UC Berkeley's CS10 Spring 2019 Final Exam ANSWERS: Prof. Dan Garcia

_______________________ Your Name (first last)   _______________________ SID   _______________________ Lab TA's Name

_______________________ ← Name of person on left (or aisle)   _______________________ Name of person on right (or aisle) →

Fill in the correct circles & squares completely…like this: ● *(select ONE)* ■ *(select ALL that apply)*

What's that Smell? Oh, it's Potpourri! (2 pts each for 1-6, low score dropped)

Question 1: What is $101_2 + 21_3$? (select ONE)

$101_2 = 1*2^2 + 0*2^1 + 1*2^0 = 4_{10} + 0_{10} + 1_{10} = 5_{10}$ and $21_3 = 2*3^1 + 1*3^0 = 6_{10} + 1_{10} = 7_{10}$ and 5+7=12 → C_{16}

○	○	○	○	○	●	○	○	○	○	○	○	○
122_{16}	8_{16}	9_{16}	A_{16}	B_{16}	C_{16}	D_{16}	E_{16}	F_{16}	10_{16}	11_{16}	12_{16}	13_{16}

Question 2: Which of the following was in the *Human-Computer Interaction* lecture? (select ONE)

○ Solid planning by good design teams always beats "enlightened trial and error"

Nope, In fact, the quote was exactly the opposite. *"Enlightened trial and error out-performs the planning of flawless intellect."* –David Kelly

○ The digital pen was invented after 2000.

Nope, you saw an example of it with the 1964 black and white video of Ivan Sutherland giving his SketchPad demo.

● The HCI design cycle is "Design", "Prototype", "Evaluate" (and repeat!).

Yep!

○ With the rise of cloud computing, we have moved from Ubiquitous computing to Mainframe-based computing.

Nope, Mark Weiser noted that we are moving / have moved from the 50s-80s era from Mainframe-based computing (one computer, many people) through to the 80s-2000s era of PC-based computing (one person, one computer) to the current age of ubiquitous computing (one person, many computers)

○ None of these

Question 3: Which of the following was in the *Saving the World with Computing* lecture? (select ONE)

● After using higher resolution models, some said earlier "doomsday" global warming trends were too extreme.

Yep, there was a slide that showed the heading of "*A Terrifying Sea-Level Prediction Now Looks Far Less Likely*" and "*Then came the skeptics. Dan Martin, a computational scientist at Lawrence Berkeley National Lab, argued that his and his colleagues' work showed that ice cliffs might simply be a product of running a computer model of ice physics at a too-low resolution* ".

○ One of the projects at the lab was to use computers to study Ebola outbreaks and how to contain them.

Nope, I just made that up.

○ The data structures to model the earth don't affect the computation; "big fat" or "long skinny" triangles are ok.

Nope, exactly the opposite. Prof. Yelick on slide 7 talked about different ways to come up with a way to "discretize" the earth which had a sphere's topology, and there's still some debate which is better, hexagons or a "stretched cube" – and both of these were much better than the standard latitude/longitude lines which ends up with "skinny triangles" near the pole, resulting in numeric computation challenges at the poles.

○ Genome assembly is fairly easy and straightforward; it's just splicing the data from the read strips together.

Nope, on slide 23 Prof Yelick mentioned that the read data has hundreds of characters with errors, and lots of work has to be put in to make sure they are aligned correctly and that the read errors are handled.

○ None of these

Question 4: Which of the following was in the *Limits of Computing* lecture? (select ONE)

○ The "knapsack problem" is all about geometry – how to fit the most different-shaped boxes in a knapsack.

Nope, the "knapsack problem" is about maximizing profit by a thief who has an option of many boxes with various weights and values; the key is the knapsack has a *weight* limit, not a *size/geometry* limit.

○ The "subset sum problem" is solvable in linear time – you just add up the subset of the numbers you want.

Nope, that would have proved that P=NP, since the subset sum problem has been shown to be NP-complete.

○ Alan Turing proved all problems are decidable; people used to believe it wasn't.

Nope, exactly the opposite. People used to believe all problems *were* decidable, he proved it wasn't with the elegant *halting problem*, which is not decideable.

○ They recently proved that P=NP, sharing this amazing discovery was the main point of the lecture.

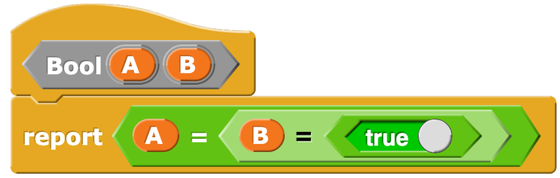
Nope, the point was to explain P and NP (and decidability), and share that trying to solve whether P=NP or P≠NP is one of the most important problems in theoretical computer science.

