Binary Trees

In computer science, a **binary tree** is a type of data structure - or way of organizing information. It organizes information or values across nodes and branches on a tree; and because it is called a binary tree, each node will have at most two branches.

There are several types of data structures in computer science, and many of them organize data in a linear way. But a binary tree is different! We will learn that, as a structure, trees branch out and grow exponentially and that there are several different paths we can take to travel through a tree's branches.

Trees sort information hierarchically, rather than linearly. We see hierarchical structures all the time, in examples such as family trees, government organizations, and the classification of living things.

Binary trees are composed of nodes and branches. The nodes contain the information or values, and the branches connect them. With the binary tree, each node will have (at most) two branches.

As we draw and make binary trees, we will notice that they grow very quickly. Even though we may start with one initial node (the root) and branch, it multiplies exponentially, and we can see just how many branches we have when branches double only a few times.

These lessons are a simple introduction to binary trees by way of drawing and collaging, and even flipping coins. They are fun and creative, so we encourage you to adapt them as you see fit for you and your child(ren).

Binary Trees

Activity 1: Draw a Binary Tree

Objective
Children will learn what a binary tree is and demonstrate this understanding by drawing one, either independently or with help.

Ages: 4-9 years

Materials
- blank paper
- colored pencils, pens, crayons, paint, etc.

Setting Up
Set up the materials you will use - blank paper to draw on, and materials to mark with: pencils, crayons, pastels, paint...whatever!

Find a space free of clutter and distraction, that gives you enough space to work and potentially get a little messy. A table works best.

Process

1. Explain: today we are going to draw binary trees! Depending on the age of the child, you may explain and discuss...

Have you ever heard the word *binary* before? What do you think it means?

You may have heard other words that start with "bi" ...

- **Bifocals** have two different lenses.
- **Binoculars** are two telescopes side-by-side.
- Someone who is **bilingual**, speaks two languages.
- To **bisect** is to cut something into two pieces.
- A **bicycle** has two wheels.

What do these words have in common?

They all have two of something - "bi" means two.

On the Binary Tree, each branch has two branches.

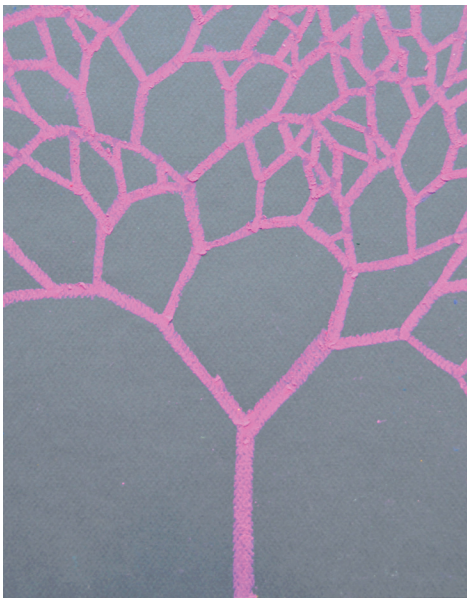
2. You may want to draw a binary tree as an example, or point to the images in this document, on the next page. Point out that with a binary tree, each branch will have two more branches. And the point at which it branches is called a **node**.

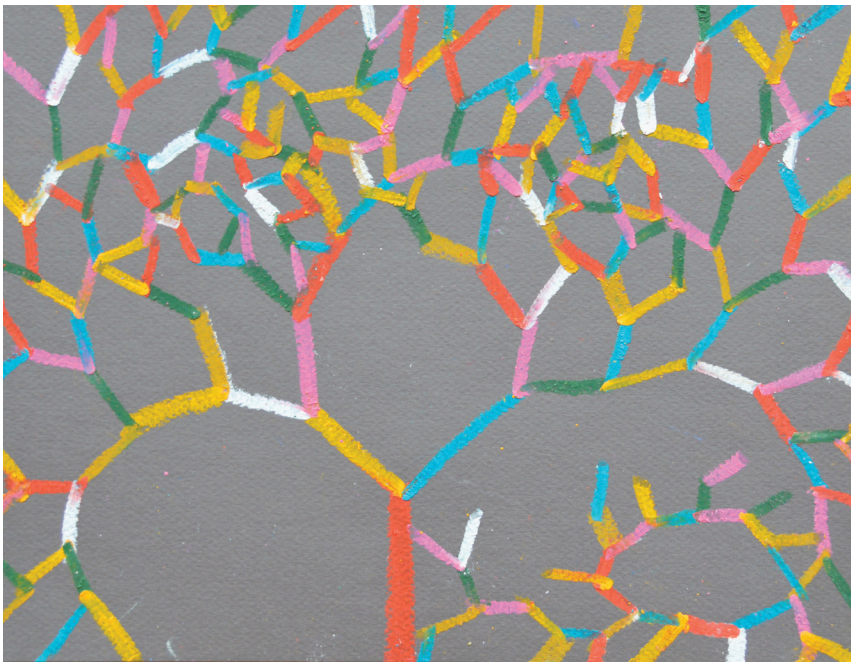
3. With the paper and drawing materials, invite the child to try and draw a binary tree. Depending on their age, you may need to help or start the tree.

