MaPP Challenge ’20 – Mystery of the Missing Archeologist

Mathematical Puzzle Programs

Version 2019/08/09

MaPP Challenge '20 – Mystery of the Missing Archeologist

How to Play

Rules

Leagues

Each team is registered in either the **Competitive or Recreational League**. If both Leagues are playing simultaneously today at your campus, then all scoring and awards are handled separately in both Leagues.

Puzzle Packets and ClueKeeper

Each team has received multiple **Puzzle Packets**. However, there is not enough information in this packet to begin solving any puzzles.

Once the game begins, clues will become available in the **ClueKeeper** app that will allow players to begin solving puzzles in the packet. Once a puzzle is solved, its solution can be submitted via the app. As time progresses, hints for unsolved puzzles will unlock, helping teams who are stuck. The game ends when your time in ClueKeeper has expired.

The Bonus Puzzle solution is submitted directly to Game Control (not ClueKeeper) and is awarded partial credit, see below for details.

Main Puzzles

Once the game begins, you'll be presented with four mini-puzzles, each of which unlocks a **Main Puzzle**. If your campus is using Cluekeeper's GPS functionality, you will have take your device to a certain location on campus in order to unlock each puzzle.

Each Main Puzzle can be solved directly using mathematical modeling and problem-solving abilities. Each puzzle solves to a short word or phrase. Correct solutions are worth **1500 Victory Points each** for a total of **6000 Victory Points**.

Cryptic Puzzles

You will be given the opportunity to solve an additional **Cryptic Puzzle** after every Main Puzzle you solve. The way to solve these puzzles is left, well, cryptic. However, your team should still be able to use your critical thinking to extract a hidden word or phrase. Correct solutions are worth **500 Victory Points each**, for a maximum total of **2000 Victory Points**.

Bonus Puzzle

After solving all four Main Puzzles, the Bonus Puzzle will become unlocked in ClueKeeper. Your team will be asked to optimize a certain task, and present your solution to Game Control in person, which will be graded and awarded **up to 500 Victory Points**.

You may submit up to three solutions throughout the game (including any disqualified submissions), and your best solution of the three will be counted toward your score.

Metapuzzle

Once your team has solved two Cryptic Puzzles, the final **Metapuzzle** becomes available, worth **1000 Victory Points**.

Another Puzzle?

We cannot confirm nor deny the ability to earn an additional **500 Victory Points**, somehow.

Hints

Recreational teams may ask for hints at Game Control at any time during the game, and may receive direct assistance from their teachers/chaperones as desired. Competitive teams may ask Game Control for rules clarifications, but otherwise will only receive help via hints made availabe in ClueKeeper.

Winning the Game

The team that earns the **most Victory Points out of 10000** by the end of the game is the **winner**. If any teams are tied, then the tie will be broken based on how quickly those teams solved their puzzles (the time each team submitted its last correct non-Bonus puzzle solution).

Additional Rules/Advice

- Players should not do anything which would interfere with other teams solving puzzles. Be a good sport!
- Submissions for each puzzle, besides the Bonus Puzzle, are unlimited. Every submission for the Bonus Puzzle will be carefully graded by Game Control, so only three submissions are allowed.
- Before visiting Game Control to ask for a hint or clarification, make sure you've read all the material accompanying the puzzle! Chances are, your question is covered there.
- Teachers and chaperones are not allowed to help Competitive teams solve puzzles.
- Teams may use any supplies they've brought and even look things up online to solve puzzles, but Competitive Teams may not receive any direct assistance from outside their team (e.g. you can't Phone a Friend).
- Players must remain within any physical boundaries set by both Game Control and their teacher/chaperone at all times, and must always travel with a teammate when leaving their headquarters.
- Teachers/chaperones are responsible for their students at all times.
- Since this game will be played at different campuses on different days, please do not spoil any of today's puzzles or solutions online until the game book is released publicly by MaPP!
- Contact Game Control immediately in the case of emergency or any issues with these rules.

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Game Resources

Reference Sheet

Letter	Decimal	Binary	Morse	Braille	ROT13
A	1	00001	.-		N
B	2	00010	-...		O
C	3	00011	-.-.		P
D	4	00100	-..		Q
E	5	00101	.		R
F	6	00110	..-.		S
G	7	00111	--.		T
H	8	01000	....		U
I	9	01001	..		V
J	10	01010	.---		W
K	11	01011	-.-		X
L	12	01100	.-..		Y
M	13	01101	--		Z

Letter	Decimal	Binary	Morse	Braille	ROT13
N	14	01110	-.		A
O	15	01111	---		B
P	16	10000	.--.		C
Q	17	10001	--.-		D
R	18	10010	.-.		E
S	19	10011	...		F
T	20	10100	-		G
U	21	10101	..-		H
V	22	10110	...-		I
W	23	10111	.--		J
X	24	11000	-..-		K
Y	25	11001	-.--		L
Z	26	11010	--..		M

Some famous numbers and formulas

$\sqrt{2} \approx 1.\,41421\,35623\,73095\,04880\,16887\,24209\,69807\,85696\,71875\,37694\,80731\,76679\,73799\,07324\,78462\,10703\,88503\,87534\,32764\,15727$

$e \approx 2.\,71828\,18284\,59045\,23536\,02874\,71352\,66249\,77572\,47093\,69995\,95749\,66967\,62772\,40766\,30353\,54759\,45713\,82178\,52516\,64274$

$\pi \approx 3.\,14159\,26535\,89793\,23846\,26433\,83279\,50288\,41971\,69399\,37510\,58209\,74944\,59230\,78164\,06286\,20899\,86280\,34825\,34211\,70679$

Pythagorean Theorem

$$a^2 + b^2 = c^2$$

Quadratic Formula

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Euler's Formula

$$e^{ix} = \cos(x) + i\sin(x)$$

Part I

Player Book

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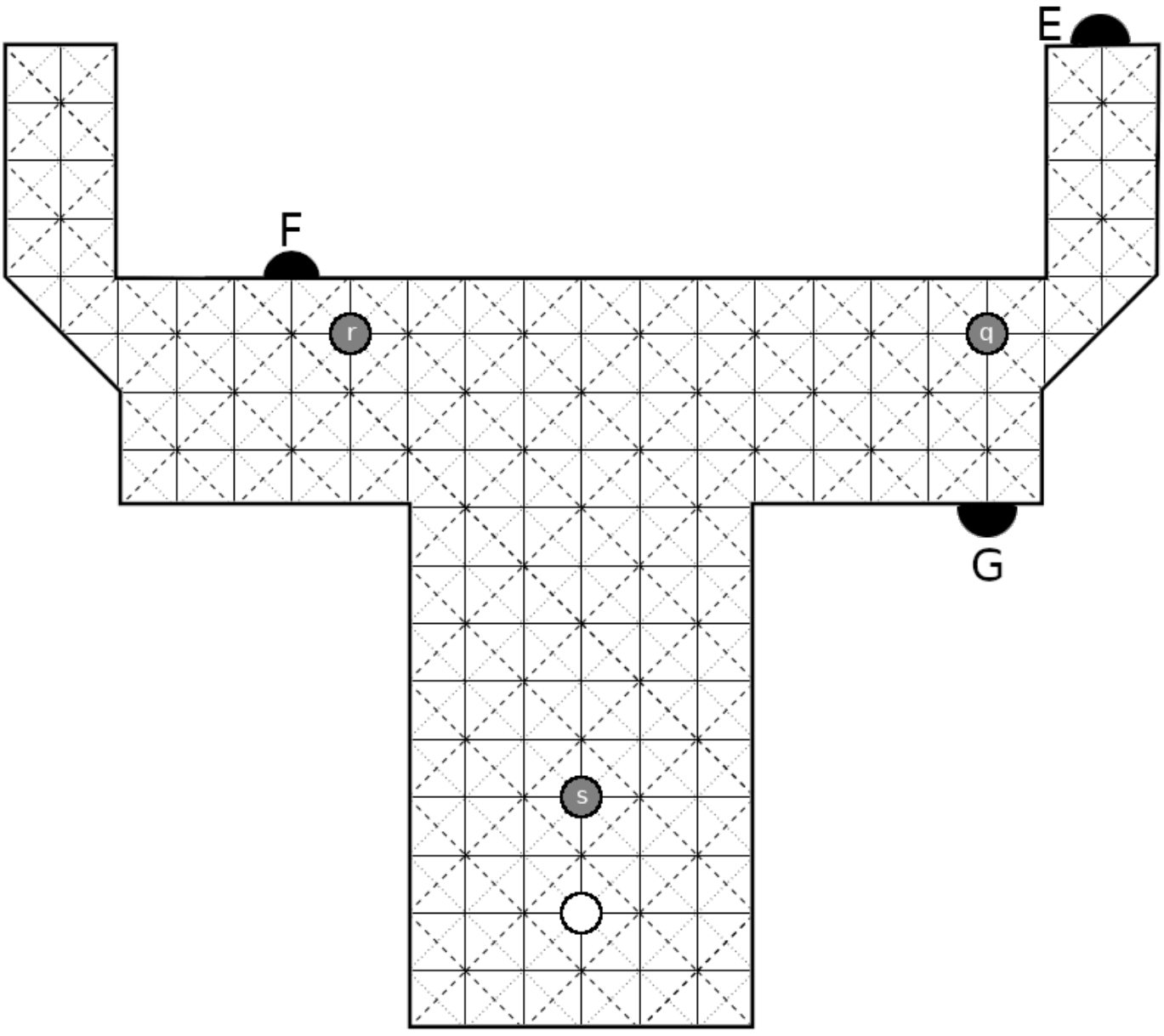
Arena 1