● None of these

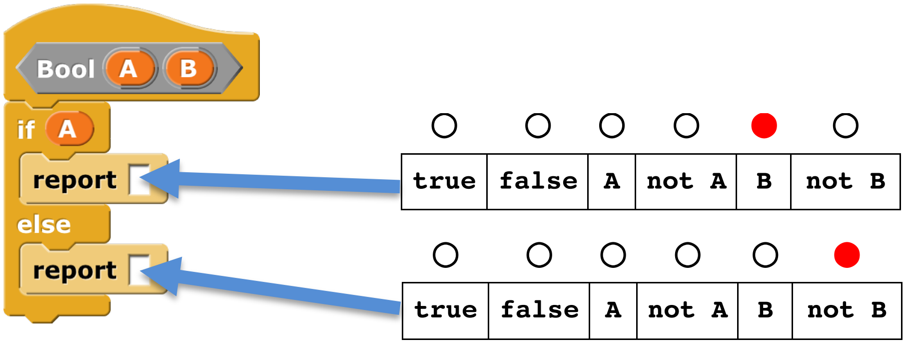
Question 5: Based on the *Artificial Intelligence (AI)* lecture, which one is easiest for a computer? (select ONE)
○ Detecting a stop sign from an image captured by a camera.
Nope, this is done through a complex process, typically by a neural network trained to recognize stop signs.
○ Translating an essay from one language to another.
Nope, this requires understanding both of the languages and common mappings for any idiosyncratic phrases.
○ Having a conversation in English with a person.
Nope, This requires a remarkable amount of understanding of the English language (done through Natural Language Processing algorithms), determining what response to say and how to say it. Try talking to any state-of-the-art system (Alexa, Siri, Google) and you'll see how far we have to go here.
● Winning a game of Chess.
Sure, this is just search – we showed how to write a game solver in class with a few lines of Python code for the 10-to-0-by-1-and-2 game.
○ Opening a door.
Nope, if you consider all the possible handles, grasp requirements, and forces at play.

Question 6: Which one of these WAS NOT one of the participants of the *Alumni Panel*? (select ONE)
○ An indie game developer who advised to take CS classes outside of CS dept.
○ A software engineer at YouTube who advised you not to avoid challenge.
○ A backend engineer at Lisnr who advised you to delete your social media.
○ A data visualization consultant who advised taking personal finance courses.
● None of these, they were all on the panel!
This question was meant to be a "gimme" if you attended the Alumni Panel lecture.

(The Bool block on the right is used for Questions 7 & 8; 2,3 pts)



Question 7: Fill in the blanks so the predicate is the same as the original Bool block. (select ONE from each)

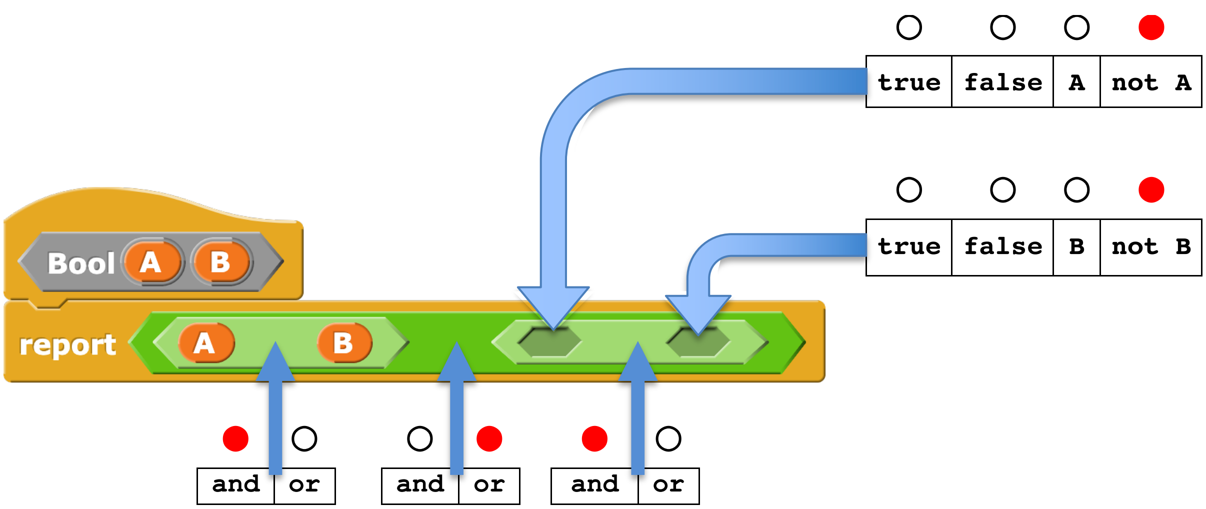


When does the original block return true? If B is true and A is equal to it (also true) – so A=true,B=true. What if B is false? Then B is not equal to true, so that rightmost = is false but what if A is equal to it? Then bool would return true. So we have A=false, B=false also. Therefore it turns out that bool simply returns whether A = B!

