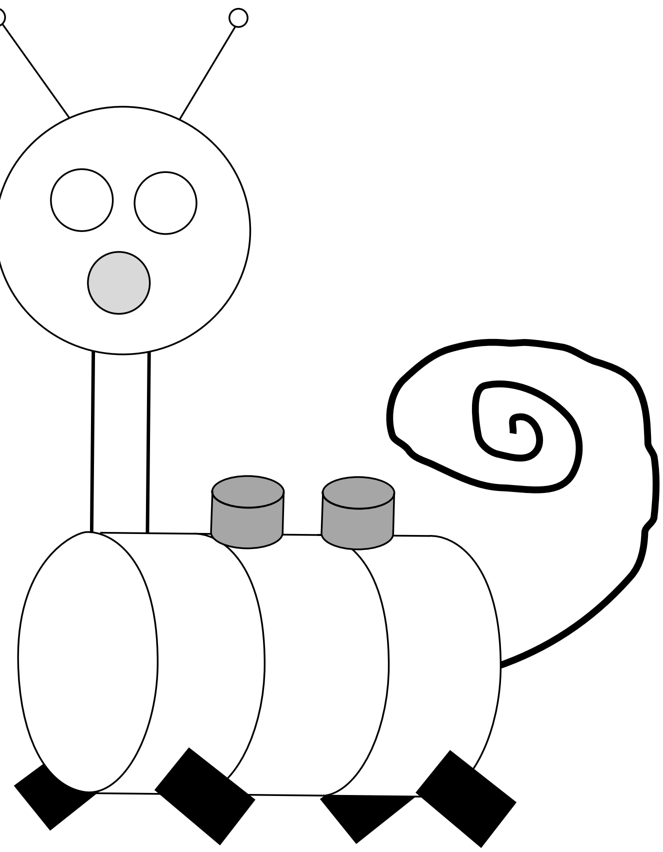
Reebops



A model "organism" for teaching genetics concepts

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Introduction

Reebops helps illustrate how meiosis is an important reason for the tremendous variation that exists in every species. Reebops are imaginary organisms made out of marshmallows and other inexpensive materials. Reebops tend to live in discarded pop (that's "soda" for you non-Midwesterners) cans. However, they are rarely seen in the wild as they are extremely fast. Once you have a male and a female in captivity, your room will soon be filled with Reebops. They are very prolific and require minimal care. My Reebops live quite comfortably in a covered shoebox with small holes punched in the sides for ventilation.

Reebops was developed by Patti Soderberg, with support from a grant to the Center for Biology Education, UW-Madison, from the Howard Hughes Medical Institute.
Graphic design by Tracy Saffran.

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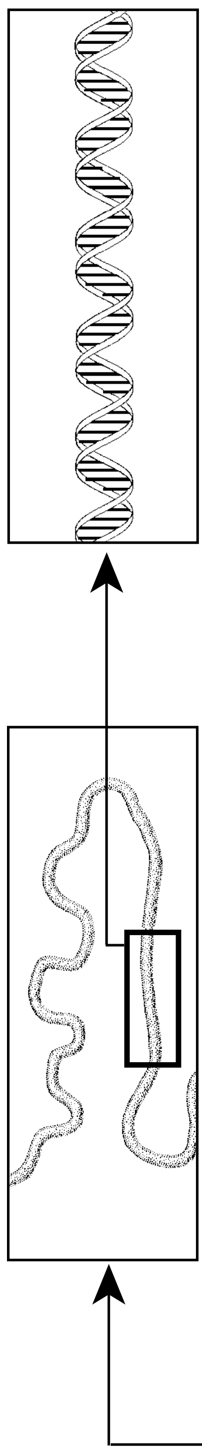
Notes for the teacher

DNA double helix



This is background information for teachers who would like to use the Reebop activity in their classroom, but feel a little hesitant about their genetics knowledge. The Reebop activity was originally written for middle and high school students. However, many elementary teachers find that they can use Reebops to teach a variety of lessons to younger students.

