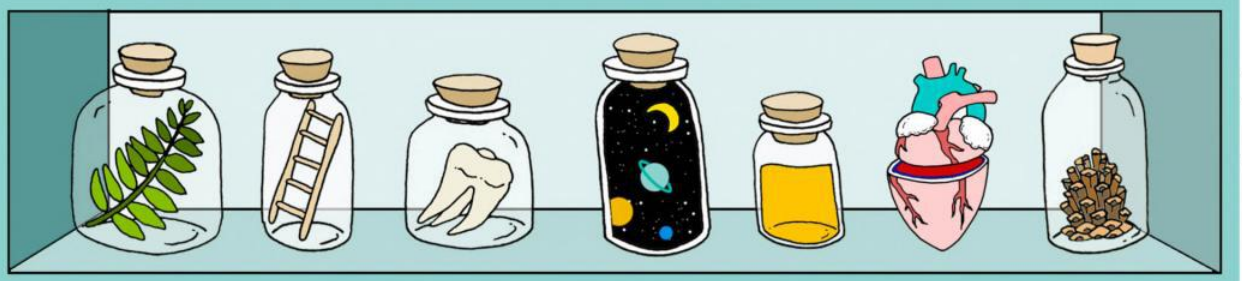
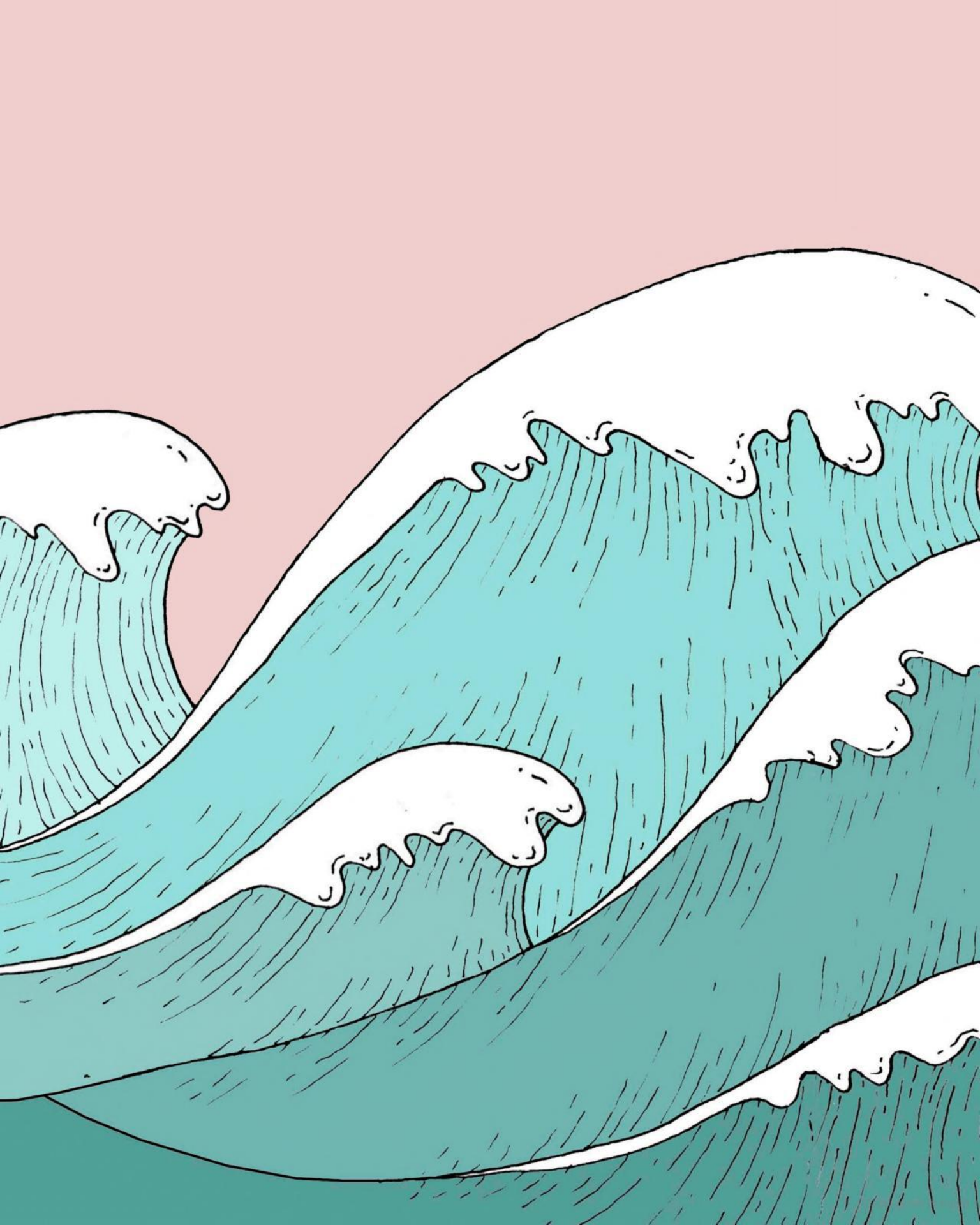
SEEING SCIENCE

AN ILLUSTRATED GUIDE TO THE WONDERS OF THE UNIVERSE



BY IRIS GOTTLIEB



SEEING SCIENCE

AN ILLUSTRATED GUIDE TO THE WONDERS OF THE UNIVERSE

BY IRIS GOTTLIEB

CHRONICLE BOOKS
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FOR ALL THOSE WHO ARE CURIOUS—AND, OF COURSE, TO BUNNY THE DOG

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Introduction

BY IRIS GOTTLIEB

The bowerbird inspired *Seeing Science*. Nature's ultimate collector, the male bowerbird is a masterful architect of color-coordinated, sculptural nests comprised of sticks as well as collected man-made or natural objects, often all in the same color palette. Like the bowerbird building his nest, I collected snippets and specimens from across the scientific universe to make this book.

