

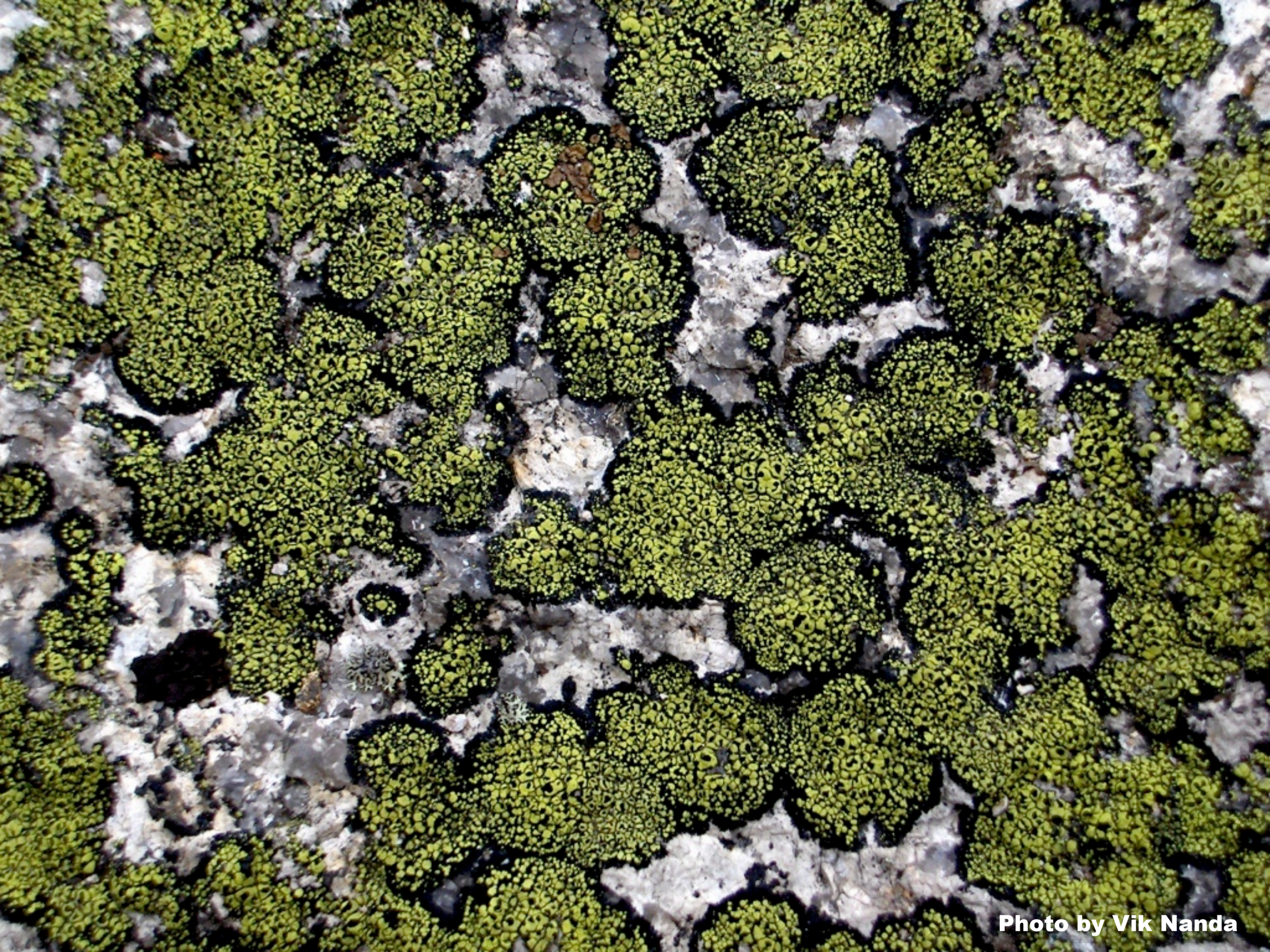
Photo by Vik Nanda

Is this a Symbiotic Set?

2, 10, 13, 15, 25, 26

Photo by Vik Nanda

Is this a Symbiotic Set? No

2, 10, 13, 15, 25, 26

Photo by Vik Nanda

Is this a Symbiotic Set? No

2, 10, 13, 15, 25, 26

25 = ?

Photo by Vik Nanda


Photo by Conor Lawless

Is this a Symbiotic Set?

3, 5, 6, 7, 8, 15, 21

Photo by Conor Lawless

Is this a Symbiotic Set? No

3, 5, 6, 7, 8, 15, 21

Photo by Conor Lawless

Is this a Symbiotic Set? No

3, 5, 6, 7, 8, 15, 21

15 = 21-6 = 3x5

Photo by Conor Lawless

Photo by Steve Martin

Is this a Symbiotic Set?

4, 6, 14, 20, 24, 60, 80

Photo by Steve Martin

Is this a Symbiotic Set? No

4, 6, 14, 20, 24, 60, 80

Photo by Steve Martin

Is this a Symbiotic Set? No

4, 6, 14, 20, 24, 60, 80

20 = 24-4 = 80-60

Photo by Steve Martin

Is this a Symbiotic Set?

3, 5, 7, 8, 15, 25, 40

Is this a Symbiotic Set? No

3, 5, 7, 8, 15, 25, 40

Is this a Symbiotic Set? No

3, 5, 7, 8, 15, 25, 40

15 = 3x5 = 40-25

Photo by Steve Martin

Is this a Symbiotic Set?

4, 7, 10, 17, 21, 28

Photo by Steve Martin

Is this a Symbiotic Set? No

4, 7, 10, 17, 21, 28

Photo by Steve Martin

Is this a Symbiotic Set? No

4, 7, 10, 17, 21, 28

7 = 17-10 = 28-21

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Is this a Symbiotic Set?