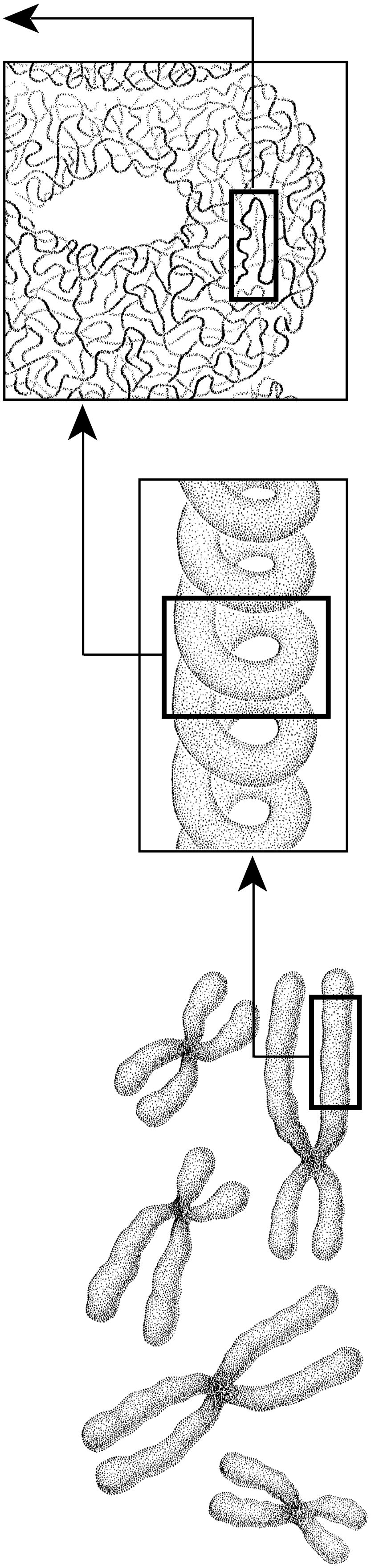
This outlines the basic relationship between DNA, genes and chromosomes. It also provides enough information to help you decipher any unfamiliar (or vaguely familiar) genetics vocabulary you may find in the Reebop activity.

Each cell in all living organisms contains hereditary information that is encoded by a chemical called *DNA* (deoxyribonucleic acid). DNA is an extremely long molecule. When this long, skinny DNA molecule is all coiled up and bunched together it is called a chromosome. Each chromosome is a separate piece of DNA, so a cell with eight chromosomes has eight long pieces of DNA. A gene is a segment of the long DNA molecule. Different genes may be different lengths. Each gene is a code for how a certain molecule can be made. The molecules produced by the genes can generally be sorted into two different types: ones that run the chemical reactions in your body, and ones that will be the structural components of your body. How an organism looks and functions is a result of the cumulative effect of all the molecules.

Chromosomes can be seen if one looks through a microscope at a cell stained with dye. The DNA in a cell will coil up to form chromosomes right before the cell is about to divide. Therefore, you need to look at cells that are in the process of dividing to see chromosomes. Otherwise, the DNA will be uncoiled and strung out all over the nucleus of the cell.

Any organism that has "parents" has an even number of chromosomes, because half of the chromosomes come from the "father" and the other half from the "mother." For example, in plants, a pollen grain is the "father's" contribution and an ovule is the "mother's" contribution. These two cells combine to make a single cell which will grow into a seed (the offspring). Humans have 46 chromosomes. The chromosomes sort into 23 pairs. One chromosome in each of the 23 pairs is from the person's father, the other from the person's mother.