How do we make A=B in an if/then/else template? Let's see, if A is true, the "then" part of the if would be followed. We want to return true if B is true also, so the first slot is simply B.

If A is false, we want to return true when B is also false (same as B) so therefore we return "not B".

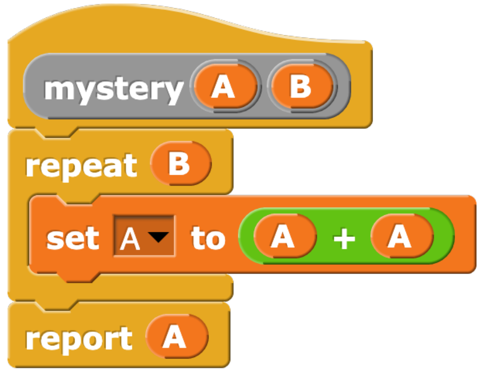
Question 8: Fill in the blanks so the predicate is the same as the original Bool block. (select ONE from each)



When we were describing the values that cause the original block to return true, we said: "A=true,B=true but also A=false,B=false". If we say it with just Boolean phrases, we would say: "(A=true AND B=true) OR (A=false AND B=false)", and one way to say "X = false", is just write "not X". Thus, we get the final answer of "(A=true AND B=true) OR (not A AND not B)"

Question 9: *Roll up for the magical `mystery` block, step right this way…* (4 pts)

What does **`mystery`** (below) report, if B is a counting number (i.e., 1, 2, 3, …)? (select ONE)



○	○	○	○	○	○	●	○	○	○	○	○	○
A×B	A^B	B^A	$A×B^B$	$A×B^A$	$A×A^B$	$A×2^B$	$A×B^2$	A+B	$A+B^2$	$A+2^B$	Error	Infinite Loop

One way to solve this is to see what happens for very small B.
If B = 1 (the loop happens once), then A gets set to A+A → 2A.
If B = 2 (the loop happens twice), then the first time A gets set to A+A → 2A, but then A gets doubled again to 4A after the second loop.
From this, it's apparent that A will get doubled with every loop, so we can see that on the 3rd loop it's 8A, 4th loop it's 16A, etc. Therefore, the return value is simply 2^B×A, and because × is commutative, it's also $A×2^B$

Question 10: *It's a mad, mad, mad, mad world…* (4 pts)

Two people (A and B) were told to find a hidden paper bag, which initially has $10 in it. Each one was told that when they found it, they would look at the contents, then wait a random amount of time within another week before returning to the spot, burning the paper bag (and whatever was in it) to ashes, and replacing it *with an identical paper bag and contents to the one they initially saw*, except:

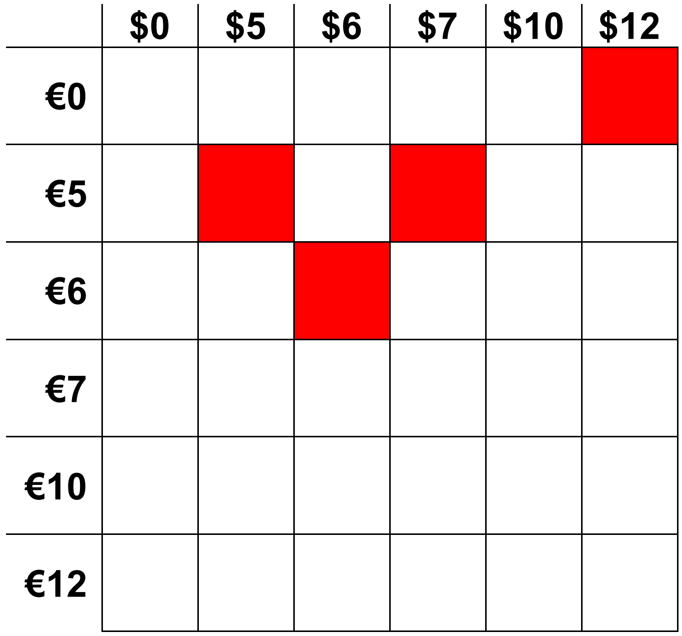
- **Person A:** The $ amount has been increased by 2. E.g., if the paper bag initially had $200, they would swap it with a paper bag with $202 inside. If the paper bag had $200 and €1000, they would swap it with a paper bag that had $202 and €1000 inside.