4. You can also go back and forth, each drawing a line. *Notice how quickly the tree grows! The branches are doubling each time, and so it grows very quickly!*

5. You can point out that as the tree is growing, we are running out of space! This is called **exponential growth**, because each branch is doubling as it grows.


Look at this tree.
Do you see a pattern?
hint:
How many branches grow out of each branch?





Binary Trees

Activity 2: Make a Binary Tree

Ages: 3-9 years

Materials needed:
- Miscellaneous paper: construction paper, magazines, etc.
- scissors
- large piece of paper, solid color
- glue / glue stick

Process
1. You can cut out the rectangular pieces together, or have them cut ahead of time. It is useful to have a variety of lengths, and they should all be somewhat slender.

2. Review or discuss the concept of a binary tree (see Activity 1 for reference).

3. With the cut out rectangles and glue, invite the child to create their own binary tree. Laying down the first branch at the bottom of the tree, and then gluing two branches from the branch, etc...

4. You can work together, or have the child work independently, depending on their age.

5. It can be fun to take turns gluing down pieces, and as it grows, there are so many branches that it may become challenging to find space! Because each branch is doubling, it is growing very quickly.
This is called **exponential growth.**

Extensions

a. Place a small bean or some kind of marker on the end of a branch, and ask the child to start at the root, and trace a path up the tree with their finger.
b. Use found objects, from nature or from around the house.
c. Try to build a three-dimensional binary tree.
d. Take a walk, noticing and pointing out different trees. Observe the way they grow... where is the trunk, why do the branches get smaller toward the top? How is it different than the binary tree?

Binary Trees

Activity 3: Heads or Tails

Objective
Children will learn how we can map out the possible sequences of coin flips as a binary tree - knowing that each flip will have one of two states: head or tails.

Ages: 4-9 years

Materials
15 pennies
paper
pencil

Setting Up
Find a spot clear of clutter and distraction, a table works well so that you can write on a hard surface.

Set out your piece of paper, and a pen/pencil/marker.

Process
1. Hand a penny to the child.

2. Teach the child how to flip a coin; point out that there are two sides and that they are different. *We call this side, heads, and this side tails.*

3. We can use flipping coins to understand the binary tree. When we flip the coin, it is always heads or tails. Have the child flip the coin several times, calling out which comes up.

4. If I asked you to flip the coin three times in a row, what do you think would happen? How do you know? Explain and discuss that there are several different possibilities for what the sequence of the three coin flips will be.

5. Ask the child to flip the coin three times in a row, and each time ask the child to write down the sequence. For example, it may read: (H, T, H or H, H, H or T, H, T, or T, T, T, etc...) Ask the child to do this a few times, flipping the coin 3 times each round and recording the outcome.

6. How many different outcomes do you think there are? Discuss...Each time we flipped the coin three times in a row, the outcome varied. There are several different outcomes!