Since chromosomes come in pairs, genes do too. One gene is located on one member of chromosome pair, the other gene is in the same location on the opposite chromosome. The location where the gene can be found on the chromosome is referred to as the *gene locus*. The gene "pair " is technically referred to as a *gene*, as both members of the pair code for the same trait. A gene can consist of a variety of different forms, but only two forms are ever present per gene (one from the mother, the other from the father). The two different gene forms on the pair of chromosomes may be identical or different. For


human chromosomes

example, in the Reebops activity, the gene for tail shape has a “T” form and a “t” form. These forms are arbitrarily represented by capital and lower case letters. If both chromosomes have a “T” form, or both have a “t” form, the gene is said to be *homozygous* (two of the same form). If one chromosome has a “T” form and the other has a “t” form, the gene is said to be *heterozygous* (two different forms). The different forms that comprise a gene are called *alleles*. Therefore, “T” and “t” are alleles for the tail shape gene.

If you look at the Key to Reebop Traits found on page eight, you will notice that two “T”s (TT) or a “T” and a “t” (Tt) code for the same thing: a curly tail. If the Reebop has a small “t” on each chromosome, he or she will have a straight tail. Because both the heterozygous (Tt) and one of the homozygous (TT) forms happen to code for the same variation of tail shape, curly tail is said to be the *dominant* variation and straight tail is the *recessive*. (Most people like to assign the capital letter to the dominant allele. This is purely an arbitrary designation.)

Now look at the decoder symbols for the nose color gene. Notice that in this case, the heterozygous condition (Qq) codes for a different nose color variation (orange) than either of the homozygous states (QQ = red, qq = yellow). This is an example of *codominance*. Many people mistakenly believe that a dominant allele (“T” in the tail shape example) is the most prevalent form or that the dominant allele can switch off or mask the recessive allele. Actually, all dominance refers to is what the heterozygous combination codes for. If it codes for one of the homozygotes, that variation is dominant. If it codes for a variation that is different than either homozygous state, then that variation is co-dominant.

If an expectant mother chooses to have an amniocentesis, she will learn some information about her baby’s chromosomes, but not about the baby's genes. Chromosomes are large enough to be seen with a microscope, genes are not. Specialized tests are required to look for a particular gene that can cause a genetic disorder. Typically, an amniocentesis is used to see if the baby has the correct number of chromosomes. The chromosomes of fetal cells taken from the amniotic fluid are examined in the procedure.

The baby’s chromosomes are photographed through a microscope. Each pair of chromosomes differs in length. The chromosomes are cut out of the photo and arranged by length into 23 pairs. The pairs are numbered longest to shortest, with the longest pair labeled as number one. This chromosomal picture is called a *karyotype*. If a mistake occurs when cells are dividing to produce egg or sperm cells, the baby may end up with an incorrect number of chromosomes. This error would show up in the karyotype. *Non-disjunction* is the general term for errors in chromosome division. For example, a pre-sperm cell with 46 chromosomes could divide into one sperm cell with 22 chromosomes and another with 24. If the sperm cell with 24 chromosomes fertilizes an egg with 23 chromosomes, the baby will now have 47 chromosomes. A child with *Down Syndrome* has an extra number 21 chromosome. The extra chromosome can come from either the father or the mother, depending on if the non-disjunction occurred during the production of either the sperm or egg cell.

