Algorithms and Searching
Choose the Right Tool for the Job

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Based on an exercise from *Computer Science Unplugged* (csunplugged.org)

What is an Algorithm ?

A set of steps that describe a method of solving a problem.

Algorithm for washing hair:

1. Wet hair
2. Apply shampoo
3. Lather hair
4. Rinse hair
5. Repeat steps 2 – 4. **How many times?**

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A More Formal Definition

An algorithm is:

- A well-ordered sequence of…
- unambiguous and …
- effectively computable operations that…
- produces a result, and…
- halts in a finite amount of time.

Schneider and Gersting, 1995

A Well-Ordered Sequence

When necessary, the steps are in order.

Algorithm for planting a seed in a pot:

1. Put soil in pot
2. Make a small hole in the soil
3. Put the seed in the hole
4. Cover the seed with soil
5. Water the soil
6. Put the pot in sunlight

These must be in the order shown. Why?

Either order will do. Why?

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Unambiguous

The meaning must be clear.

- Add A and B, then multiply the sum by C — **Unambiguous**
- Add and multiply the numbers. — **Ambiguous**

Effectively Computable Operations

Can the "computing agent" (person or machine) actually do what is needed?

- Check if A is greater than B **Computable**
- End world hunger. **Not computable**
- *Caution:* there are some problems that "look computable" but are not. Such problems are called *undecidable*.
- For an example, search for "the halting problem."

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Produces a Result

Remember our simple definition:

An algorithm is a set of steps that describe a method of solving a problem.

If there is no visible result, how can we tell whether our problem was solved? (We can't!)

Halts in a Finite Amount of Time

"Algorithm" to print all positive integers:

1. Set Number to zero
2. Add one to Number
3. Print Number
4. Go to step 2.

This will never end because there are infinitely many positive integers…

So it *cannot solve the problem* of printing all of them.

That Formal Definition

An algorithm is:

- A well-ordered sequence of…
- unambiguous and …
- effectively computable operations that…
- produces a result, and…
- halts in a finite amount of time.

Schneider and Gersting, 1995

It's Not the Code, it's the Algorithm!

- An algorithm *is a set of steps that describe a method of solving a problem.*
- A computer program (the "code") is *a concrete implementation of one or more* ***algorithms*** *in a specific programming language for a specific computer and operating system.*
- You have to have the algorithm before you can write the code!

The “Pokémon” Game

- Work in pairs.
- One of you gets an **A** worksheet and one gets a **B** worksheet.
- **Do not let your partner see your worksheet!**
- Start with **1A** and **1B**.

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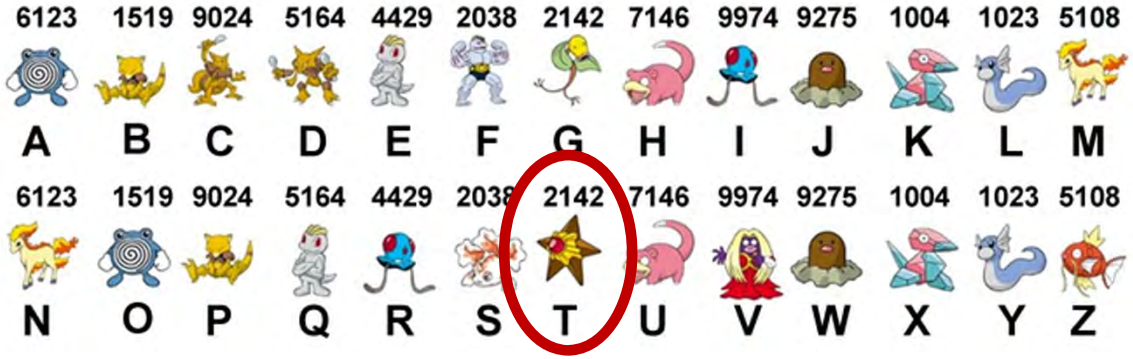
Selecting Targets

Pick one of your Pokémon, draw a circle around it, and tell the other player the **number** (not the letter) of the Pokémon. That's the other player's search target. Both players do this.