7. We can use a diagram of a binary tree to map out all of the possible sequences for our three coin flips. On the

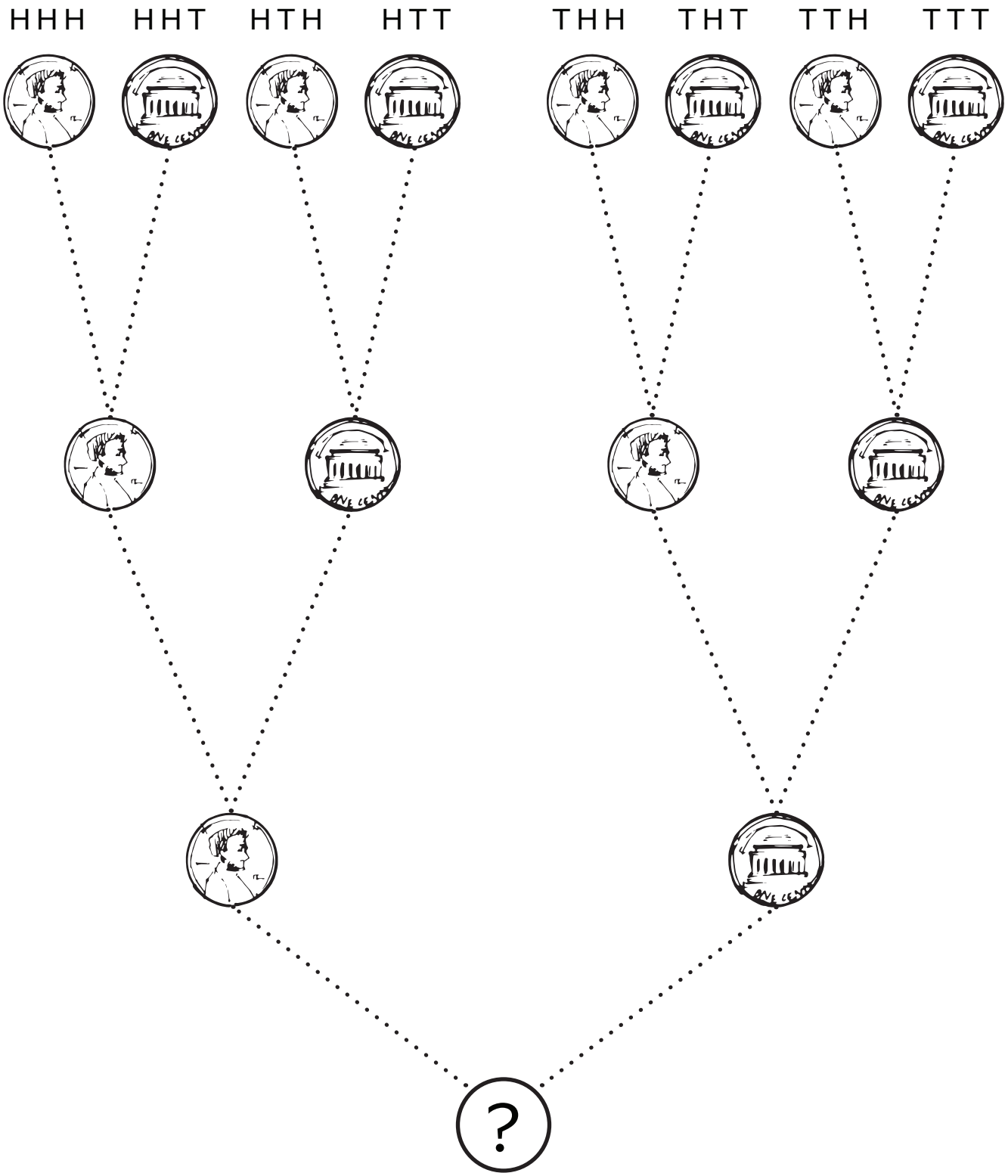
piece of paper, place two pennies at the bottom, with space in between them. On the left, the penny is heads up and on the right, the penny is tails.

8. Point to the penny on the left, with the heads up, and ask: after this first coin flip, what are the next possible outcomes? (one heads, and one tails) Place two more pennies above the coin on the left, and draw lines to connect them.

9. Depending on the age of the child, either invite them (with help as needed) to complete the rest of the tree - for each coin flip map out the next two possible outcomes (see the following diagram for reference). It may be easier to place the pennies first and then draw the connecting lines. After you create the diagram together, you could invite the child to create their own.

10. After the diagram is completed, ask the child to write the possible outcomes above the last penny (HHH, HTH, HTT, etc). This will be like a path up the tree, with each penny a node along the way. How many possible outcomes are there?

11. With the tree and the pennies still arranged, ask the child to flip another penny 3 times in a row, recording the outcome. Now ask the child to point to the tree with the pennies, following on the tree the outcome that occurred. Repeat.


HHH
HHT
HTH
HTT
THH
THT
TTH
TTT
?