Balls: s, q, r – Holes: E, F, G



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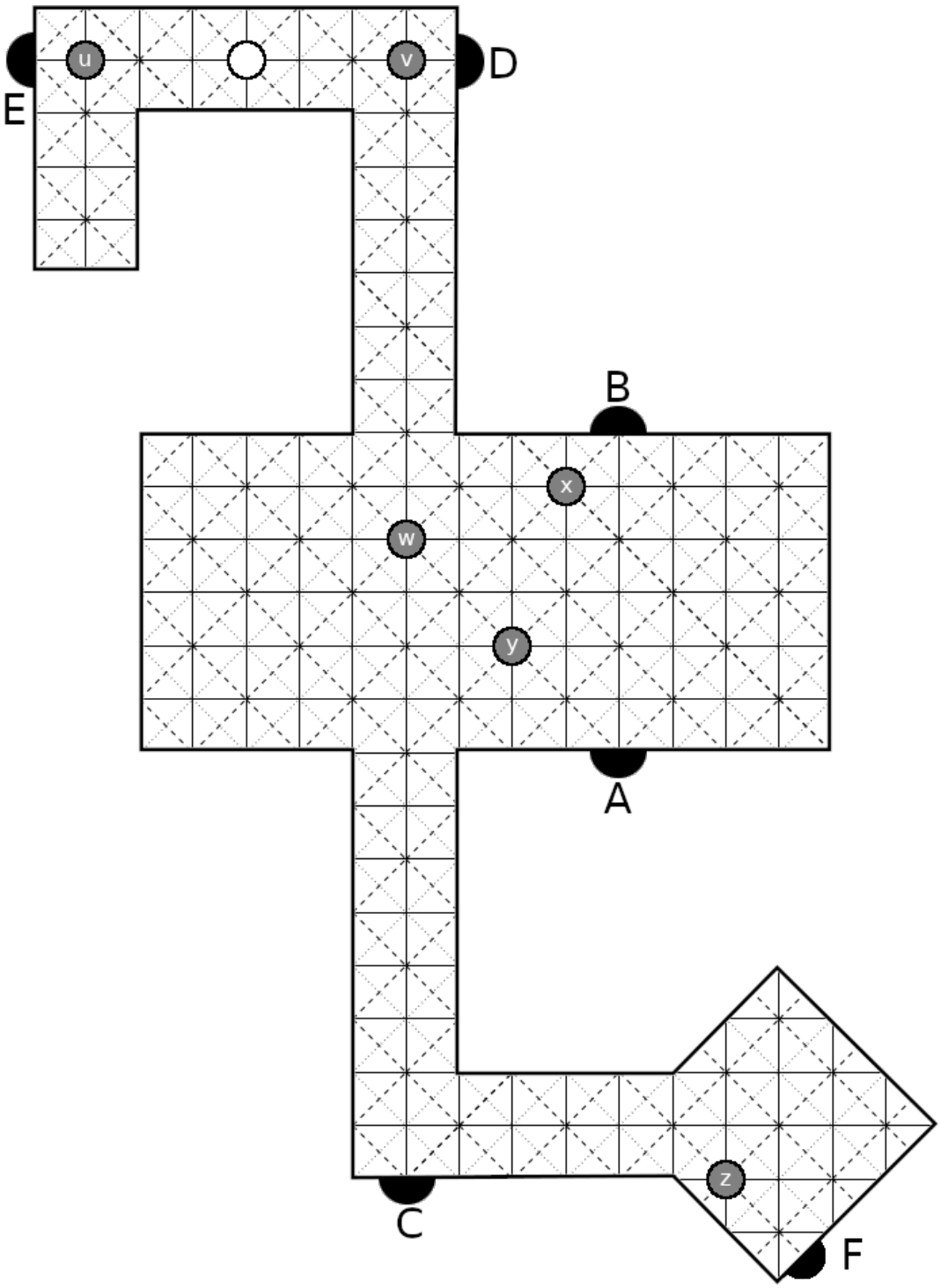
Arena 2

Balls: u, v, w, x, y, z – Holes: A, B, C, D, E, F



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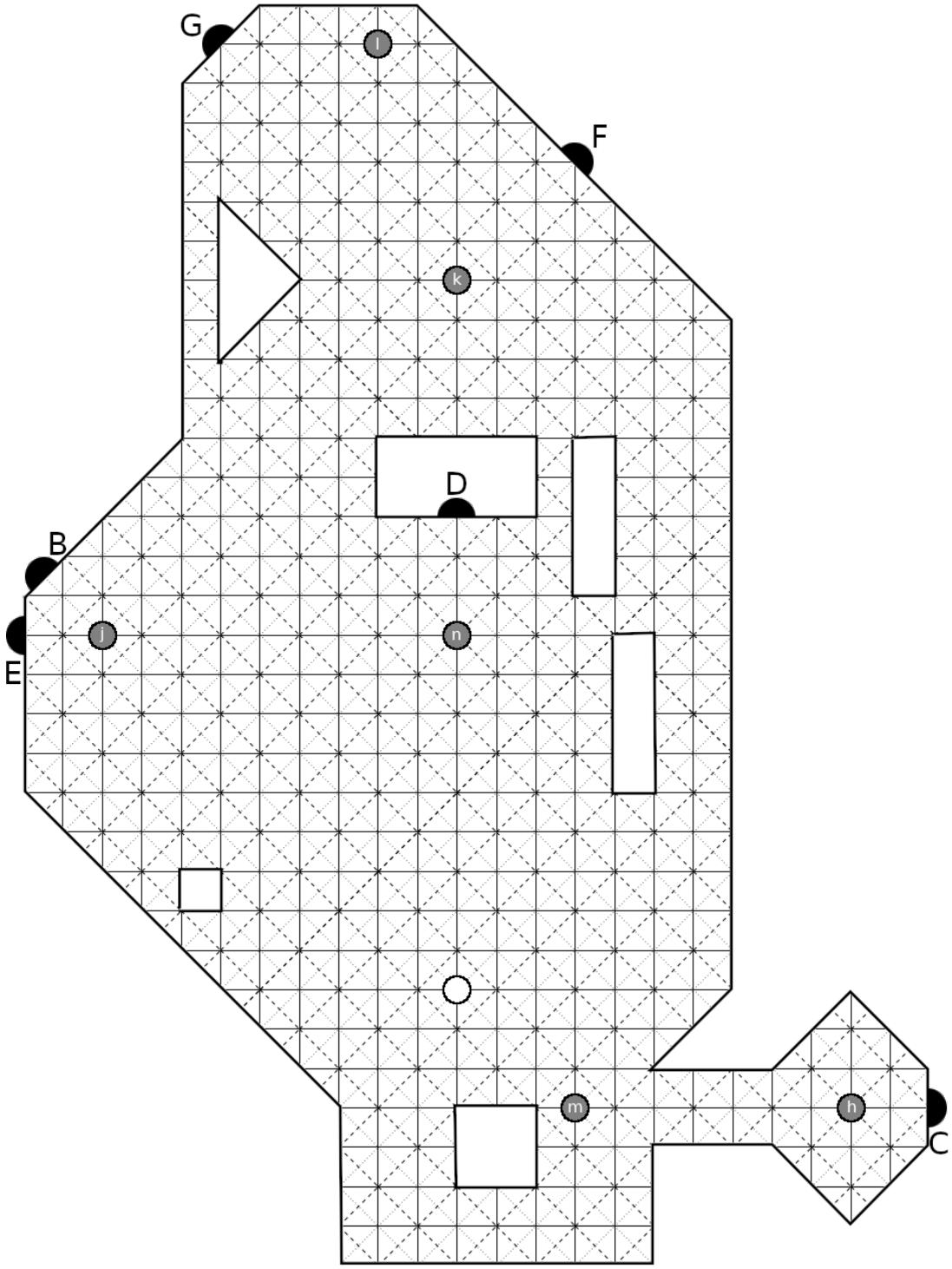
Arena 3