Lab Activity: Teacher Guide

Reebops

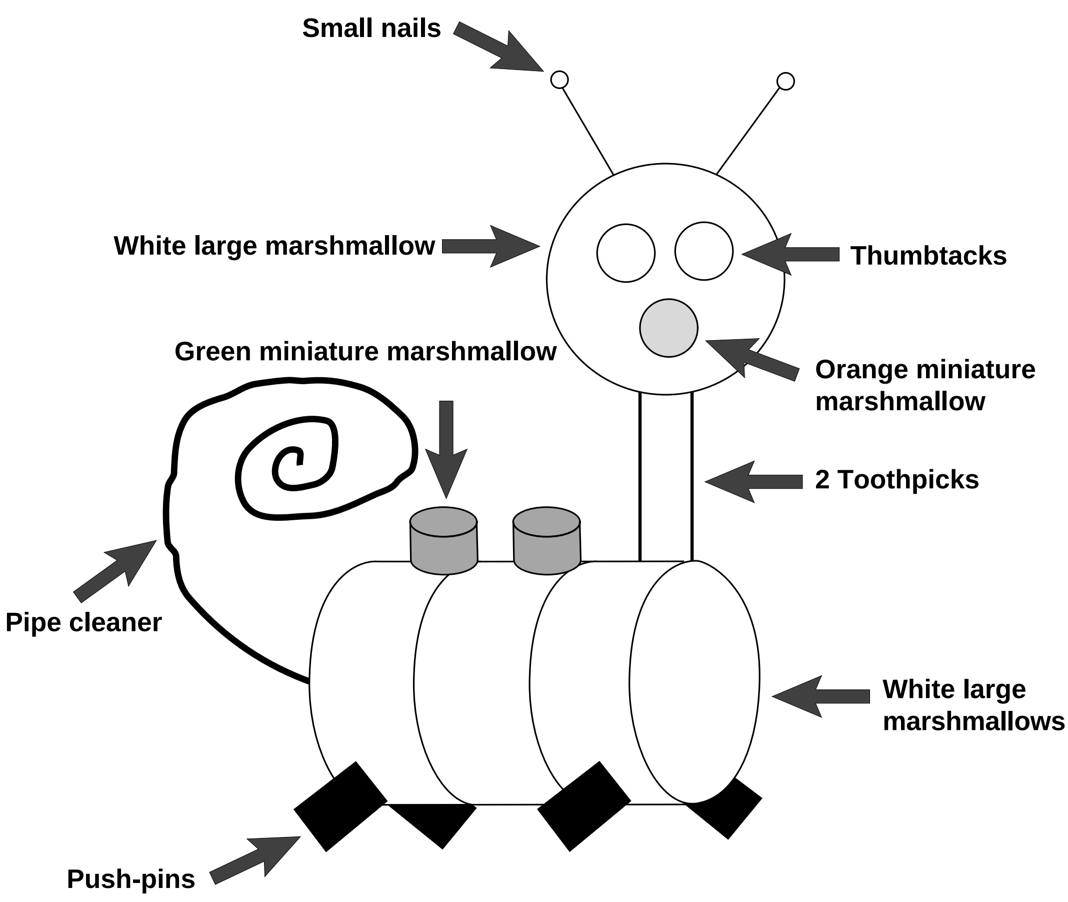
During the Reebop activity, your students will have the opportunity to observe all of the offspring produced by one set of Reebop parents. Your students will sort Mom and Dad Reebop's chromosomes, select the new baby Reebop's chromosomes, decode the "secret code" found on the baby's chromosomes, and construct the baby Reebop according to the code. In other words, your students will be modelling the processes of meiosis, fertilization, development and birth. After all of the babies are "born," the Reebop family will be assembled so the offspring can be compared to one another.

Setting up for the activity

Assembling Mom and Dad Reebop

Prior to class, you need to assemble Mom and Dad Reebop. Mom and Dad each have two antennae (small nails), a head (white large marshmallow), a neck (two toothpicks), two eyes (thumb tacks), an orange nose (an orange miniature marshmallow), three body segments (white large marshmallows), two green humps (green miniature marshmallows), four blue legs (blue push pins), and a curly tail (a pipe cleaner). Assembly works best if you let the marshmallows sit out over night to firm up. The Reebops tend to be too floppy to stand properly if fresh marshmallows are used.