I have been investigating and documenting the natural world since I was a child. Introverted around humans, I befriended all sorts of creatures: mole crabs at the beach, a six-foot-tall plant named Bill the Weed, worms and fireflies in the backyard, a dead fish named Sleepy (who was already dead when we met), many identical gerbils over the years, and my current best friend, Bunny the Dog. This book allowed me to explore so many of the concepts I have been, to my family's loving irritation, asking forever. How many grains of sand are there on earth compared to stars in the universe? Why isn't all body hair the same length? Why is there high tide?

The scales of science are incomprehensibly vast, from quantum particles to the outer boundaries of the universe, and most of it is hard to actually see or touch. I have learned about the scientific world through drawing. Being able to *see* what's in front of me and translate it into digestible visual information allows me to grasp infinite, abstract ideas or microscopic interactions. Bringing these inaccessible systems to the human scale in a universal visual language makes the information easier to understand and beautiful to behold.

I am writing this book from a non-academically trained science perspective. Scientific truth is truly stranger than fiction, and it deserves to be explored, understood, and appreciated by us all, regardless of our formal education. I want to open up the world of complex science with art and metaphor and storytelling. It is my hope that this book makes science more accessible, less intimidating, and more magical to anyone who has a sense of wonder—and a sense of humor.

Life Science

The study of living organisms, including determining what is living, and life processes

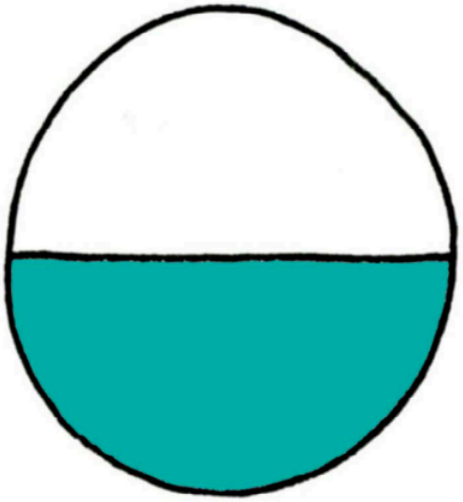
Anatomy
Biology
Botany
Ecology
Genetics
Microbiology
Neuroscience
Zoology

What Is Alive?