Balls: j, k, l, m, n, h – Holes: B, C, E, F, G



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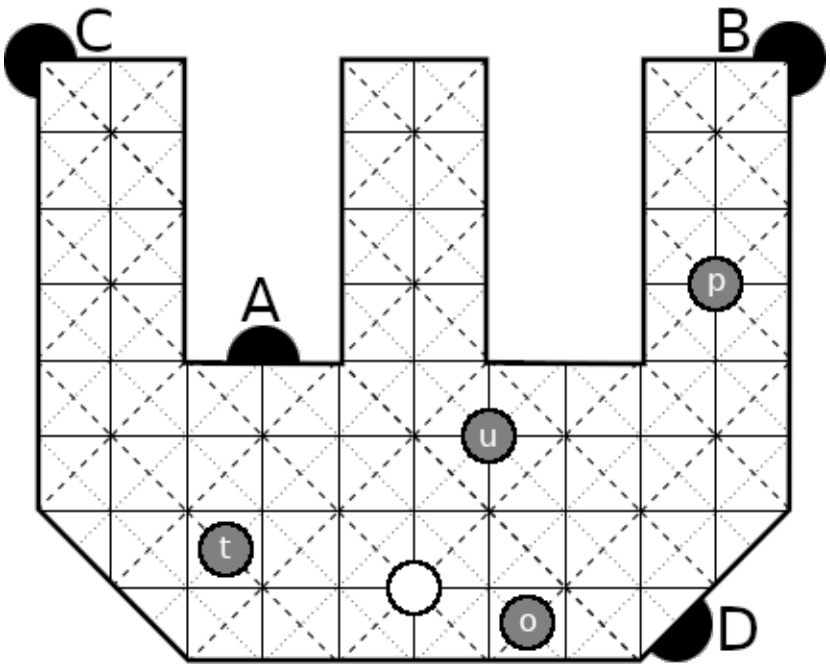
Arena 4

Balls: o, p, t, u – Holes: A, B, C, D



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Story 1

Pomegranates, Fish, and Bread

Story Set-up:

- The first shopkeeper declared that 1 pomegranate is equivalent to 1 fish. ($P \leftrightarrow F$)
- The second shopkeeper declared that 1 fish is equivalent to 1 pomegranate, 1 fish, and 1 loaf of bread. ($F \leftrightarrow P + F + B$)
- The third shopkeeper declared that 1 loaf of bread is equivalent to 1 pomegranate and 1 fish. ($B \leftrightarrow P+F$)

Story Versions:

1. Noether entered the bazaar with 1 pomegranate and left with 2 pomegranates.
2. Noether entered the bazaar with 2 pomegranates and left with 2 loaves of bread.
3. Noether entered the bazaar with 1 pomegranate and left with 3 pomegranates.
4. Noether entered the bazaar with 1 pomegranate and left with 3 poomegranates and 1 fish.
5. Noether entered the bazaar with 1 pomegranate and left with 1 loaf of bread.

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Story 2

Tapestries, Saddles, and Vases

Story Set-up:

- The first shopkeeper declared that 1 tapestry is equivalent to 1 saddle and 1 vase. ($T \leftrightarrow S + V$)
- The second shopkeeper declared that 1 saddle is equivalent to 1 tapestry and 1 saddle. ($S \leftrightarrow T + S$)
- The third shopkeeper declared that 1 vase is equivalent to 1 tapestry and 1 vase. ($V \leftrightarrow T + V$)

Story Versions:

1. Noether entered the bazaar with 2 tapestries and 1 vase and left with 1 tapestry.
2. Noether entered the bazaar with 1 tapestry and left with 50 tapestries.
3. Noether entered the bazaar with 1 tapestry and left with 1 tapestry and 1 saddle.
4. Noether entered the bazaar with 1 tapestray and left with 1 vase.
5. Noether entered the bazaar with 1 tapestry and left with 3 tapestries.

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Story 3

Spice, Vases, and Magic Crystals

Story Set-up:

- The first shopkeeper declared that 1 bag of spice is equivalent to 1 vase. ($S \leftrightarrow V$)
- The second shopkeeper declared that 1 vase is equivalent to 1 bag of spice and 1 magic crystal. ($V \leftrightarrow S + C$)
- The third shopkeeper declared that 1 magic crystal is worth 2 magic crystals. ($C \leftrightarrow 2C$)

Story Versions:

1. Noether entered the bazaar with 1 bag of spice and left with 2 bags of spice.
2. Noether entered the bazaar with 2 bags of spice and left with 1 bag of spice and 2 vases.
3. Noether entered the bazaar with 3 bags of spice and left with 3 magic crystals.
4. Noether entered the bazaar with 1 bag of spice and left with 1 vase and 2 magic crystals.
5. Noether entered the bazaar with 4 bags of spice and left with 2 bags of spice, 2 vases, and 5 magic crystals.

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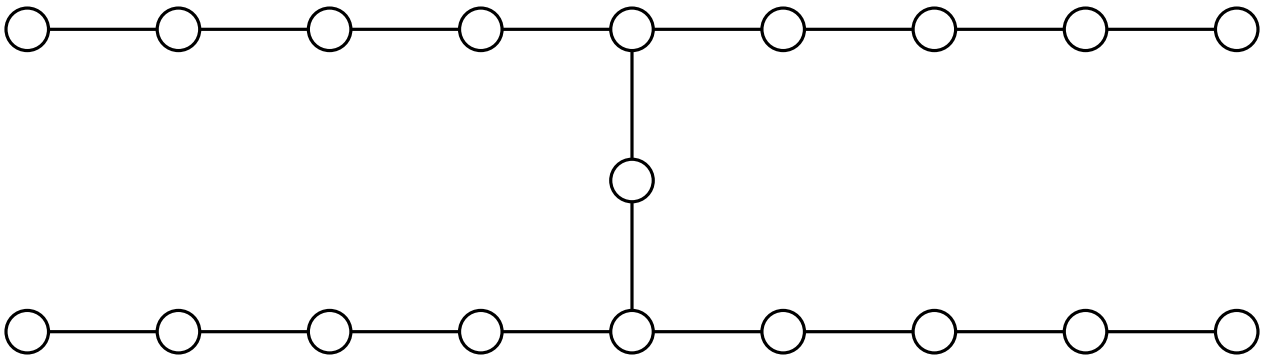
Site 1



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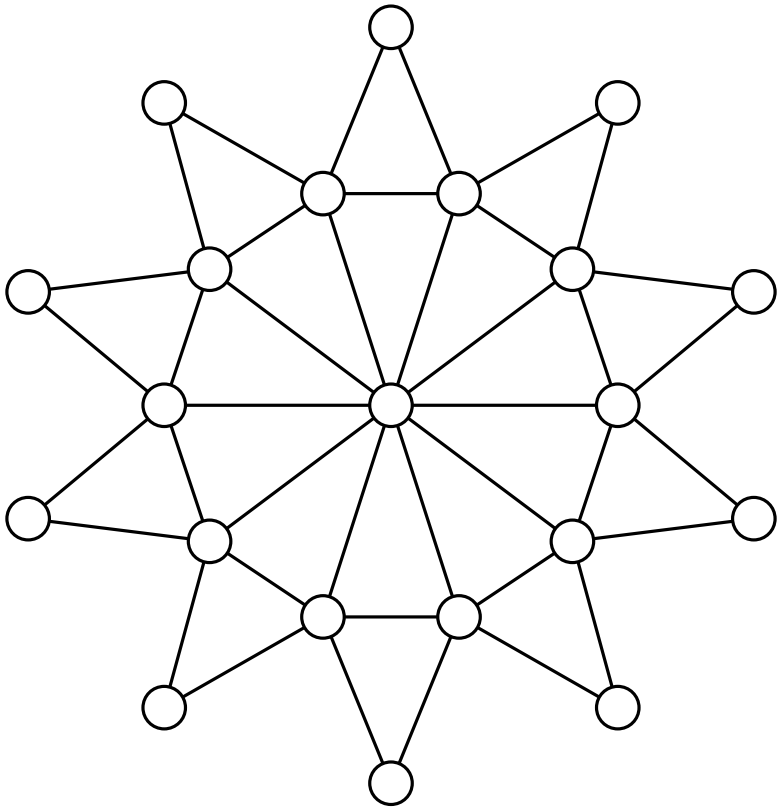
Site 2



