Access prior knowledge

➢ Why do offspring often resemble their parents? Yet rarely look *exactly* alike?
➢ Is it possible for offspring to display characteristics that are not apparent in their parents?
➢ What does the word "<select word>" mean to you? Check out the glossary for some ideas.

Materials

Ask students to find a partner.

Materials that need to be accessible to each pair:

1	hair	**2**	hands
1	eye	**1**	Set of trait cards
1	tongue	**1**	Sheet of scrap paper
2	ears	**1**	Pen / pencil

Activity 1: Make an Alien Baby

Have students look at the pieces in their kit. There are differences between the pieces, some are obvious and some subtle. After letting the students explore for themselves, walk them through what each piece is. Explain that each plastic piece represents a human phenotype.

Option 1: Give the students some time to discuss how their own phenotypes compare to the plastic equivalents.
Option 2: Hand out the famous family images and ask students to match the traits of a famous character to the plastic equivalents as best they can.

Then, get them to use the pegs provided to attach the plastic phenotypes to a foam piece. The result will be an Alien Baby.

At this stage, you want the students to distinguish between traits (e.g. eye colour) and phenotypes (e.g. blue vs. green vs. brown eyes).

Science Background

- **Traits** refer to the features and characteristics of a living thing.

- Offspring inherit traits from their parents and ancestors.
- A **phenotype** describes the characteristics of a trait. It is the physical manifestation of the genotype (+environmental factors).

Observing & Supporting Learning

- Students might notice that their phenotypes aren't represented by the 3D-printed traits available e.g. "But I have grey eyes!". This is OK; many of the so-called simple traits are more complicated than first thought and often involve more than one gene. This doesn't mean that single genes cannot have a significant effect. For instance, the difference between light (blue-green) and dark (brown) eyes is largely controlled by one gene, even if there is a whole spectrum of eye colours.
- It is not uncommon for students to make super-weird aliens. This can be used as a teaching moment e.g. "Is your alien a different species to others? How will its traits be inherited?" In the end, all the Alien Babies should follow the same body plan, differing only in their phenotypes.

Activity 2: Genotype, Phenotype

Students will now learn that phenotypic variation is often a result of genetic variation.

For each trait, ask students to select the card that *best represents* the phenotype they observe in their Alien Baby. When they are done, there should be 5 trait cards laid out in a row - one for each phenotype.

Discuss the information presented. The students may comment on the following:

- There is one 'dominant' and one 'recessive' variant for each trait.
- Dominant variants are associated with upper case letters and recessive variants are associated with lower case letters.
- Dominant and recessive variants produce differing phenotypes.
- Differences in a single nucleotide can be sufficient to change a phenotype
- Variants that affect phenotypes are sometimes inside genes, but they don't have to be.
- All these variants occur on autosomal chromosomes (1-22), not sex chromosomes (X,Y).
- Gene descriptions offer clues as to *how* a gene product might generate a phenotype.

Science Background

- Traits can be influenced by small differences between otherwise identical DNA sequences called **variants**.
- Variants that occur in the same gene are also referred to as **alleles**.

Observing & Supporting Learning

- There's quite a lot on these cards, particularly on the side containing information about the gene. Ask students lots of *how* questions e.g. "How do you think having a 'G' vs. 'A' variant could result in blue vs. brown eyes?", "How do you think melanin could affect eye colour & hair colour?"
- The chromosome picture also hides some information. The horizontal line shows whether the variant lies inside or outside the associated gene (cross-hatched pattern). "How can a difference outside of a gene result in phenotypic change?".

Activity 3: These Aliens ain't Haploid!

Genes (nearly) always come in pairs. This means that behind every phenotype there are at least 2 variants, one from each parent.

This is where it's important to understand the idea of dominance. If there is no difference between variants, then dominance is not an issue. Dominance relationships only become apparent when multiple variants exist within the same individual.

Dominant variants always produce phenotypes that mask recessive variants. There are various ways that this can occur. Let's look at an example: eye colour.

Ask students to make an educated guess as to which trait card they need to make a pair. Have them place it on the table. Typically:

- A recessive trait will always pair with a recessive trait
- A dominant trait can pair with a dominant or recessive trait in most cases, without altering the phenotype. This is **complete dominance.**
- The one exception is the hair colour trait, where the brown hair phenotype results from one dominant and one recessive copy. This is **incomplete dominance.**

Science Background

- A **genotype** refers to the sum total of variants within an individual.
- Where several variants combine to make up a genotype (e.g in a **heterozygous** organism), they can interact with one another in interesting ways to produce a phenotype. These interactions are called dominance relationships and there are a number of types, e.g:
    - **Complete dominance** is a relationship between variants in which the dominant variant completely masks the effect of the recessive variant in a heterozygous organism

- ○ **Incomplete dominance** is a relationship between variants in which the heterozygous phenotype is intermediate to the corresponding homozygous phenotypes.