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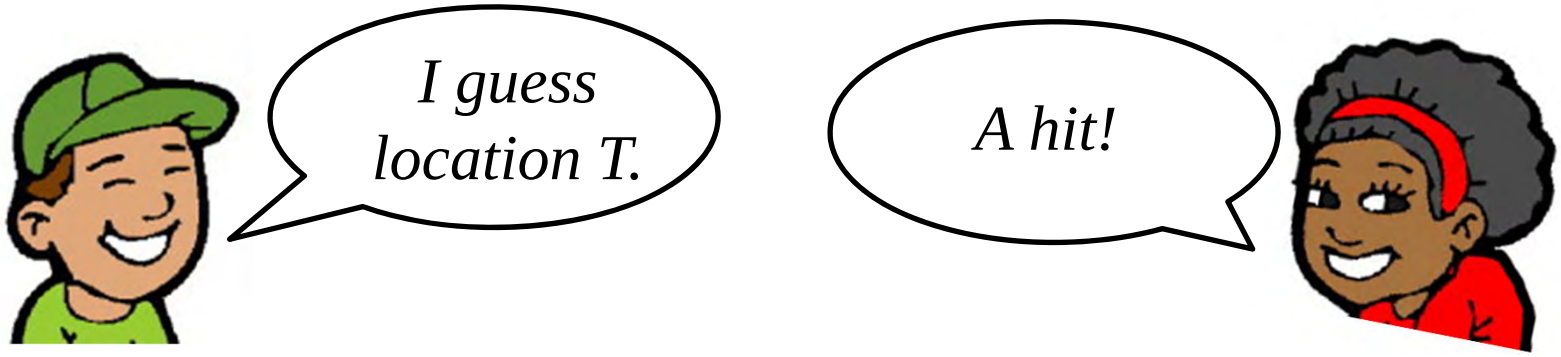
Take Turns Locating Each Other's Pokémon

Guess (or compute!) a letter that is the location of the Pokémon.

Record guesses until you get a hit; count that one, too.



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How Many Guesses Did You Take?

- How did you approach this problem?
- Did anyone get it on the first guess?
- Did anyone go through all 26 possibilities.
- Mostly, the number was somewhere in between.
- Did you notice that the numbers are in order? Did that help you?
- On the average, it could have taken 13 guesses. (That's half the 26 possibilities.)

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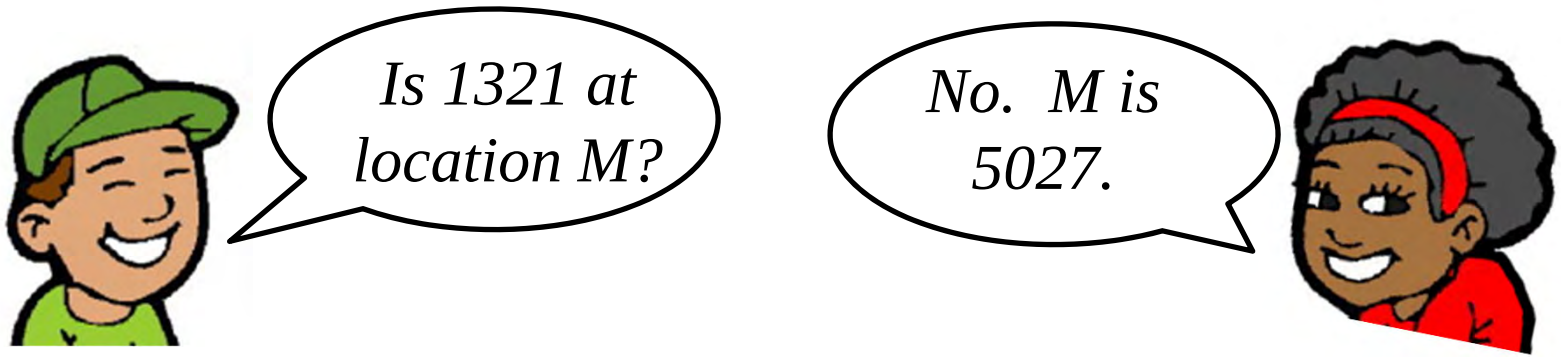
It's a Search Algorithm!