The gross anatomy of a Reebop



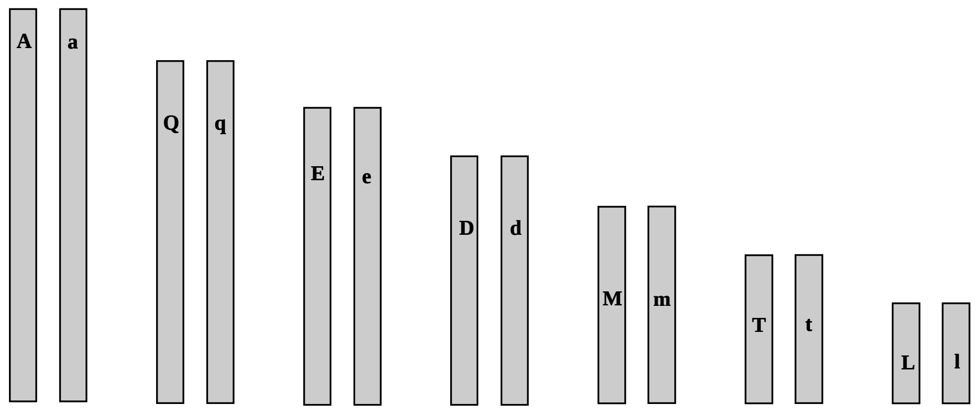
Toothpicks function as the unseen ligaments and tendons

Setting up
(continued)

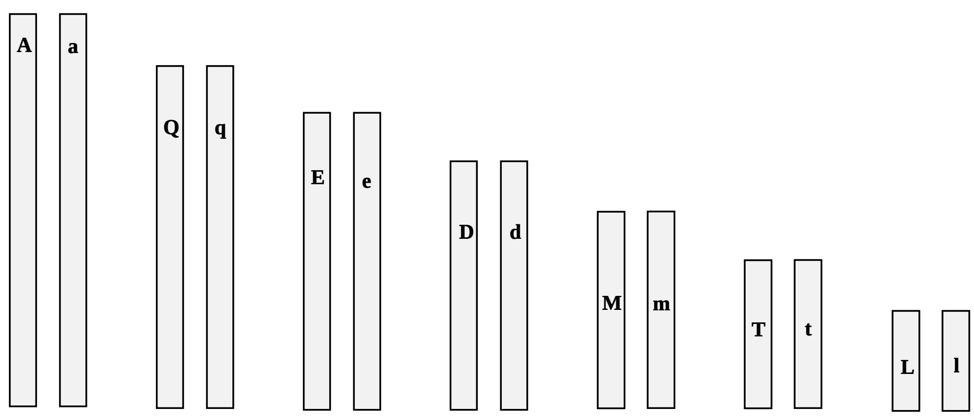
Constructing chromosomes

Next, you will have to construct identical sets of Mom and Dad Reebop's chromosomes for the students to sort. Place each set in a large envelope. Chromosomal analysis has revealed that Reebops have seven pairs, or fourteen total chromosomes. Cut strips of red and green construction paper to create the chromosomes (see below). Each envelope should contain two different colored subsets of 14 chromosomes (a total of 28). Each parental set consists of pairs of chromosomes of 7 different lengths. The 14 red chromosome are Mom's chromosomes and the 14 green ones are Dad's. Write the "secret code" symbols (the alleles) on the chromosomes with a magic marker. I set it up so that the parents are heterozygous at all loci and each gene locus is on a different chromosome (seven traits, seven pairs of chromosomes). More traits, such as sex, can be easily added if you wish. Create enough sets so each pair of students will have their own set to work with.

Mom and Dad Reebop chromosomes



Mom Reebop chromosomes (red)



Dad Reebop chromosomes (green)

Seven pairs of chromosomes seems to be a large enough number to insure that no two offspring produced by a class will appear identical. However, if you are working with a large group of students, you may want to increase the chromosome number to insure the certainty of variation among all offspring. There are 128 chromosome combinations possible from an organism that has seven pairs of chromosomes (2 to the 7th power). Or, in other words, there are 128 possible genotype combinations from this arrangement. However, the actual number of phenotype combinations is less than this number as some of the allele combinations code for the same phenotype, such as blue legs = LL or Ll. If each gene locus exhibited codominance, then the number of genotype combinations would be the same as the number of phenotype combination.