2, 5, 13, 18, 24, 26

Photo by Conor Lawless

Is this a Symbiotic Set? No

2, 5, 13, 18, 24, 26

Photo by Conor Lawless

Is this a Symbiotic Set? No

2, 5, 13, 18, 24, 26

18 = ?

Photo by Conor Lawless

Standards for Mathematical Practice

All MathPickle recommendations, including **Lichen Puzzles**, are guaranteed to engage a wide spectrum of student abilities while targeting the following Standards for Mathematical Practice:

MP1 Toughen up!
This is problem solving where our students develop grit and resiliency in the face of nasty, thorny problems. It is the most sought after skill for our students.

MP3 Work together!
This is collaborative problem solving in which students discuss their strategies to solve a problem and identify missteps in a failed solution. MathPickle recommends pairing up students for all its puzzles.

MP6 Be precise!
This is where our students learn to communicate using precise terminology. MathPickle encourages students not only to use the precise terms of others, but to invent and rigorously define their own terms.

MP7 Be observant!
One of the things that the human brain does very well is identify pattern. We sometimes do this too well and identify patterns that don't really exist.

Common Core State Standards

Lichen Puzzles target Common Core State Standards for students practicing multiplication. Although it covers curricular topics in grade 3, I'm only recommending it for good grade 3 classes and forward because the puzzles become quite challenging.

Grades 3-4

CCSS.MATH.CONTENT.3.OA.A.1
Interpret products of whole numbers, e.g., interpret 5 × 7 as the total number of objects in 5 groups of 7 objects each.

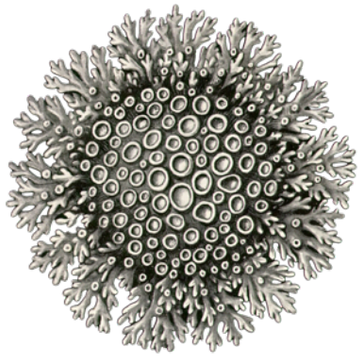
CCSS.MATH.CONTENT.3.OA.A.4
Determine the unknown whole number in a multiplication or division equation relating three whole numbers. For example, determine the unknown number that makes the equation true in each of the equations 8 × ? = 48, 5 = _ ÷ 3, 6 × 6 = ?

CCSS.MATH.CONTENT.3.OA.C.7
Fluently multiply and divide within 100, using strategies such as the relationship between multiplication and division (e.g., knowing that 8 × 5 = 40, one knows 40 ÷ 5 = 8) or properties of operations. By the end of Grade 3, know from memory all products of two one-digit numbers.

CCSS.MATH.CONTENT.4.OA.A.1
Interpret a multiplication equation as a comparison, e.g., interpret 35 = 5 × 7 as a statement that 35 is 5 times as many as 7 and 7 times as many as 5. Represent verbal statements of multiplicative comparisons as multiplication equations.

CCSS.MATH.CONTENT.4.NBT.B.5
Multiply a whole number of up to four digits by a one-digit whole number, and multiply two two-digit numbers, using strategies based on place value and the properties of operations.

http://www.corestandards.org/Math/Practice/



Lichen Puzzles

multiplication & subtraction

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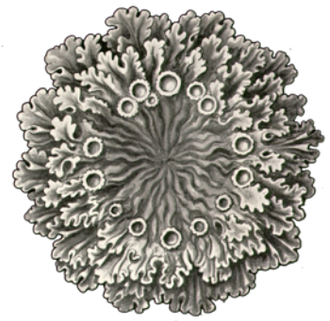

Three of these six are Symbiotic Sets

- 7, 9, 16
- 3, 4, 9, 12, 27
- 3, 5, 8, 16, 24, 72
- 3, 5, 7, 8, 15, 21, 24
- 1, 3, 8, 16, 21, 23, 24
- 1, 2, 10, 13, 23, 25, 26

Three of these six are Symbiotic Sets

- 8, 9, 17
- 3, 5, 7, 8, 15
- 4, 5, 9, 11, 20
- 3, 7, 10, 11, 21
- 2, 5, 8, 13, 15, 16
- 1, 2, 4, 7, 8, 12, 14

Put Your Students in a Pickle!

I'm a father of two elementary school children, a mathematician, and designer of puzzles and board games. Students call me Dr. Pickle. There is nothing I enjoy more than stumping students and having them stump me.

I founded MathPickle.com in 2010 to inject new ideas into the classroom. MathPickle's primary objective is to get thirteen curricular unsolved problems into classrooms worldwide - one for each grade K-12. A conference in November 2013 established the thirteen unsolved problems. To aid with the dissemination of these awesome problems, MathPickle is looking at setting up a $1,000,000 reward for each - the prize money to be split between the person who solves the problem and their most inspirational K-12 educator.

MathPickle is also developing a range of curricular puzzles like the ones you'll find at TpT. These help teachers them with their number one challenge:

"How to engage the spectrum of student ability?"

Whenever an elementary school teacher wants to teach addition, she will invariably face 20% of students who already know how to add and another 20% who are struggling with last year's curriculum. How can she engage the top students without losing the bottom students? How can she engage the bottom students without boring the top students?

One solution: Parents of top students often ask that their child be allowed to accelerate through the curriculum. This exacerbates the problem for future teachers, and sets up a failure-impoverished education experience for the bright student.

A wiser approach is to use curricular puzzles, games and mini-competitions to simultaneously teach curriculum to the students who need it, and to deflect top students into tough problem solving activities. This is never time wasted, because problem solving is the primary reason we teach mathematics.

The experience of mathematics should be profound and beautiful. Too much of the regular K-12 mathematics experience is trite and true. Children deserve tough, beautiful puzzles.

Gordon Hamilton
MMath, PhD