The seven criteria of living beings

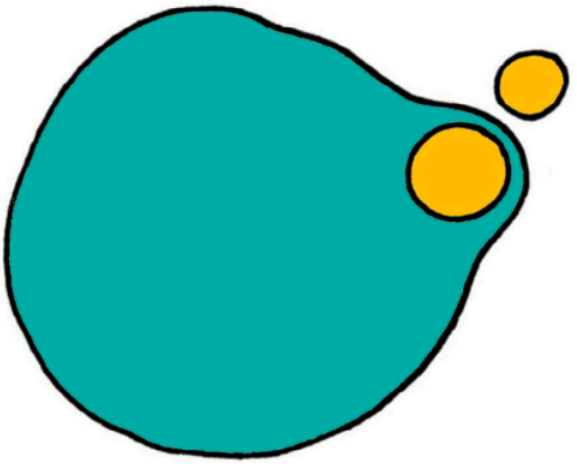
Homeostasis

THE ABILITY TO REGULATE AND MAINTAIN INTERNAL STATE



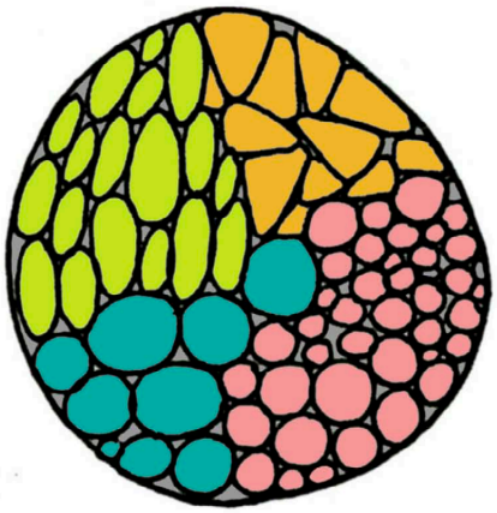
Metabolism

THE ABILITY TO TRANSFORM EXTERNAL ENERGY INTO INTERNAL ENERGY AND WASTE



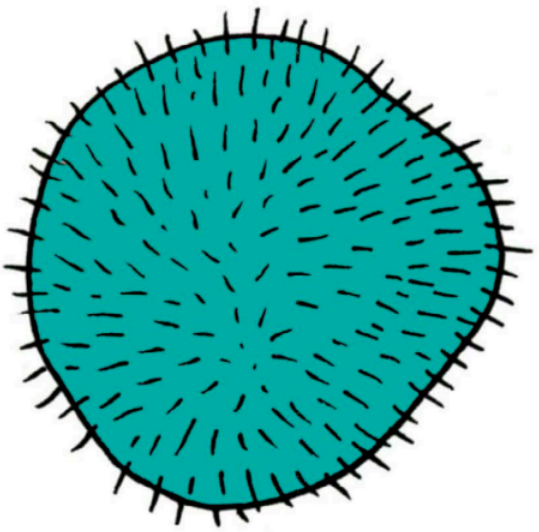
Organization

COMPOSED OF ONE OR MORE TYPE OF CELL



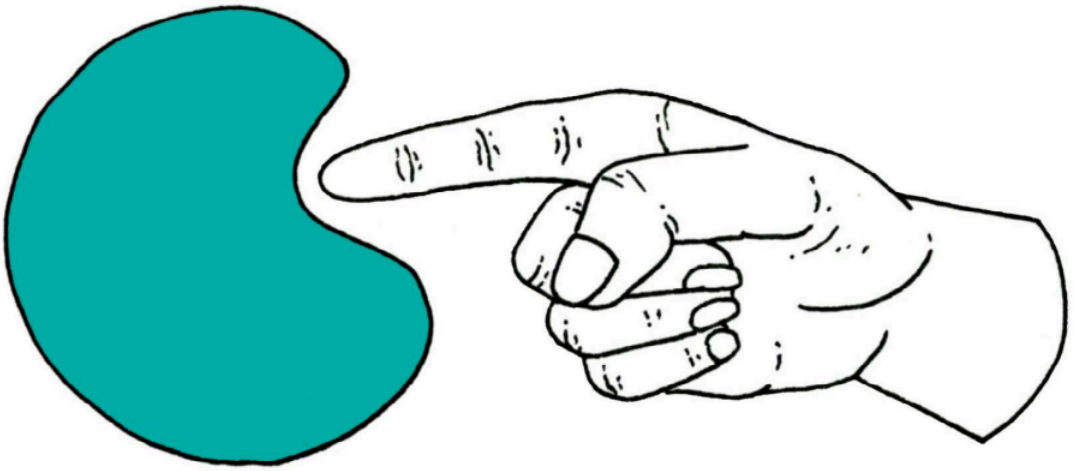
Adaptation

THE ABILITY TO CHANGE OVER TIME IN RESPONSE TO THE ENVIRONMENT



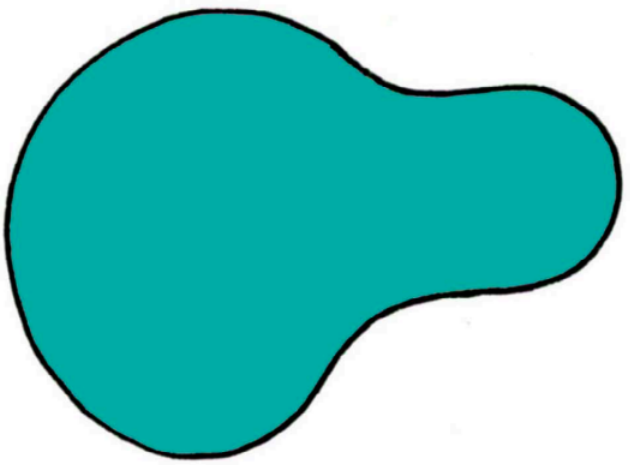
Response to stimuli

THE ABILITY TO REACT TO EXTERNAL STIMULI, OFTEN INFORMED BY SENSORY ORGANS