- **Person B:** They would convert half of the $ to € (assume the exchange rate is the same, $1 = €1). E.g., if the paper bag initially had $200, they would swap it with a paper bag that had $100 and €100.

What are possible contents of the paper bag at the end, *after both had done their swap*? (select ALL that apply by **filling in the box completely** for a value of dollars ($) in the column and euros (€) in the row.)

This is a concurrency (race conditions) problem. Let's see what possible cases come about:
1. **A** finds the bag, does the "+$2" swap (making it $12), then **B** finds *that* bag and does the "half $ → €" swap (making it $6,€6).
2. **B** finds the bag, does the "half $ → €" swap (making it $5,€5), then **A** finds *that* bag and does the "+$2" swap (making it $7,€5).
3. **A** and **B** both find the original bag, each prepares their separate replacement bags (**A** has $12, while **B** has it $5,€5).
   a. **A** puts their $12 bag first, leaves, then **B** burns that bag and replaces it with their $5,€5 bag.
   b. **B** puts their $5,€5 bag first, leaves, then **A** burns that bag and replaces it with their $12 bag.

Question 11: *Did we assign all student ID numbers correctly?* (9 pts)



There's been a problem with the student ID system and campus is not sure everyone has a unique number! Here are 3 algorithms to find out whether all student IDs (SIDs) are unique or not. For all problems, assume the number of students (N) is a power of 2 and really big. (How big?) Really big. Also, "clock time" is the actual elapsed time if you used a clock or stopwatch to time the running of the algorithm.

Algorithm I – "Musical Chairs" algorithm

1. The music starts, everyone mills around the room and when the music stops, they find a random partner and compare SIDs.
2. If anyone matches their SIDs with their partner, they yell "NOT UNIQUE!!" and stop.
3. If not, they wait for the music to start again, and repeat 1-3.
4. This continues for exactly N rounds, and if nobody has yelled "NOT UNIQUE", they all yell "UNIQUE".

Algorithm II – "Recursive Halving" algorithm

1. All people in the room pair up and compare SIDs with their partner.
2. If anyone matches their SIDs with their partner, they yell "NOT UNIQUE!!" and stop.
3. Otherwise, there will be a smaller and a larger SID. All the smaller SID students hold hands and go find a new room together, and all the larger SID students hold hands and go find a new room.
4. Step 1-3 continues until there are N rooms occupied with one person in each room, at that point they all yell "UNIQUE" and stop.

Algorithm III – "Down the Line" algorithm

1. Everyone lines up, and the first person is designated as the "unique tester".
2. The "unique tester" person goes down the line, comparing their SID to that of each new person, 1-on-1.
3. If ever the SIDs match, they yell "NOT UNIQUE!!" and stop.
4. If they get to the end and haven't matched, they go to the back of the line and the new first person is designated as the "unique tester", and they repeat steps 2-4.
5. If that initial first person ever ends up being first again, the yell "UNIQUE" and stop.

a) If each algorithm says "UNIQUE", are you *guaranteed* all SIDs are unique? (select ONE per row)

Algorithm	Yes	No	Reason
Musical Chairs	○	●	There is nothing in the algorithm that mandates partner swapping, so each round could have the same partners meeting, which doesn't allow us to "learn" anything new. Therefore, two people could have the same SID but never meet to confirm it, so if it says "UNIQUE", we really can't trust it.
Recursive Halving	○	●	The algorithm is peculiar, since once the initial pairings happen (say into the LEFT group and the RIGHT group), every LEFT person only meets one person in the RIGHT group. So it's possible that there are many duplicate SIDs, every other person in the RIGHT group could be the same as a single SID in the LEFT group and we'd never catch it. Therefore, if it says "UNIQUE", we really can't trust it.
Down the Line	●	○	This works! That is, this guarantees that every person will eventually check their SID with every other person (twice, actually, once with each partner being the "unique tester", so it's a little inefficient by a factor of 2), so that by the end, if it says "UNIQUE", we can certainly trust it.

b) In the WORST case, what's the *number of comparisons* (NOT running time)? If it's actually between two categories, pick the bigger category. E.g., N^4 is bigger than *cubic*, so pick *exponential*. (select ONE per row)

Algorithm	**Constant**	**Logarithmic**	**Linear**	**Quadratic**	**Cubic**	**Exponential**
Musical Chairs	○	○	○	●	○	○
Recursive Halving	○	○	○	●	○	○
Down the Line	○	○	○	●	○	○

Reasoning:

- *Musical Chairs* has N rounds where there are N/2 simultaneous comparisons each round. Therefore, that's $N^2/2$ comparisons, which is Quadratic (since constants don't matter).
- *Recursive Halving* has log N rounds where there are N/2 simultaneous comparisons each round. Therefore, that's N/2 * log N comparisons. We know that's bigger than Linear, and we know log N is smaller than N (it's its own category, after all), so N/2 log N is smaller than Quadratic. So its complexity of "N log N" (again, we drop constants) falls between categories we're told to pick the bigger one, therefore it's also Quadratic.
- *Down the Line* has N people each doing exactly N-1 comparisons, so it's $N*(N-1) = N^2 – N$ which is Quadratic, (since we drop smaller terms).

So they're all Quadratic, cool!

c) If the SID comparisons between different pairs of people could happen at the same time, *how much clock time* (NOT running time) would each algorithm take in the WORST case? (select ONE per row)

Algorithm	**Constant**	**Logarithmic**	**Linear**	**Quadratic**	**Cubic**	**Exponential**
Musical Chairs	○	○	○	○	○	○
Recursive Halving	○	○	○	○	○	○
Down the Line	○	○	○	○	○	○

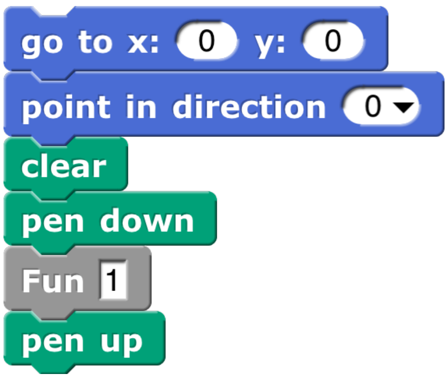
Reasoning:

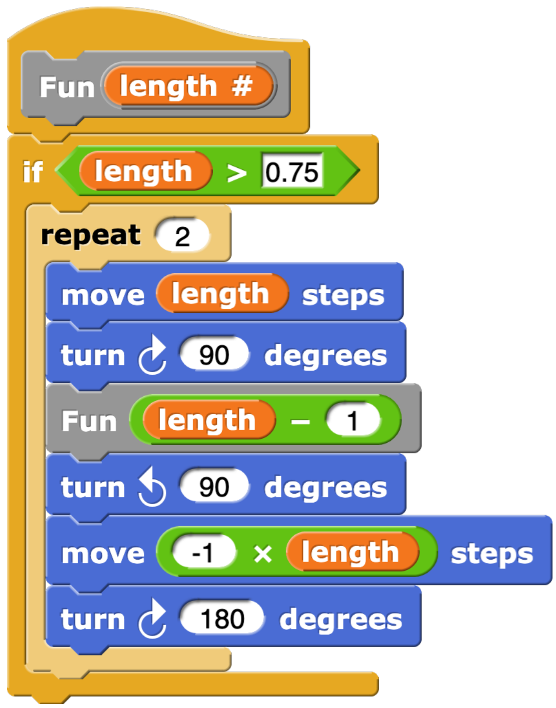
- *Musical Chairs* has N rounds where there are N/2 simultaneous comparisons each round. These N rounds make for Linear clock time.
- *Recursive Halving* has log N rounds where there are N/2 simultaneous comparisons each round. These log N rounds make for Logarithmic clock time.
- *Down the Line* has N people each doing exactly N-1 comparisons, so it's $N*(N-1) = N^2 – N$ which is a Quadratic, number of comparisons (since we drop smaller terms), and only one comparison happens at a time, so it's Quadratic clock time.