Activity

Breeding Reebops

Introduce your students to Mom and Dad Reebop and distribute the chromosome sets, one to each pair of students. Ask one member of each pair to take the red chromosomes, and the other the green. Have them turn the chromosomes face down on the table so that no letters are visible, and ask each student to sort them by length. At this point you may want to ask the students to hypothesize why chromosomes come in pairs. Then have each pair of students arbitrarily take one chromosome of each length and place it in a separate "baby pile." This will be their Reebop baby's chromosomes. The remaining chromosomes can be returned to the envelope. Each Reebop baby will have 14 chromosomes, half red and half green. If you happen to have a pair of students who sort their chromosomes improperly and end up with either the wrong number of chromosomes or 14 chromosomes without each of the seven lengths, resist pointing this out to them. Their Reebop baby will be a wonderful example of the need for both the correct number and kind of chromosomes given to the baby by Mom or Dad.

The students can discover what their baby will look like by turning over their baby's chromosomes and decoding them, referring to the Key to Reebop Traits. Each pair of students will construct their baby according to their "secret code." Have the proud parents place the completed Reebop babies in a designated nursery. Each Reebop baby should look different than all the other Reebop babies. If none of the groups of students missorted their chromosomes, you may wish to have a pre-constructed baby that has extra parts and is missing others. This baby will be a perfect lead-in to talking about non-disjunction.

Key to Reebop traits

1 antenna = AA
2 antennae = Aa
No antennae = aa

Red nose = QQ
Orange nose = Qq
Yellow nose = qq

2 eyes = EE or Ee
3 eyes = ee

2 body segments = dd
3 body segments = DD or Dd

1 green hump = MM
2 green humps = Mm
3 green humps = mm

Curly tail = TT or Tt
Straight tail = tt

Blue legs = LL or Ll
Red legs = ll

The advantage of using Reebops

The advantage of the Reebops is its suitability to a wide range of ages. We have found that elementary teachers as well as college instructors are enthusiastic about the lessons they have taught with Reebops. Of course, the goals of the Reebop activity will vary depending on the grade level of the students. For example, with young children, the goal of the activity may be simply to understand what generations are. With older students, the goals may be to understand that each parent contributes the same amount of genetic information to a child, why siblings in a given family look similar yet are all different, and why identical twins are "identical." The Reebops can be used with advanced students to teach concepts such as linkage and multiple alleles. They can even be used to teach population genetics, as Reebop offspring can interbreed to produce numerous generations. Multiple generations of Reebops can also be used to introduce a genetics unit. You can have students construct Reebop pedigrees, look for patterns of inheritance of the different traits, and subsequently infer models that account for these patterns.

I have found that the Reebop activity generates numerous questions from students, especially when we discuss the effect of non-disjunctional events in humans. There are very few viable forms of aneuploidy (extra or missing chromosomes) in humans. One example is Down Syndrome. Most adolescents are familiar with Down Syndrome, particularly if they have seen the weekly television show "Life Goes On." Fetuses with either trisomy 13 or 18 who survive to birth will usually die shortly after. There are living individuals who have a variety of sex chromosome aneuploidies. However in most cases, aneuploidy in humans will not result in viable offspring and a miscarriage will occur. A conservative estimate calculates that at least sixty percent of all miscarriages that occur before the twelfth week of gestation are due to an incorrect chromosome number in the developing fetus.

Conclusion

The strength of the Reebop breeding activity is that it helps students to understand that the function of meiosis is not only to reduce the number of chromosomes, it is an important mechanism to insure the variation which is vital to all species. Variation is the "raw material" for the process of natural selection, the driving force of evolution. After breeding Reebops, students are more apt to recognize and understand both functions of meiosis, because they are not getting bogged down in the jargon of phase names or genetics phenomena. Finally, the best part about Reebops: You can eat the leftovers!

Glossary

Allele — A form of a gene. A gene actually consists of two forms, one on the chromosome that came from the father, the other on the chromosome given by the mother.

Aneuploidy — Having extra or missing chromosomes.

Chromosome — A very long piece of DNA coiled around some proteins. Each chromosome is a separate strand of DNA.