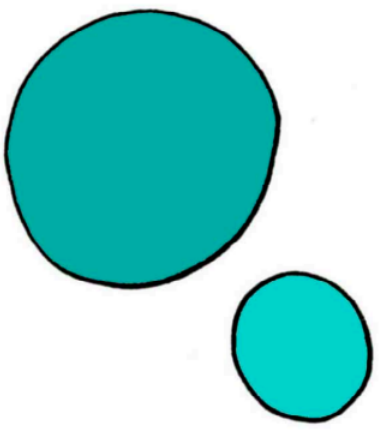
Growth

THE PROCESS OF INCREASING IN SIZE OVER TIME



Reproduction

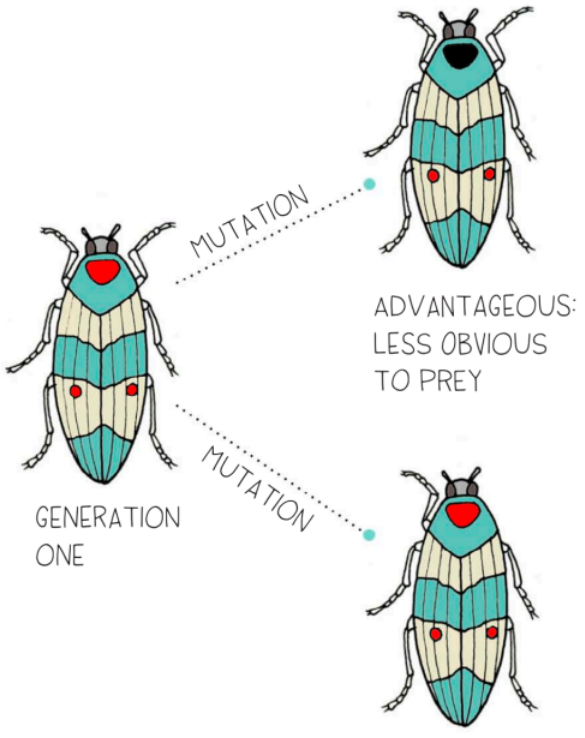
THE ABILITY TO PRODUCE OFFSPRING VIA SEXUAL OR ASEXUAL REPRODUCTION



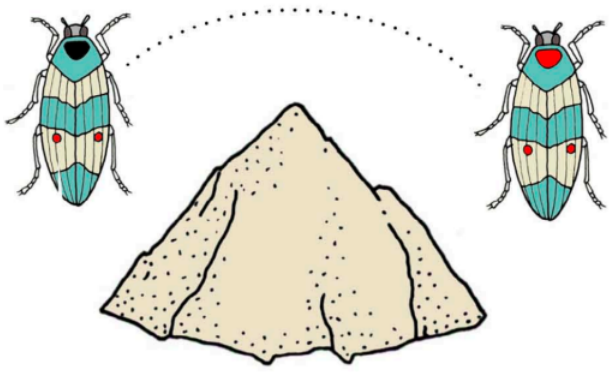
Evolution Pt. I

EVOLUTION IS THE PROCESS OF DEVELOPMENT AND DIVERSIFICATION OF LIVING ORGANISMS OVER TIME THROUGH THE MECHANISMS OF MUTATION, MIGRATION (OR GENE FLOW), GENETIC DRIFT, AND NATURAL SELECTION. THESE PROCESSES ALL RESULT IN GENETIC SHIFTS, WHICH IS THE BASIS OF EVOLUTIONARY CHANGE.