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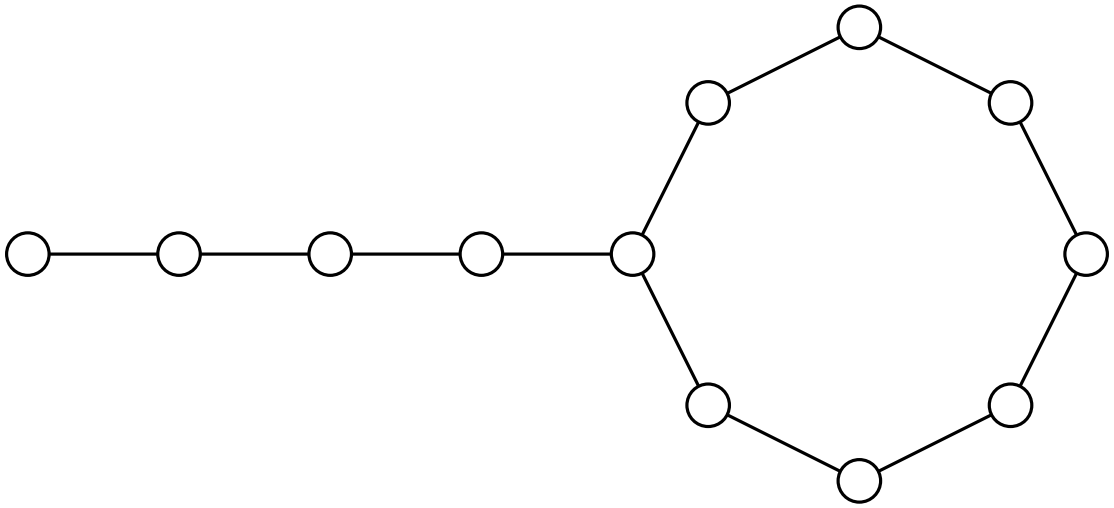
Site 3



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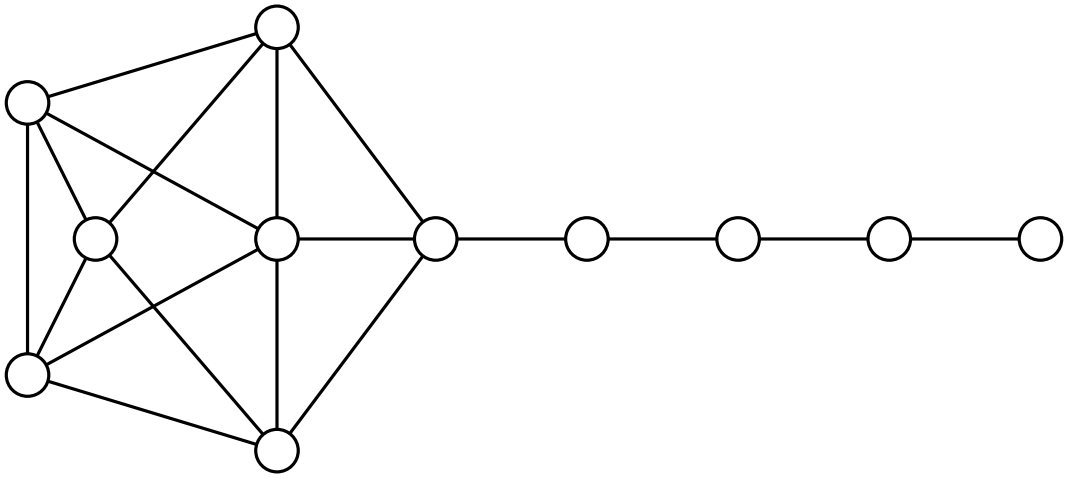
Site 4



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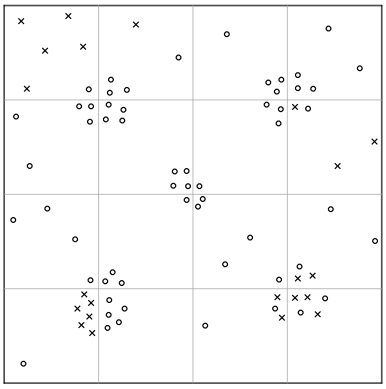
Tribe A

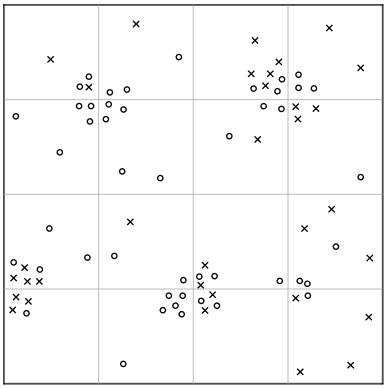
Population = 80

Year 1



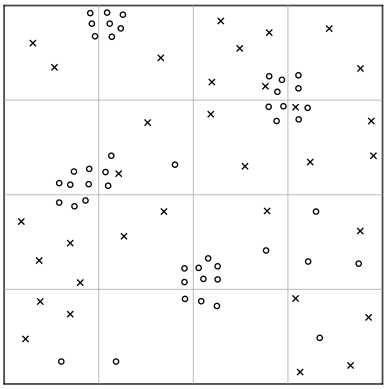
Total Vote Count
X - 22
O - 58

Year 2



Total Vote Count
X - 33
O - 47

Year 3



Total Vote Count
X - 33
O - 47

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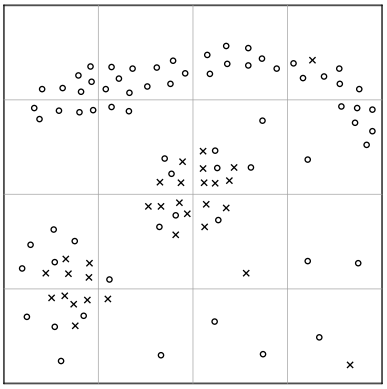
Tribe B

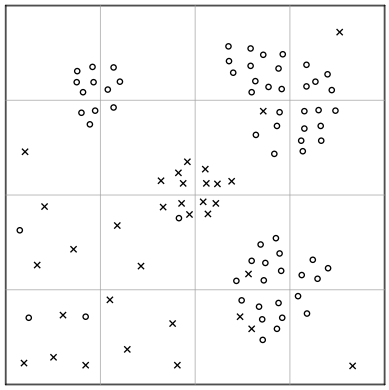
Population = 100

Year 1



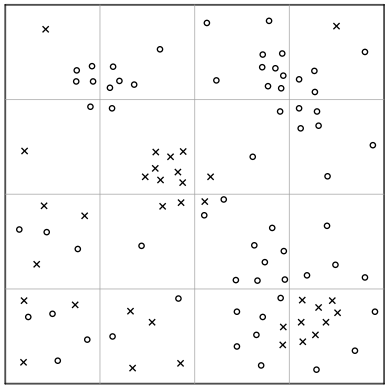
Total Vote Count
X - 31
O - 69

Year 2



Total Vote Count
X - 34
O - 66

Year 3



Total Vote Count
X - 35
O - 65

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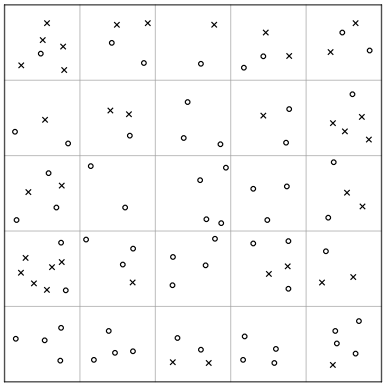
Tribe C

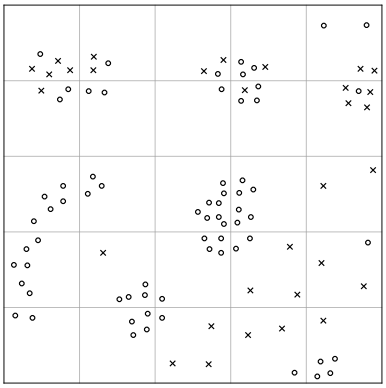
Population = 100

Year 1



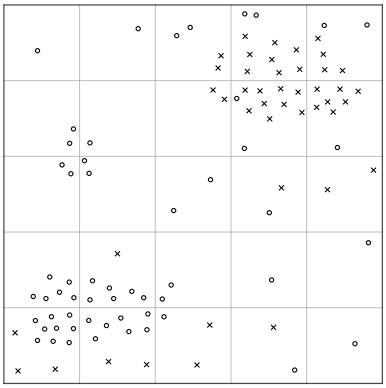
Total Vote Count
X - 38
O - 62

Year 2



Total Vote Count
X - 31
O - 69

Year 3



Total Vote Count
X - 44
O - 56

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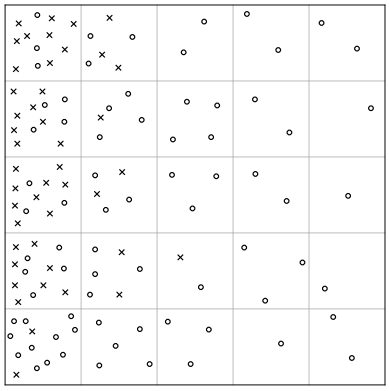
Tribe D