- Some of you checked locations one at a time until you found the right one.
- The one-at-a-time algorithm is called a *linear search*. You go "down the line" checking.
- If there were no order to the Pokémon numbers, a linear search is the best way to approach this problem.
- If the size of the list doubled, you'd need twice as many guesses, on average.

Searching is Very Important

- Think about Google; here's recent result:
  About 1,320,000 results (0.59 seconds)
- A zillion items searched, over a million results, much less than one second!
- Depending on the data, there are algorithms that work better than the linear search.

The Binary Search: Divide and Conquer!



"M" is the *middle* of the 26 letters.

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The Binary Search: Divide and Conquer!

Because 1321 is *less than* 5027.

The range before M is A – L.

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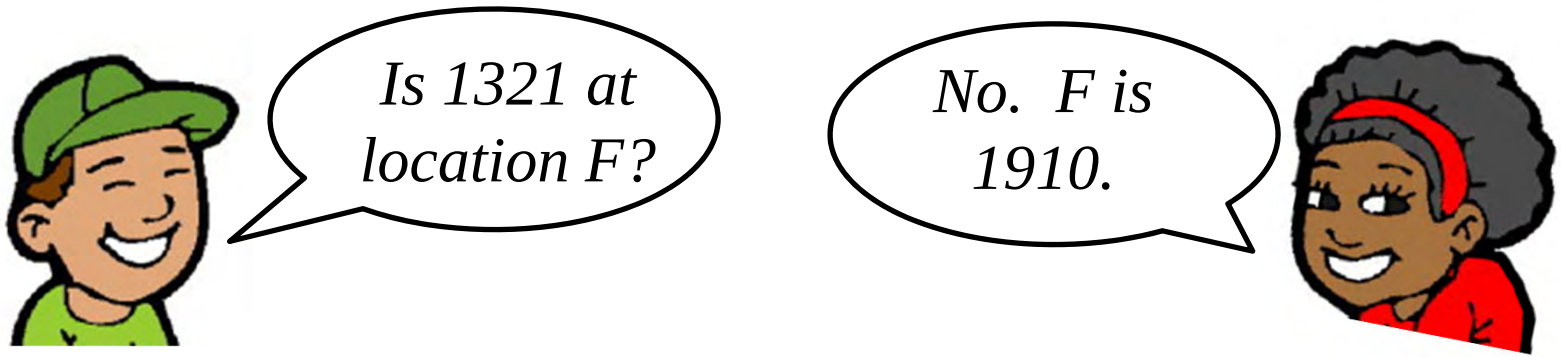
The Binary Search: Divide and Conquer!



"G" is the *middle* of A – L.

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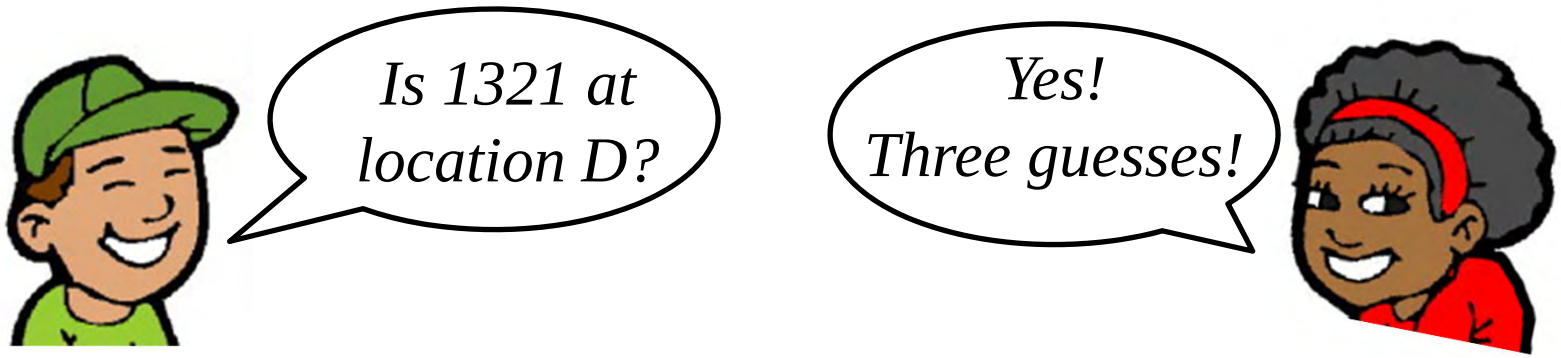
The Binary Search: Divide and Conquer!