1. Mutation: RANDOM, UNBIASED CHANGES IN DNA. CAN BE CAUSED BY IMPERFECT COPYING OF DNA DURING CELL DIVISION OR BY CHEMICAL EXPOSURE OR OUTSIDE FORCES LIKE RADIATION



2. Migration: WHEN GENETIC DIVERSITY IS BROUGHT TO NEW PLACES OR POPULATIONS. IF FOOD IS SCARCE AND A POPULATION RELOCATES AND MATES WITH INDIVIDUALS IN THE NEW LOCATION OR POLLEN IS BLOWN BY THE WIND TO A NEW FIELD



3. Genetic drift: CHANGES THAT ARE PURELY BY CHANCE AND NOT FAVORING GENES THAT ARE MORE ADVANTAGEOUS FOR SURVIVAL. A WEATHER EVENT, ACCIDENT, OR HUMAN-CAUSED DEATH (NON-NATURAL PREDATOR) OF CERTAIN INDIVIDUALS THAT DOES NOT REFLECT THEIR GENETIC STRENGTHS OR WEAKNESSES AS INDICATORS

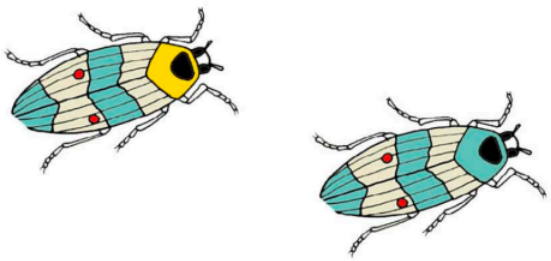
A WORD ABOUT NATURAL SELECTION BEFORE COVERING IT IN ITS ABBREVIATED ENTIRETY. WE HUMANS HAVE A LONG HISTORY OF USING EVOLUTION AS AN ARGUMENT TO PERPETRATE JUDGMENT, HATE, AND VIOLENCE UPON OTHER HUMANS AS WELL AS THE NATURAL WORLD. "SURVIVAL OF THE FITTEST" HAS TURNED INTO A PHRASE USED TO DISCRIMINATE.

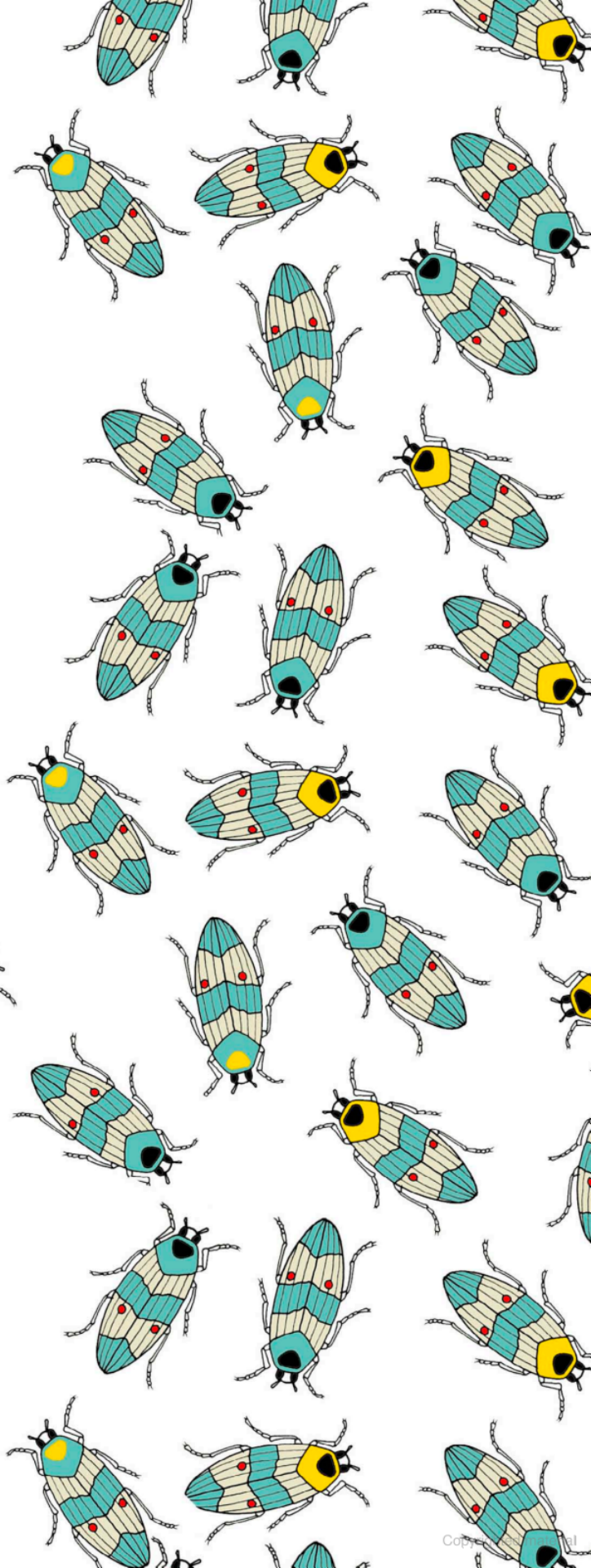
NATURAL SELECTION AND ALL OTHER MECHANISMS OF EVOLUTION FUNCTION WITHOUT A PLAN OR END GOAL OTHER THAN SURVIVAL OF SPECIES OVERTIME. EVOLUTION ITSELF DOES NOT HAVE A BIASED STAKE IN WHO EVOLVES AND WHO BECOMES EXTINCT.