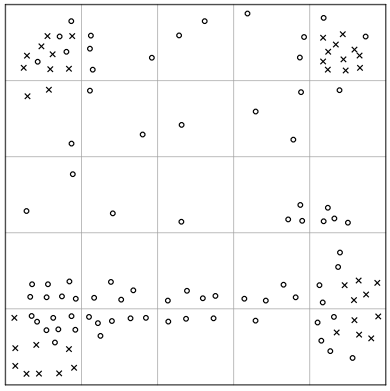
Population = 120

Year 1



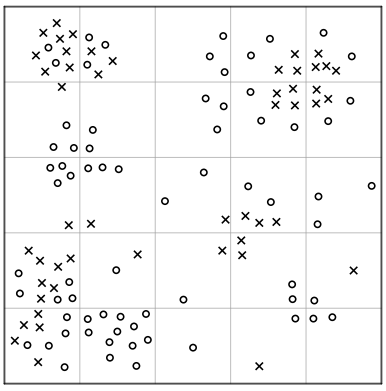
Total Vote Count
X - 45
O - 75

Year 2



Total Vote Count
X - 40
O - 80

Year 3



Total Vote Count
X - 50
O - 70

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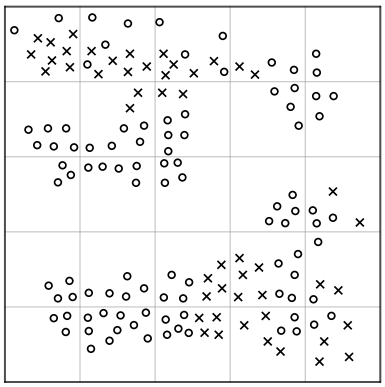
Tribe E

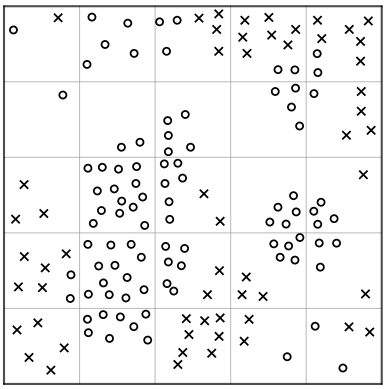
Population = 150

Year 1



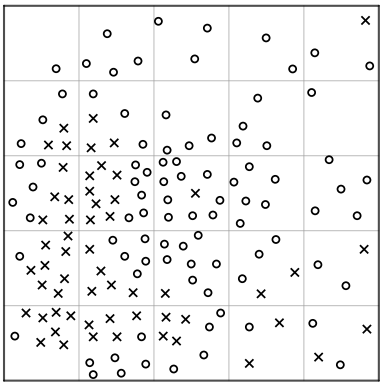
Total Vote Count
X - 50
O - 100

Year 2



Total Vote Count
X - 56
O - 96

Year 3



Total Vote Count
X - 58
O - 92

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Journal Page 1

Journal	entry	June	28,	1995		
	Succesful	dig	today.	We	found	a
lot	of	pot	shards,	some	with	remarkably
intact	artwork.	Like	in	the	tomb,	there
are	scenes	of	men	with	circles	around
their	heads,	looking	to	the	sky.	We
believe	these	represent	past	kings,	deities	, or
maybe	both.	I	recall	my	advisor's	words,
people	are	not	pots."	I	should	be
careful	before	drawing	any	firm	conclusions.	On
the	other	end	of	the	site	from
the	tomb	we	found	a	burial	site.
It	was	lined	with	red	ochre,	the
bodies	were	facing	east	with	their	arms
folded.	Already	this	site	has	yielded	so
much.	If	only	the	university	understood.	They
want	to	save	money	so	badly,	but
what	is	it	for	if	not	this?

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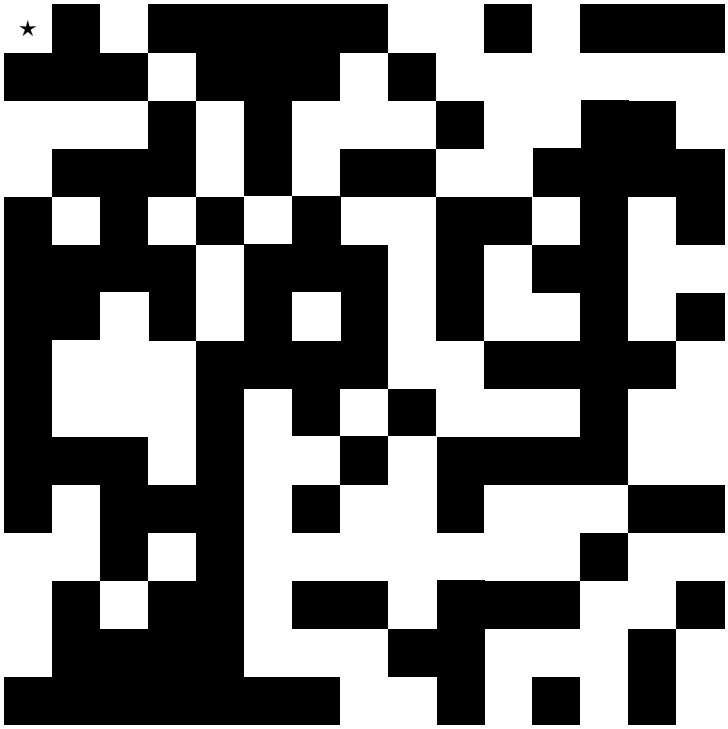
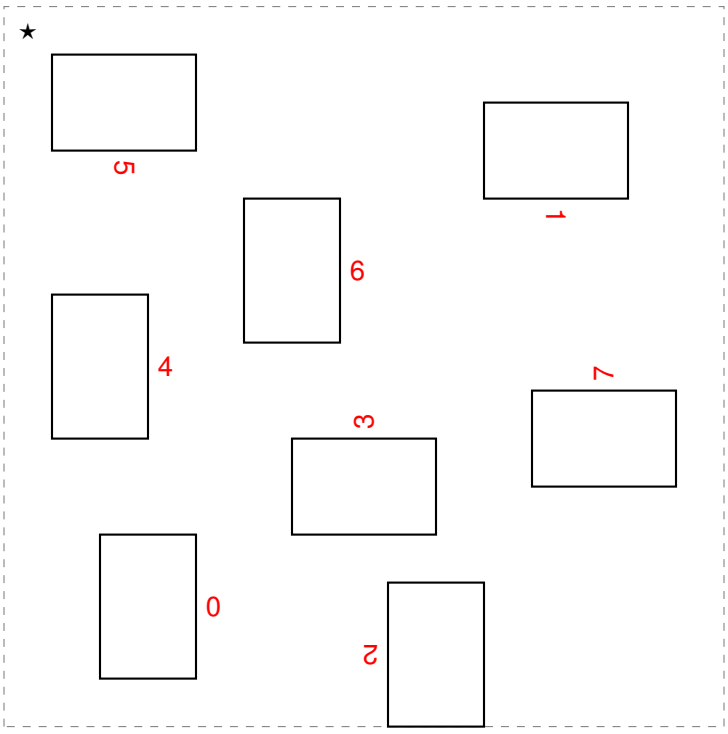
Journal Page 2





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Journal Page 3

Site Adjustment:

1. Site 1: $(?, ?) + (-4, -16)$
2. Site 2: $(?, ?) + (6, -15)$
3. Site 3: $(?, ?) + (5, -1)$
4. Site 4: $(?, ?) + (-3, -1)$

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Journal Page 4

It seems that the legendary rulers of the Skolem people were each associated with a compass direction. Fascinating!