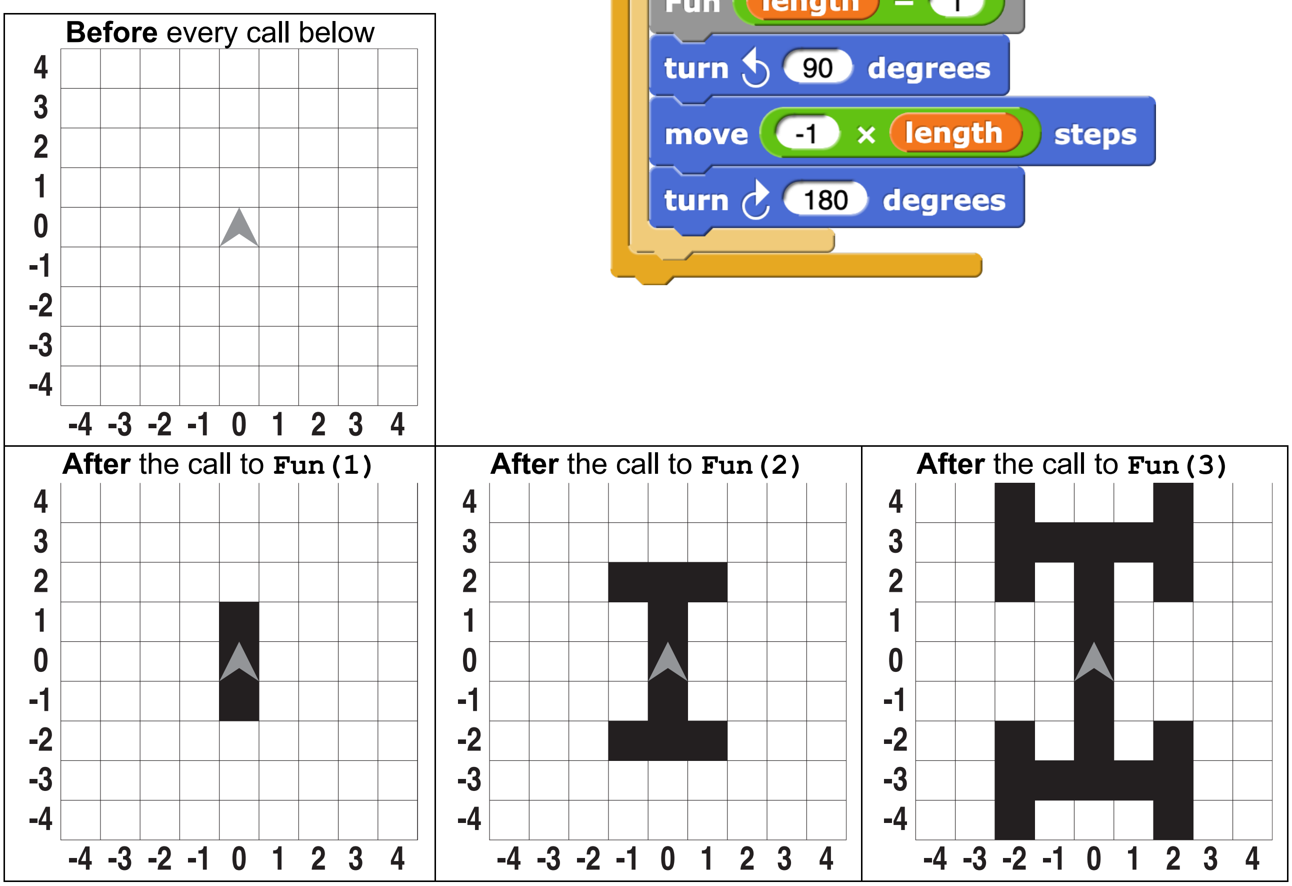
Question 12: *We put the `Fun` in Functional Programming…* (9 = 2+3+4 pts)

Consider the following code below. We're now to going to zoom in on pixels affected by calls to **`Fun`**; the stage is always cleared before the calls below, the sprite always starts in the center facing up, and the pen is in the *center* of the sprite.

Your job is to shade in (completely!) *all* the pixels that will be colored in after calls to **`Fun`** with n set to **1**, **2** & **3**. *Clarification: if the sprite were at (0,0) and moved 2 steps up, it would be at (0,2) and all pixels along the line from (0,0) through (0,2) would be shaded; 3 pixels in total.*

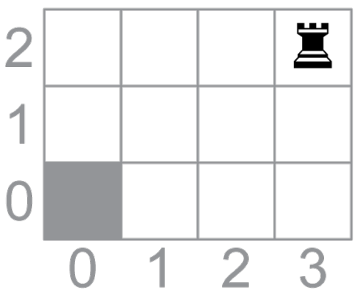


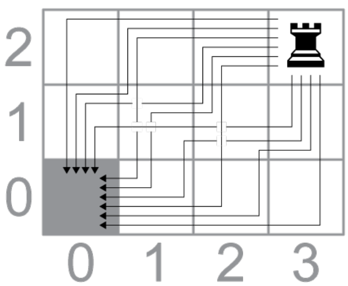




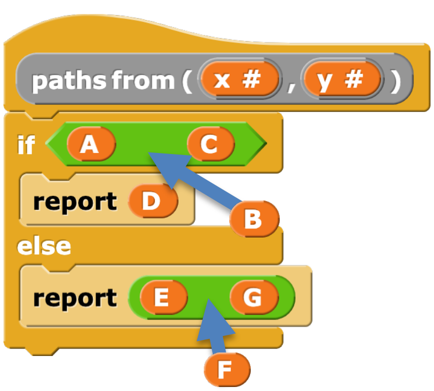
<u>Question 13: *I just want to go home…*</u> (14 pts = 1+1+1+1+4+2+4) SID: _______________

A rook is a piece in the game of chess that can move any number of squares vertically or horizontally. We put a rook somewhere on integer coordinates in the first quadrant ($0 \le x \le \infty$, $0 \le y \le \infty$) and put a spell on it so that it can only move toward the origin (i.e., either down or left). Author paths from (x , y) to calculate how many different paths there are home given an (x, y) starting point. E.g., the rook at (3, 2) could get back to (0, 0) any one of 10 ways, and the number of paths for each starting square in ($0 \le x \le 3$, $0 \le y \le 2$) is below.