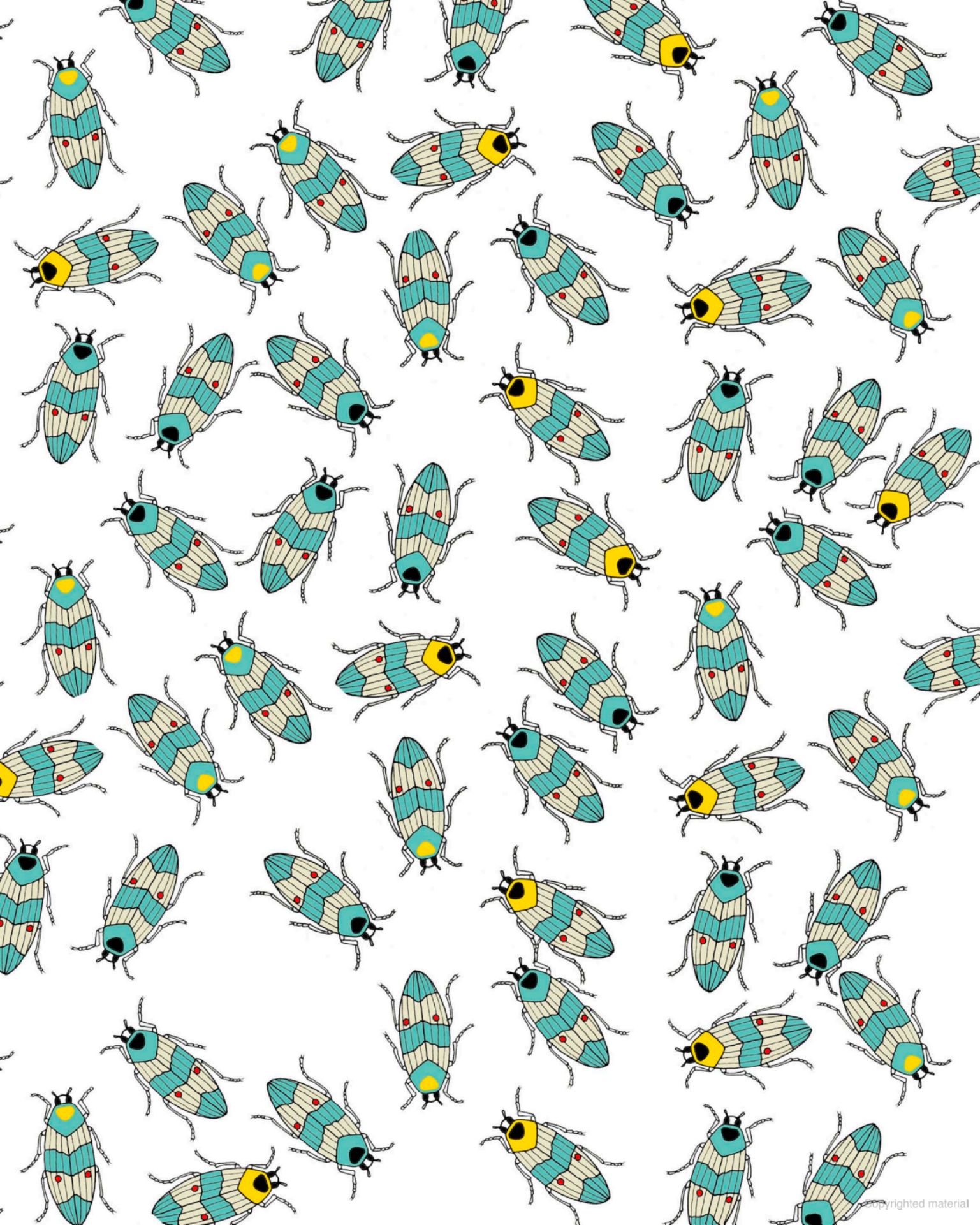
FITTEST DOES NOT REFER TO OUR SOCIETAL NOTION OF FIT. IT IS NOT DESCRIBING ONE'S STRENGTH OR SPEED OR INTELLECT. RATHER, IT REFERS TO THE ABILITY OF GENES TO SURVIVE AND ADAPT IN OFFSPRING. NATURAL SELECTION IS SIMPLY DESCRIBING A PROCESS OF CHANGE OVER TIME.

Evolution Pt. II
Natural selection

4. Natural selection: THE MOST WIDELY KNOWN METHOD OF EVOLUTION, NATURAL SELECTION IS RESPONSIBLE FOR MUCH OF THE LARGEST PATTERNS AND TRENDS OF THE EARTH'S ORGANISMS OVER THE PAST 3.8 BILLION YEARS SINCE THE FIRST SINGLE-CELL LIFE APPEARED.