Observing & Supporting Learning

- It's not always easy to determine genotype from phenotype, especially when one variant has complete dominance over another. Students catch onto this pretty fast. For the purposes of the activity, let them choose whether they want their Alien Baby to be homozygous or heterozygous.

Activity 4: The Next Generation

Now that we know the genotype of the parents, we can make a new Alien Baby.

Take the trait cards that represent your Alien Baby and put them in a container so that the students cannot see the cards. This randomizes things and represents **Mendel's Law of Independent Assortment**. Next, find another student pair to work with. Take turns drawing trait cards and placing them letter-side up in front of you. Each parent can only contribute one card per trait, so discard any duplicates. This represents **Mendel's Law of Segregation**. The result should be a row of 5 paired trait cards. This is the genotype of your new Alien Baby.

Using their knowledge of dominance relationships, students should be able to describe the phenotype of their new Alien offspring. If there are enough 3D-printed pieces and time, encourage them to make it.

Science Background

- Somatic cells are usually diploid; they have two copies of each gene. During meiosis, sister chromatids separate and each resulting gamete is left with only one copy of each allele. The alleles are forever 'segregated' from one another, allowing for completely new combinations to form during fertilization. This is **Mendel's Law of Segregation**.
- **Mendel's Law of Independent Assortment**. Mendel thought that all genes were inherited independently of each other. He was partially right, but we now know that genes are organized on chromosomes and that genes in close proximity are often inherited together.

Observing & Supporting Learning

- If students are struggling with the *why* of this activity, this is a good time for a refresher on meiosis. Take 2 strips of paper and lay the trait cards on top. These are your

homologous chromosomes. Describe meiosis as you
move them apart. The end result are the gametes, both of which get thrown in the randomization bag.

Activity 5: Punnett Squares

Students will now use the Alien Babies they have made to understand how traits are inherited in the next generation. A Punnett Square is a tool that illustrates the statistical probabilities of genotype combinations that result from mixing two parental genotypes together.

Organize the trait cards so that the upper and lower case letters are facing up. Get students to pick a phenotype on their Alien Baby for which they know the genotype (e.g. dry ear wax = ww). If genotype is unclear (e.g. wet ear wax = WW or Ww), just let them choose. Arrange trait cards on a sheet of paper, as shown in Figure X. Have students complete the table by filling in all possible genotypes. Calculate the probability of each phenotype appearing in the next generation.

Science Background

- **Punnett Squares** are a useful tool for visualizing the possible offspring genotypes that result from blending the genotypes of two parents, as determined by Mendelian inheritance rules. They can also be used to determine the probability of seeing a particular phenotype.

Observing & Supporting Learning

- Once students have completed the table, ask them if the Alien Baby they created in Activity 4 contained the most likely traits, or if there were some surprises along the way
- If they find it easy to do one trait at a time, challenge them to predict the probabilities of variant/allele combinations in a dihybrid cross (4 * 4 table)

Questions for deeper understanding

- Do all genes control single characteristics? No - example is melanin, which controls both hair, eye and skin colour (see: pleiotropy)
- Can all phenotypes be grouped into discrete types? No - we've already seen this with eye and hair colour. Height is the classic example (also see: continuous variation, polygenic inheritance, environmental effects, variable expressivity, incomplete penetrance)

Learning Extensions

Resource	Good for...
Pigeonetics (Utah U)	Taking the Alien Babies activity into the real world. Download the worksheet and head outside to ID the phenotypic traits of the humble pigeon. Well backed up with a teacher guide, a whole bunch of extension resources and an excellent digital interactive (that isn't currently working).
Teaching Genetics with Dragons (Concord)	Targeted at middle through high school students, these web-based applications use dragon breeding as a premise to teach meiosis and heredity. There are 3 options for teachers that want to spend 3 days, 2 or 4 weeks on a genetics unit. It's like Alien Babies, only in the cloud.
Game of Thrones family trees (HBO)	If teachers want to take the famous family cards to the next level, this is a useful online resource for figuring out the family trees present in Game of Thrones.
23&Me Case Studies (In Development)	Each of the Alien Babies traits was picked because 23&Me provides a detailed report on that trait. They offer clear, concise and scientifically verified information on individual traits and their geographical distribution. Useful for homework assignments and project-based work.
Trait BC (Idea)	This simple web app lets students upload their Alien Baby's phenotype, where it's then mapped onto BC and used as a tool to explore the geographical distribution of different traits. Part Citizen Science, part blurring lines between genetics and social sciences. This can also be done at the classroom level with a simple trait frequency graph.