2	1	3	6	10
1	1	2	3	4
0	1	1	1	1
	0	1	2	3



	A	B	C	D	E	F	G
0							
1				■			
2							
( ) × ( )							
( ) + ( )						■	
⟨ ⟩ or ⟨ ⟩		■					
⟨ ⟩ and ⟨ ⟩							
x < 0							
x = 0	■						
x > 0							
not x < 0							
not x = 0							
not x > 0							
y < 0							
y = 0			■				
y > 0							
not y < 0							
not y = 0							
not y > 0							
paths from (x − 1 , y − 1)							
paths from (x − 1 , y)					■		
paths from (x − 1 , y + 1)							
paths from (x , y − 1)							■
paths from (x , y)							
paths from (x , y + 1)							
paths from (x + 1 , y − 1)							
paths from (x + 1 , y)							
paths from (x + 1 , y + 1)							

Author your solution below AND then **completely fill in the boxes** above to correspond to the solution you wrote below.


```
paths from(x,y):
    if x = 0 or y = 0
        report 1
    else
        report paths from(x-1,y) + paths from(x, y-1)
```

Question 14: *Hey, let's call the function `f` on our `DATA`! Uh oh, on second thought…* (7 pts, 1 each)

Ever wanted an "undo" in life? Well, finally we have it! Given a *particular* function `f [ ]` whose domain is anything, we have invented a miracle function `undo f [ ]` that can always undo whatever `f [ ]` did. I.e., this is *always true* for any `input`:

`undo f (f (input)) = input`

"Thunk" pair

```
f (input)
report (input)
```

```
undo f (input)
report (call (input))
```

Given the following function:

```
identity (input)
report (input)
```

"List" pair

```
f (input)
report (list (input))
```

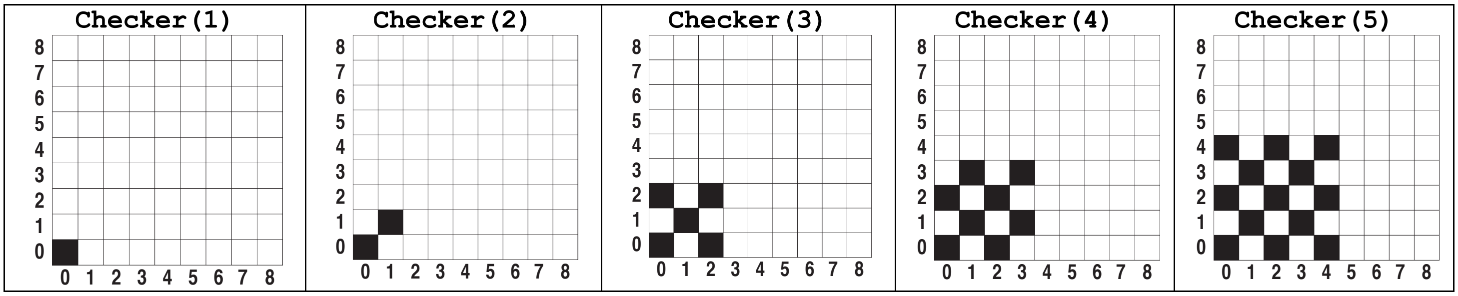
```
undo f (input)
report (item (1) of (input))
```

…which of the following are ALWAYS equivalent to the list `DATA`?
We did the first one for you. (select ALL that apply)