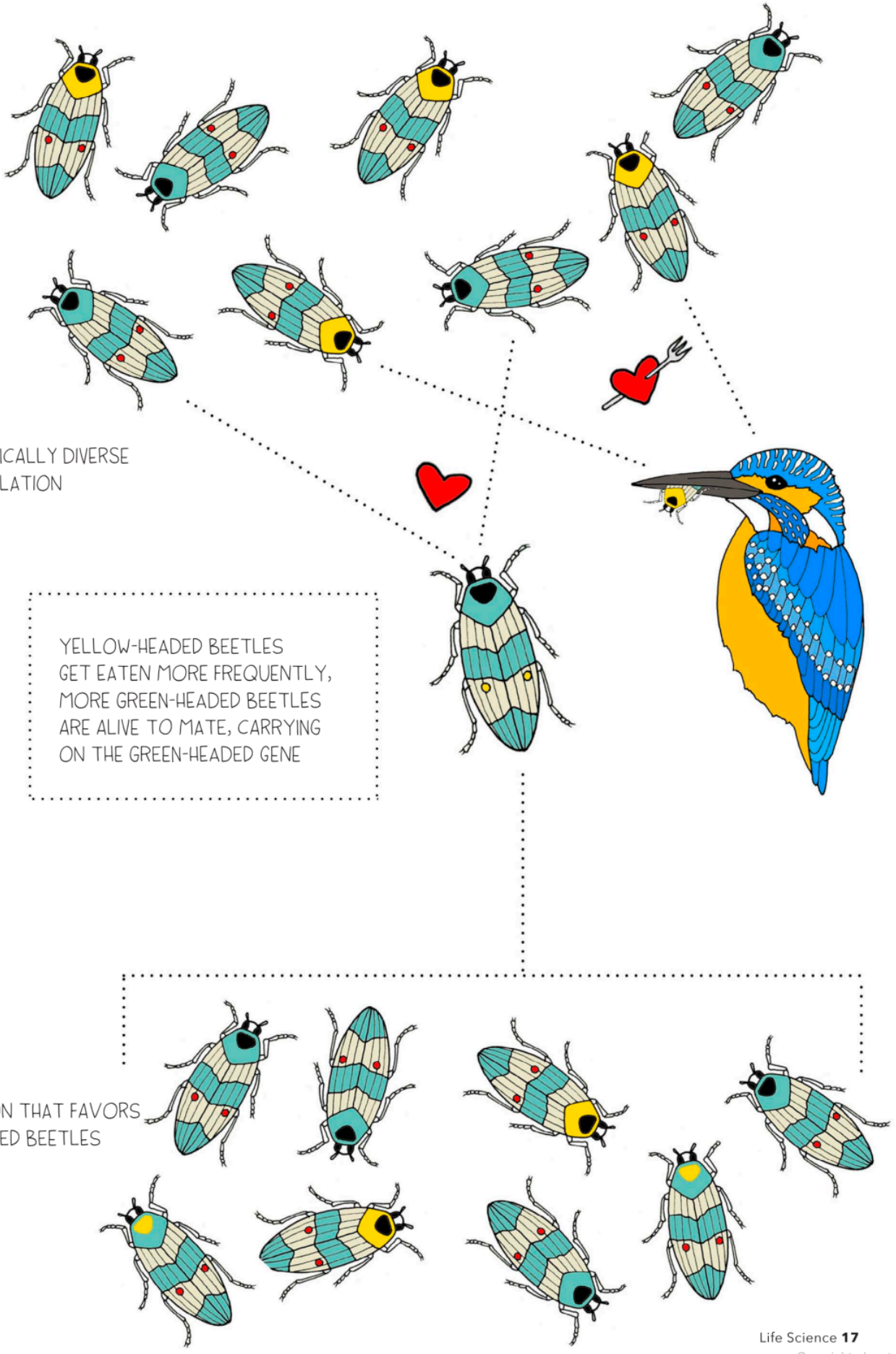




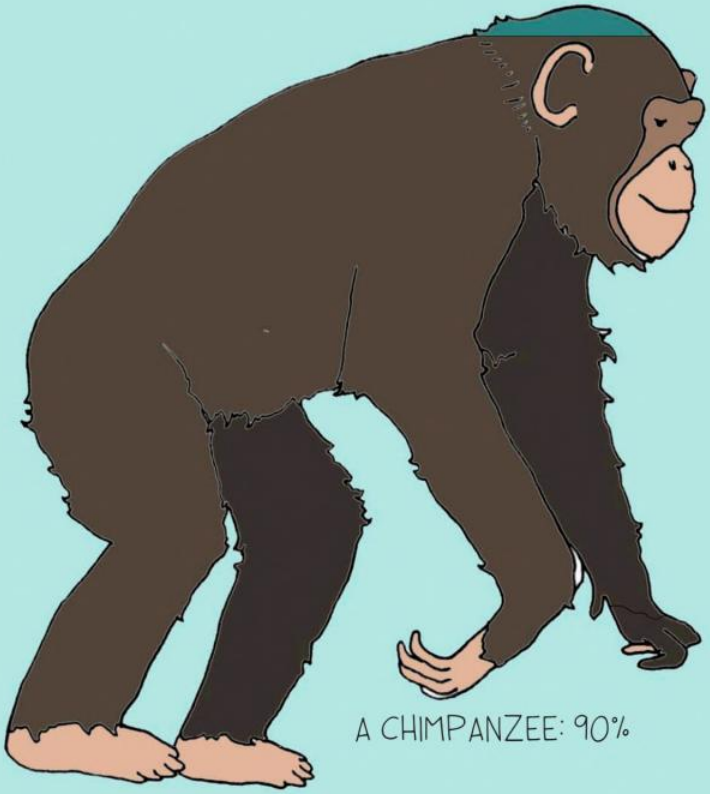
Evolution Pt. III
Natural selection

NATURAL SELECTION REQUIRES AN INITIAL CONDITION OF GENETIC DIVERSITY OR TRAIT VARIATION (SOME BEETLES IN THE POPULATION HAVE A YELLOW HEAD AND SOME HAVE A GREEN HEAD), DIFFERENTIAL REPRODUCTION (NOT ALL INDIVIDUALS CAN PERFECTLY REPRODUCE UNLIMITEDLY—THE YELLOW-HEADED BEETLE MAY BE MORE LIKELY TO BE EATEN BY BIRDS BECAUSE IT IS MORE CONSPICUOUSLY COLORED), AND, FINALLY, THAT TRAITS ARE PASSED ON TO THE NEXT GENERATION (THE YELLOW-HEADED BEETLE IS LESS LIKELY TO SURVIVE TO PASS ALONG THAT COLORATION TRAIT, AND THEREFORE IT BECOMES LESS COMMON IN THE GENE POOL AND EVENTUALLY DISAPPEARS).

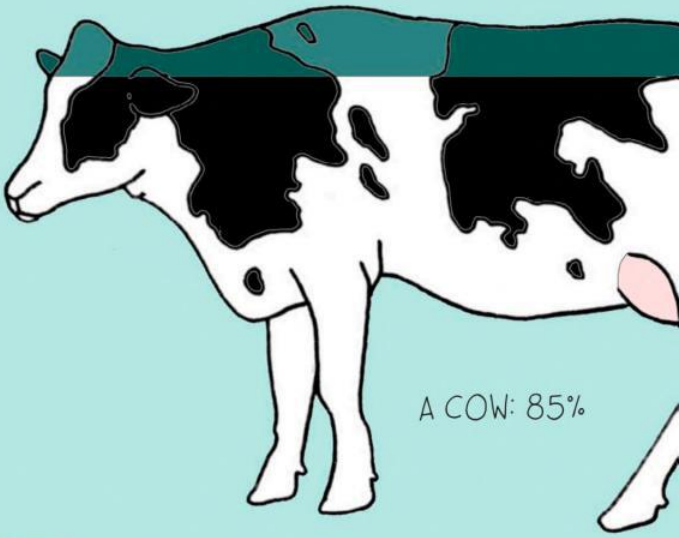
IN THIS EXAMPLE, BECAUSE THE BRIGHTNESS OF THE YELLOW-HEADED BEETLE ATTRACTS PREDATORS MORE OFTEN, IT IS GENETICALLY ADVANTAGEOUS FOR THE OFFSPRING OF THIS POPULATION TO HAVE FEWER YELLOW-HEADED GENES IN THE POOL FOR A GREATER CHANCE AT SURVIVAL. IN THEORY THIS CONCEPT IS RELATIVELY SIMPLE; HOWEVER, IN THE REAL WORLD, THERE ARE MANY FACTORS THAT COMPLICATE THE PROCESS, SUCH AS MAN-MADE ENVIRONMENTAL CHANGES, LEARNED BEHAVIOR, AND SEXUAL SELECTION. SEXUAL SELECTION IS TRICKY IN THAT IT RELIES UPON BEHAVIOR AND TERRITORY NOT NECESSARILY GENETICS THAT WOULD BE MOST FAVORABLE TO THE SURVIVAL OF THE SPECIES. THE YELLOW-HEADED BEETLE THAT IS SO FLASHY MIGHT ATTRACT MORE MATES BUT ALSO MORE PREDATORS IN THE PROCESS.



How Genetically Similar Are You To ...