Oystein Apo Skolem (N)

Engstrom Apo Ore (NNE)

Throralf Apo Thue (NE)

Shanok Apo Ore (ENE)

Trowa Apo Ore (E)

Mawort Apo Ore (ESE)

Berkov Apo Kel (SE)

Knutten Apo Kel (SSE)

Erbach Apo Kel (S)

Guabis Apo Kel (SSW)

Zabala Apo Dheub (SW)

Renfrow Apo Dheub (WSW)

Frakov Apo Dheub (W)

Gangolli Apo Dheub (WNW)

Ramkumar Apo Lewo (NW)

Skraba Apo Lewo (NNW)

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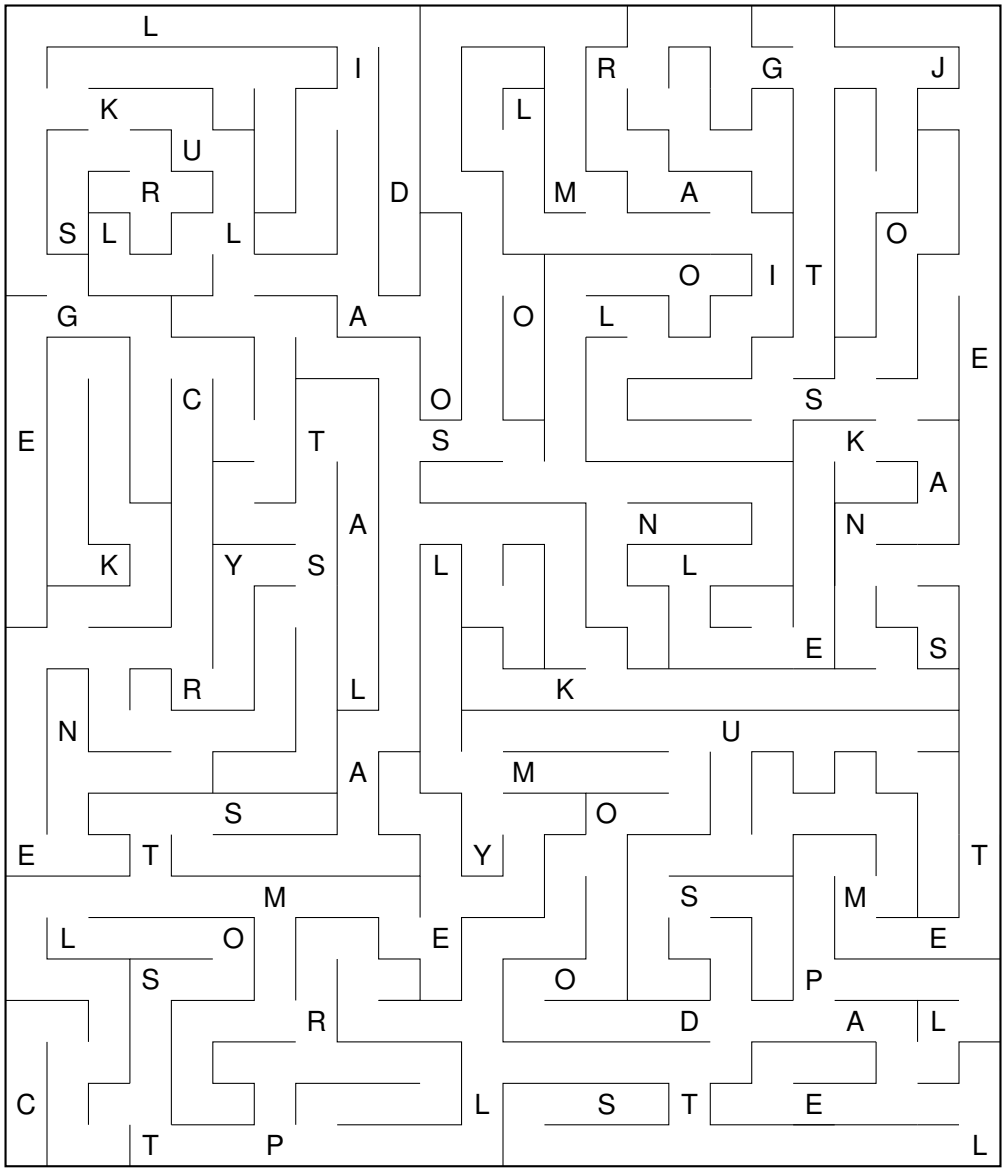
Cryptic Journal 1

Word Maze



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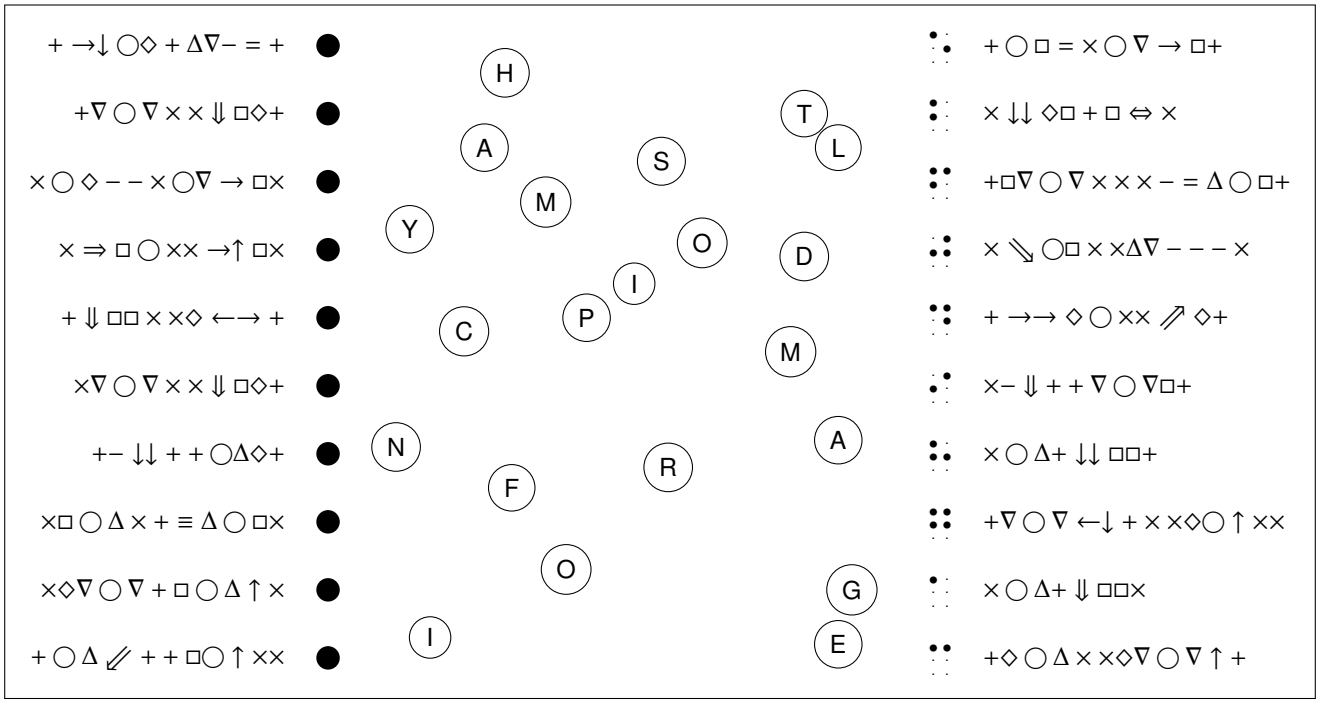
Cryptic Journal 2

Linguistic Drift



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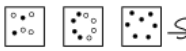
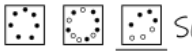
Cryptic Journal 3

Simon Says

 ~~Saturday, November 30, 1986~~

 Sunday, December First, Nineteen Eighty Six, Five AM

What an exhilarating day! Every since Champollion discovered the
wall paintings in the third dynasty tomb, we've known that like
other ancient peoples, the Fregians had a ball game, yet no
arenas or equipment had ever been found. That changed
today. I not only discovered an intact arena, but found a stone
tablet with text. We haven't been able to fully translate it yet
but on first glance it seems to contain detailed rules for the
game. Everyone thought that the wall paintings were
exaggerating or showing scenes from myths, but the Fregians
really did play the game with boulders! I know because one
nearly crushed me. After recovering my breath (and my hat)
I had to marvel at the engineering and artistry of these orbs.
They are so perfectly round and smooth, we have no idea how
the Fregians built them with the tools they had. The arena
itself was still largely intact. Based on the form of the writing,
The site is likely from the second dynasty. I checked the star
chart for that era, and if you connect a line from the arena to
the palace, it fits very closely to the trajectory of the north
star. We should use ground penetrating radar to check other
astronomical alignments. At last, I've got some good luck.

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Cryptic Journal 4

Budgeting Woes

Budgeting and begging for grants isn't the most fun aspect of archaeology, but I suppose it's a necessary evil.