DNA— A very long chemical that can coil up to form a structure known as a chromosome.

Gene — A segment of a strand of DNA that codes for how to make a particular molecule. The molecules it produces will result in a particular trait. Different genes have different lengths.

Heterozygous — Having two alleles (forms of the gene) that are different.

Homozygous — Having two alleles (forms of the gene) that are identical.

Locus — The location on the chromosome where the gene can be found. The plural of locus is *loci*.

Meiosis — The type of cell division that produces cells with half the number of chromosomes than the original cell. This is the process that creates sperm and egg cells.

Non-disjunction — An error in the process of chromosome sorting during cell division.

Trisomy — Having three chromosomes of one size instead of the normal pair

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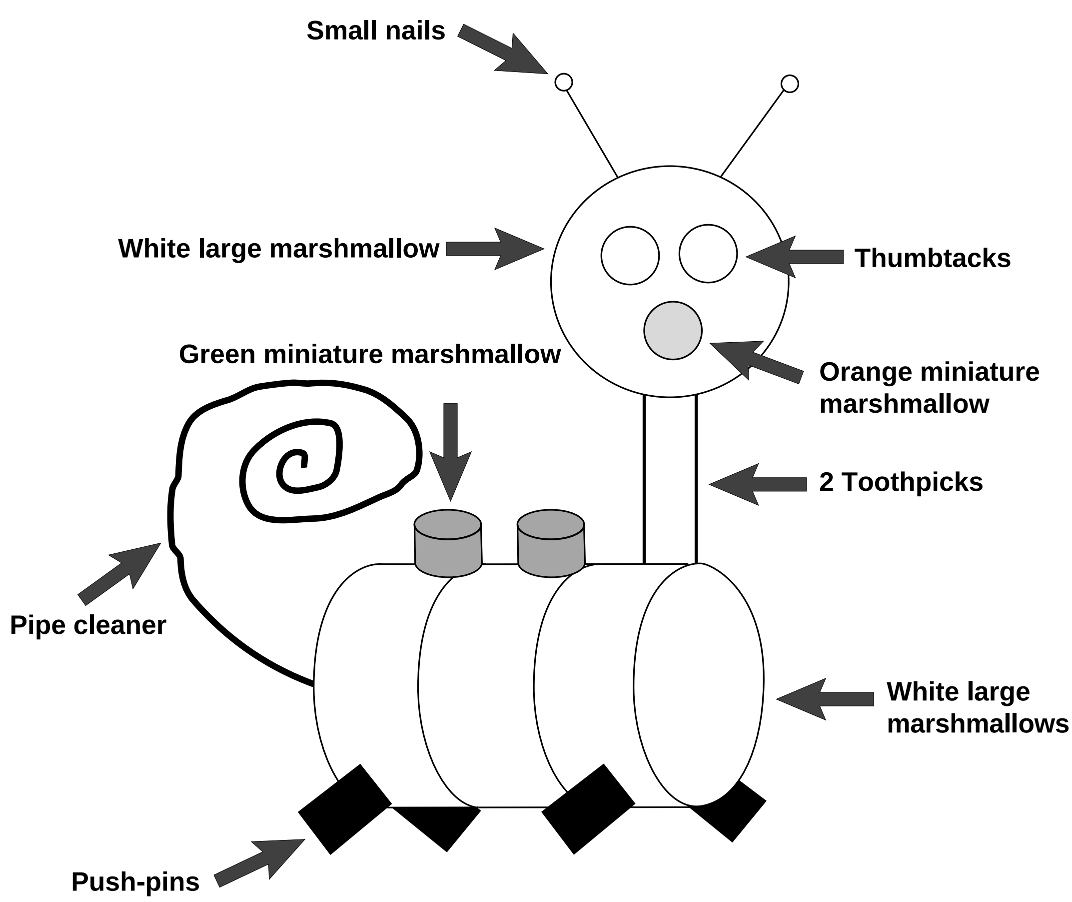

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