"D" is the *middle* of A –F.

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The Binary Search

- The binary search starts at the *middle* element.
- If the value at the middle is more than the target, the target must be in the bottom half!
- If the value at the middle is less than the target, the target must be in the top half.
- Or, we could get lucky and get it on the first try, or with fewer than the maximum number of guesses.

The Binary Search

- Doubling the number of items adds *only one* guess.
- But… the items to be searched must be in order.

Let's Play Again

The game is the same, but this time use the fact that the numbers are in order. When the other player guesses, *tell them the number at the location* they guessed.

Can you find the Pokémon with fewer guesses?

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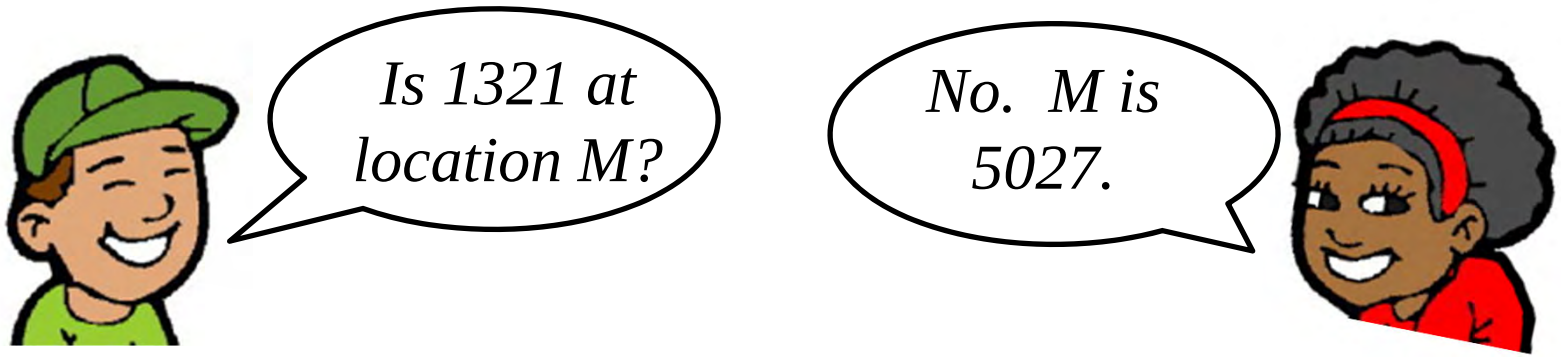
Tell the Other Player the Number



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How Many Guesses Did You Take?

- Did you change your approach?
- Did anyone get it on the first guess?
- Did anyone go through all 26 possibilities.
- Mostly, the number was somewhere in between.
- It could have taken five or fewer guesses!

Choosing the Right Algorithm

- If you have an unordered list and only need to search it once, use a linear search.
- If the list is already ordered, use a binary search.
- If you are going to do many searches on the same list, it may pay to do some pre-work.
  - Sort (once) and use a binary search.
  - Try a different algorithm, like a “hash table.”

Choosing the Right Algorithm

- There are other algorithms for searching.
- Many other tasks, like sorting, can have more than one algorithm.
- It’s not the code, it’s the algorithm!

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