Topic	Detail	Budget Code	Cost
Field work salary	Dr. M. Jonas	J	$12,718
Field work salary	B. Fraiser	A	$1,982
Travel expenditures	Lodging	G	$3,290
Travel expenditures	Airfare	J	$1,307
Excavation	Digging equipment	M	$20,183
Excavation	Artifact cleaning and cataloging	Q	$8,216
Research	Osteology consultant	R	$6,499
Research	Ceramic analysis	Q	$7,211
Research	Floral analysis	Q	$5,525
Research	Faunal analysis	J	$5,524

Part II

ClueKeeper Info

MaPP Challenge ’20 – Mystery of the Missing Archeologist

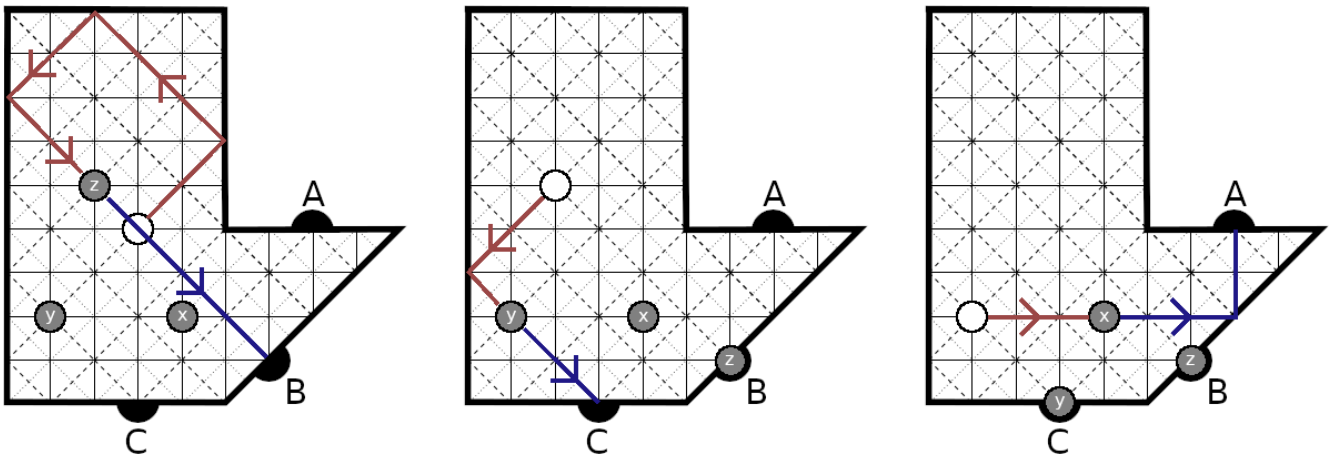
Main Puzzle 1

The Fox and the Rabbits

Dr. Mindy Jonas’ first major discovery was the remarkable boulder game of the Fregian people. The Fregian kings build massive arenas with a fantastic variety of shapes and sizes. After surviving a harrowing encounter with a boulder in a long-lost temple, Dr. Jonas found an ancient tablet. On that tablet, the rules to the game were literally written in stone:

- The game was played with two kinds of boulders: a white one called the fox and several darker ones, called the rabbits.
- The goal of the game was for the the fox to hit the rabbits into the holes at the edge of the arena. Exactly one rabbit would be hit into each hole.
- The fox could only be launched along the marked vertical, horizontal, and diagonal trajectories. When it collided with a rabbit, the fox would take the place of the rabbit and the rabbit would continue in the direction it was hit.
- The rabbits were not allowed to strike each other, and no boulder was allowed to hit a sharp corner in the arena.
- Once moving, a boulder would continue to move around the arena indefinitely, bouncing off walls until it struck another boulder or sunk into a hole.

Dr. Jonas recorded five arenas for this game in her journal. In each one there is a unique way to win the game. Dr. Jonas’ assistant, Brandon Fraiser, thinks that the solution to these puzzles will help you find the hidden message in Dr. Jonas’ journal page. Thankfully, Fraiser has already solved one of the arenas as an example:



The solution to this arena is zB-yC-xA. Solve each of the four other provided arenas, and enter each solution into ClueKeeper using this format.

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Main Puzzle 2

The Ancient Bazaar

The Skolem people of Mesopotamia had many myths and legends. Of great interest to Dr. Jonas was the story of queen Noether, famed for her ability to barter with traders and merchants. You may have met a good haggler or two in your day, but they didn't have to deal with the strange ways of the Skolem Bazaar. The Skolem people had no money, instead goods were exchanged for other goods. Moreover, at the start of each day the shopkeepers would declare their exchange rates. They were notoriously stubborn and would not change these rates no matter what happened.

Dr. Jonas believed that Noether was real, and wanted to learn as much about her as possible. Unfortunately, over time every story about Noether split into multiple versions. In one, Noether entered the marketplace with one bag of spice.

- The first shopkeeper declared that 1 bag of spice is equivalent to 4 shell bracelets and 1 clay cup. ($S \leftrightarrow 4B + C$)
- The second shopkeeper declared that 1 shell bracelet is equivalent to 3 bags of spice and 3 clay cups. ($B \leftrightarrow 3S + 3C$)
- The third shopkeeper declared that 1 clay cup is equivalent to 1 bag of spice and 1 shell bracelet. ($C \leftrightarrow S + B$)

There are two versions of the story:

1. Noether entered the bazaar with 1 bag of spice and left with exactly 7 clay cups and nothing else.
2. Noether entered the bazaar with 1 bag of spice and left with exactly 7 shell bracelets and nothing else.

Dr. Jonas reasoned that the first version was possible and that the second was impossible. Version one could happen the following way:

1. Go to shopkeeper 1: $S \rightarrow 4B + C$
2. Go to shopkeeper 2 and use 1 shell bracelet: $4B + C = B + 3B + C = 3S + 3C + 3B + C = 3S + 3B + 4C$
3. Go to shopkeeper 3 to get a clay cups: $3S + 3B + 4C = 3C + 4C = 7C$

There are many more stories about Noether. If you can figure out which ones are possible and which are impossible, you might be able to decipher the message hidden in Dr. Jonas' journal.

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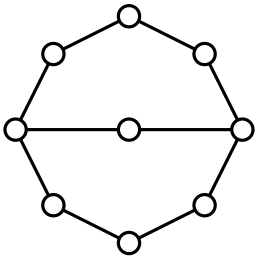
Main Puzzle 3

Searching the Tombs

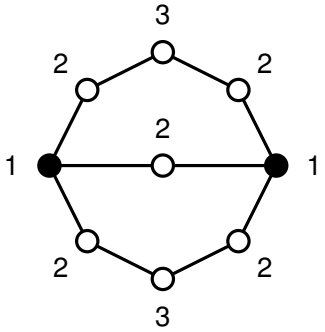
The necropolis of Ramsey is a complex of underground mausoleums, buried by earth and time. It is also where Dr. Jonas almost got fired. After finding her first mummy, she seemed to be cursed. Whenever she entered a new crypt, the mummy inside of it would be as far away from her team as possible. It's not that they had a hard time finding the mummies, in fact the walls had directions on them leading straight to the sarcophagus. Still, she had of run of impossibly bad luck.

Once the university realized how much resources Dr. Jonas was spending on her digs, they demanded she stop "wasting" their money. She needed to minimize the number of rooms her team was exploring. Using ground penetrating radar, Dr. Jonas was able to scout out possible sarcophagus locations and the passages between them. For instance, one site looked like



where the circles represent rooms and the lines represent the passages connecting them.

Dr. Jonas could send 9 people out to the site and find the mummy immediately, but that's not very efficient. Instead, she can send down just 2 people, and have the maximum number of rooms they have to explore be three 3. Following the Univeristy accounting scheme, this has a cost of 5 as opposed to 9. This is the best that Dr. Jonas can do.



2 people
+3 rooms
5 total cost

There are four more site diagrams in Dr. Jonas' notes. If you can figure out the minimum cost of exploring these crypts, B. Fraiser will be able to tell you how to deciper the next journal page.