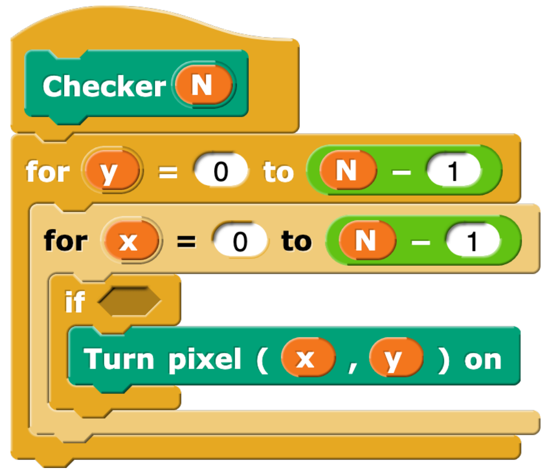
Expression	Yes, always equivalent to `DATA`	Not always equivalent to `DATA`
`undo f (f (DATA))`	●	○
Imagine if `f` and `undo f` were the functions above; it wouldn't work the other way, as in the "Thunk" or "List" pair above… `f (undo f (DATA))`	○	●
Doesn't work for the "Thunk" pair above since `f` doesn't return a list that can be mapped over… `undo f (map (identity [ ]) over (f (DATA)))`	○	●
Doesn't work for the "Thunk" pair above since `undo f` doesn't work on lists, but on functions… `undo f (map (f [ ]) over (DATA))`	○	●
Since we know `undo(f(input)) = input`, this doesn't do anything to all the elements of `data`, so it's just `data`. `map (undo f (f [ ])) over (DATA)`	●	○
Doesn't work for the "Thunk" pair above since `f` doesn't return a list that can be mapped over… `map (undo f [ ]) over (f (DATA))`	○	●
Each element gets `f(input)` then `undo(f(input)) = input`, so this doesn't do anything! `map (undo f [ ]) over (map (f [ ]) over (DATA))`	●	○
Doesn't work for the "Thunk" pair above since `f` doesn't return a list that can be mapped over… `map (undo f [ ]) over (map (identity [ ]) over (f (DATA)))`	○	●

Question 15: *Joshua: “How about a nice game of checkers?”* (4 pts) SID: _______________

You are trying to write code to generate a “N x N” checkerboard in which the bottom-left-most “origin” pixel is always turned on (black). E.g., calling it with N on values 1 through 5 should result in the following five images.



What Boolean expression should go in the **if** to accomplish this? (Select ONE)



- ● ((x + y) mod 2) = 0
- ○ ((x + y) mod 2) = 1
- ○ ((x × y) mod 2) = 0
- ○ ((x × y) mod 2) = 1
- ○ ((x mod 2) = 0) and ((y mod 2) = 0)
- ○ ((x mod 2) = 0) and ((y mod 2) = 1)
- ○ ((x mod 2) = 1) and ((y mod 2) = 0)
- ○ ((x mod 2) = 1) and ((y mod 2) = 1)
- ○ ((x mod 2) = 0) or ((y mod 2) = 0)
- ○ ((x mod 2) = 0) or ((y mod 2) = 1)
- ○ ((x mod 2) = 1) or ((y mod 2) = 0)
- ○ ((x mod 2) = 1) or ((y mod 2) = 1)

Question 16: *Berkeley python's flying circus…* (19 pts = 8 * 2 + 3pts)

We recreated an interpreter script. For each, indicate what the right answer should be.

```
>>> 1 + '2'
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
TypeError: unsupported operand type(s) for +: 'int' and 'str'
```

○ 3 ○ '3' ○ 12 ○ '12' ● Error ○ None of these

```
>>> [1] + ['2']
[1, '2']
```

○ [3] ○ ['3'] ○ [12] ○ ['12'] ○ [1,2] ○ ['1','2'] ○ Error ● None of these

```
>>> 'CAL'[1:2]
```

○ 'CA' ○ 'AL' ○ 'C' ● 'A' ○ Error ○ None of these

```
>>> A = [3]
>>> B = A
>>> A.append(2)
>>> B
```

○ [32] ○ [3] ● [3,2] ○ Error ○ None of these

We'd like to write a `backwards` function that would have the following behavior:

```
>>> school = 'cal'
>>> backwards(school)
'lac'
>>> def backwards(school):
...     return 'lac'
...
```

Is it possible to write `backwards`?

● yes ○ no

```
>>> [n+1 for n in range(2,4) if n != 3]
```

○ [3,5] ○ [4,5] ● [3] ○ [4] ○ Error ○ None of these

```
>>> ['n+1' for n in range(2,4) if n != 3]
['n+1']
```

○ ['3','5'] ○ ['4','5'] ○ ['3'] ○ ['4'] ○ Error ● None of these

```
>>> [n+n for n in ['HA','AB'] if n != 'A']
```

○ ['HH','BB'] ○ ['HA','HA','AB','AB'] ● ['HAHA','ABAB'] ○ Error ○ None of these

```
>>> def increm(n): return n+1
>>> def double(n): return n+n
>>> def square(n): return n*n
>>> D = {1: increm, 2: double, 3: square}
>>> [D[i](i) for i in [3,1,2]]
[9, 2, 4]
```