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Main Puzzle 4

Ancient Gerrymandering

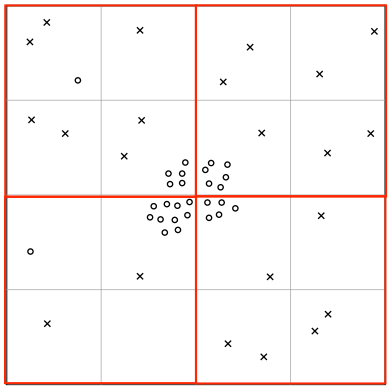
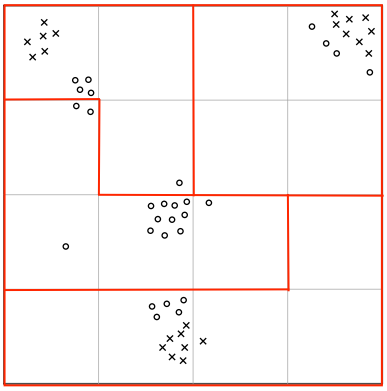
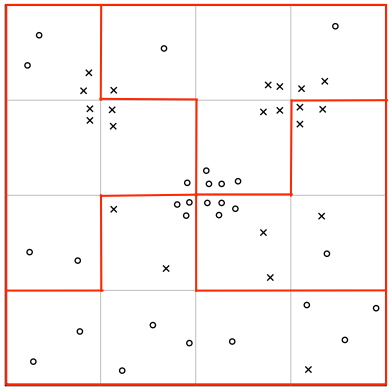
One of Dr. Jonas' greatest discoveries was the Heyting people, a democratic collection of 6 tribes that lived on the Eurasian steppes. They kept meticulous records of their elections and their rulers. Strangely, even though the Heyting people were democratic, the voting records indicated that many of their leaders recived far less than the majority of the votes. How could this happen?

Well, to simplify the voting process, the tribes had broken their land up into provinces. Each province had one vote for the next ruler of that tribe, which was based upon the majority vote from within the province. However, since the tribe leaders were allowed to redraw the boundaries of the provinces each year using the following guidelines, the minority party was able to keep power.

1. The number of provinces in each tribe had to stay the same each year.
2. Each province had to be a single connected region.
3. The difference in population between any two provinces had to be 5 or less.
4. All province boundary lines had to follow the horizontal and vertical grid lines provided.

Determine the number of provinces for each Tribe A-E from Dr. Jonas's journal that allowed the minority party to win the majority of provinces each year. Enter this into ClueKeeper using the format A#-B#-C#-D#-E#. To help, an example is given below.

Tribe X, Population = 50, Provinces = 4

Year 1	Year 2	Year 3
		
Total Vote Count X - 22 people, **3 provinces won** O - **28 people**, 1 province won	Total Vote Count X - 22 people, **3 provinces won** O - **28 people**, 1 province won	Total Vote Count X - 22 people, **3 provinces won** O - **28 people**, 1 province won

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Journal Puzzle 1

The Fox and the Rabbits

Good Work! Notice that the text of the journal entry appears in neat columns and rows. Label the columns A, B, C, D, E, F, G from left to right and label the rows h, i, j, k, $\cdots$, z from top to bottom. Then look at the third boulder from arena 1, the fifth boulder from arena 2, the first boulder from arena 3, and the third boulder from arena 4.

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Journal Puzzle 2

The Ancient Bazaar

Great work on Main Puzzle 2! I think we can use your answer to extract a hidden password from Journal Entry 2.

In each story, you figured out which of the statements 1-5 were Possible (P) or Impossible (I). What if we organize that information like this, using $I = 0, P = 1$:

	Story 1	Story 2	Story 3	Binary	Decimal
Statement 1	P	P	I	110	6
Statement 2	I	P	I		
Statement 3	P	I	I		
Statement 4	I	I	P		
Statement 5	I	P	P		

I think we're supposed to cut out the lower square, and then further cut out the rectangles that match those numbers. What will happen if we place that cut-out on the barcode-looking thing above it? Maybe the Code Sheet will help us decipher the resulting 2×3 rectangles?

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Journal Puzzle 3

Searching the Tombs

Nice Job! If you look at the cost along with the total number of chambers, you should get coordinates corresponding to all of the sites.

- Site 1: $(7, 19)$
- Site 2: $(4, 21)$
- Site 3: $(6, 12)$
- Site 4: $(5, 11)$

With this information we should be able to plot the correct coordinates on journal entry 3. The hidden message is then the combination of two of the following words: BACKPACK, COMPASS, FLASHLIGHT, HAT, MAP, ROPE.

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Journal Puzzle 4

Ancient Gerrymandering

Amazing!

While you were working, I managed to find the general locations of the tribes in Dr. Jonas's notes. I've added the information you found counting the number of provinces within each tribe.

- Tribe A (7 provinces): North-by-Northeast
- Tribe B (5 provinces): East-by-Southeast
- Tribe C (5 provinces): South-by-Southwest
- Tribe D (6 provinces): West-by-Southwest
- Tribe E (3 provinces): West-by-Northwest

I'm betting this is another one of Dr. Jonas's codes. Can you use another journal page to find the ruler of each tribe, and use the number of provinces to choose a letter from the first name of each ruler?

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Cryptic Puzzle 1

Word Maze

Cryptic Journal 1 contains a diagram of an ancient tomb. While there doesn’t seem to be an entrance or exit to this ancient labyrinth, solving the maze isn’t the point of this puzzle. Instead, you should see if you can find the following words.

SKULL LOST GRAIL DOOM TEMPLE CRYSTAL SNAKE

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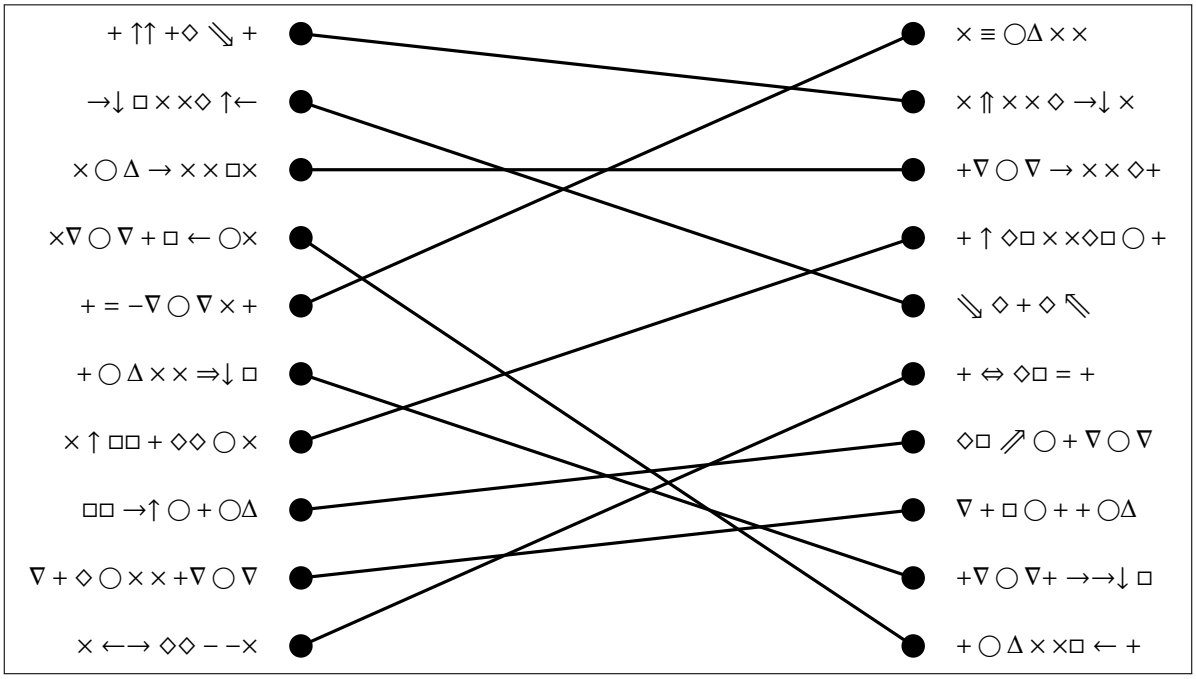
Cryptic Puzzle 2

Linguistic Drift

Language changes over time, sometimes in strange ways. In the example below, Dr. Jonas was considering the changes in an ancient script over a period of 450 years.



In the attached journal page, Dr. Jonas was looking at changes in that same script over a period of 600 years. It looks like she hid a message in the connections between the words. Here is a brief crash course in linguistics: you can expect a major change to occur every 150 years. Keep an eye out for changes in boundaries, contractions, and expansions. Good luck!

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Cryptic Puzzle 3

Simon Says

This mostly ordinary journal has strange doodles at the start of each line. In fact these are pictures of early dice from the Heyting people, or at least some of them are. Dr. Jonas was a Heyting expert, so there is no way she drew incorrect dice on accident. Both of the dates at the beginning look wrong as well. Dr. Jonas must have put them there for some other purpose.

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Cryptic Puzzle 4

Budgeting Woes

We found the following email tucked away in Dr. Jonas's hard drive:

Great news, we got funded! I put in requests to three different funding agencies, and they each agreed to cover the exact cost of three or four expenses from our budget.

Funding Agency	Amount	Budget Code Adjustment
National Science Foundation	$36,191	+5
National Endowment for the Humanities	$14,006	+1
Archaeological Institute of America	$22,258	-8