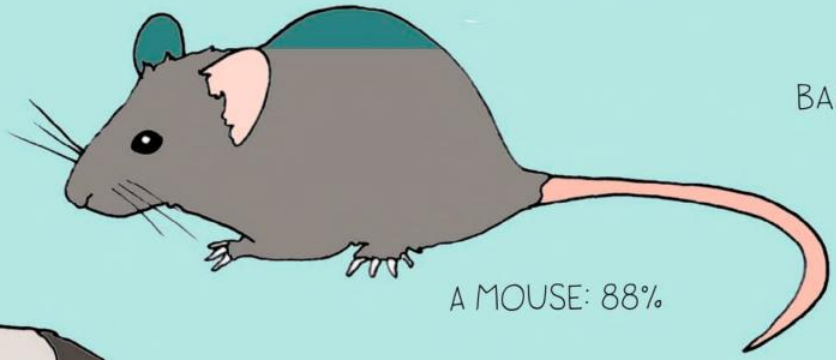


A CHIMPANZEE: 90%

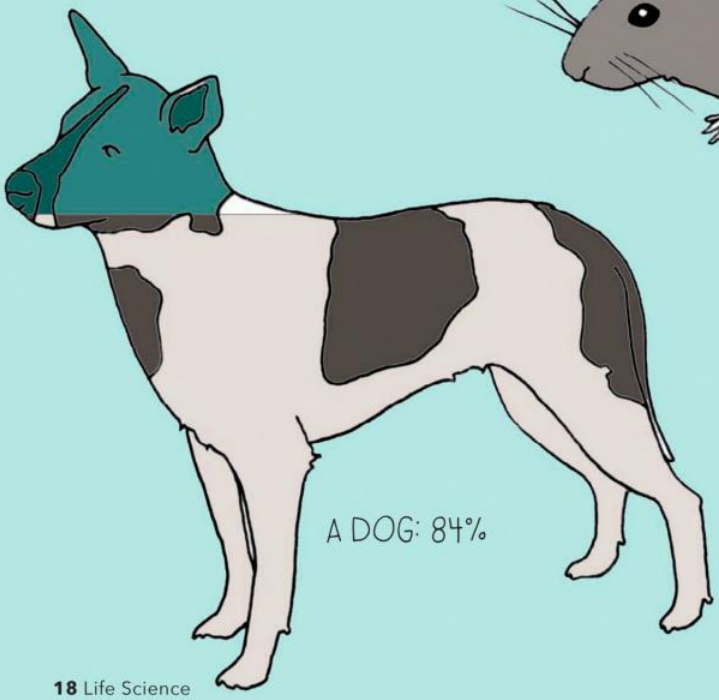


A COW: 85%

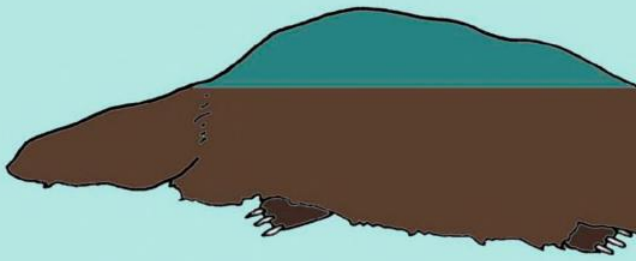
BAKER'S YEAS



A MOUSE: 88%

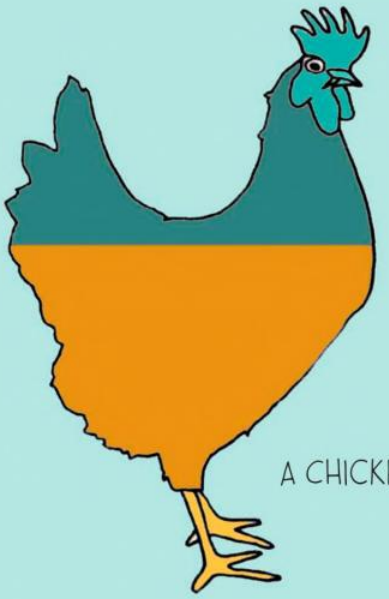


A DOG: 84%



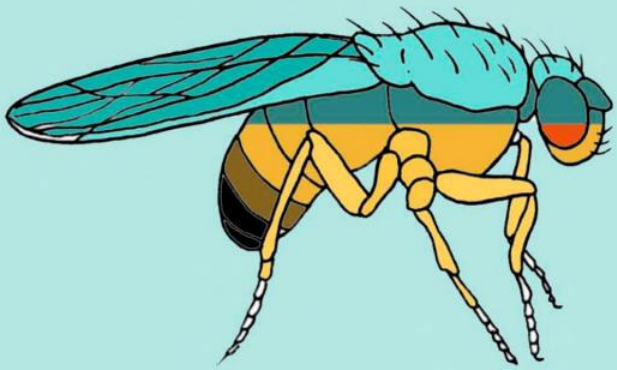
A PLATYPUS: 69%

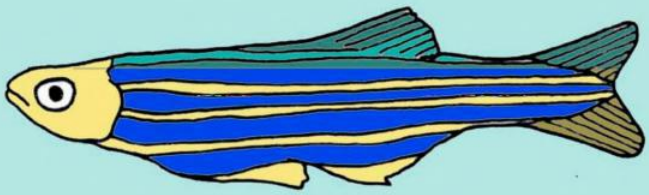
T: 18%



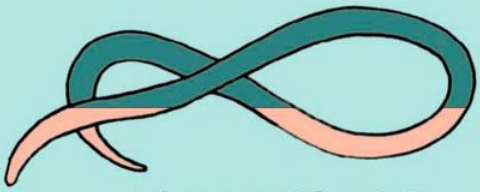
A CHICKEN: 65%

A FRUIT FLY: 47%



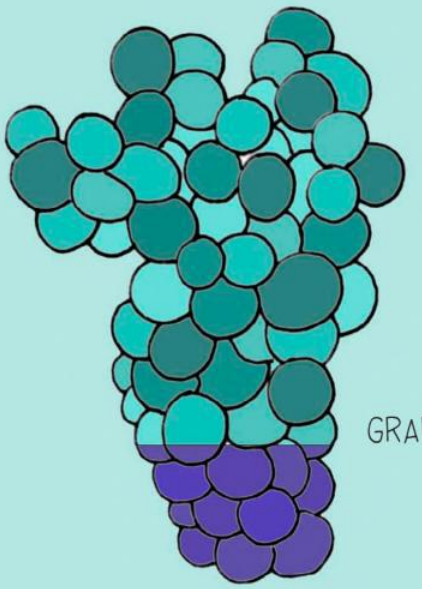


A ZEBRA FISH: 73%



A ROUNDWORM: 38%

A HONEYBEE: 44%



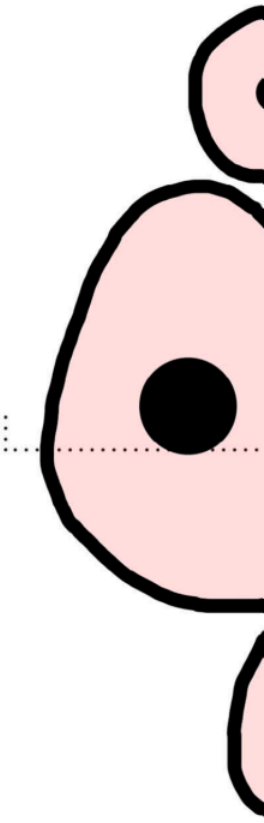
GRAPES: 24%

Sperm & Egg

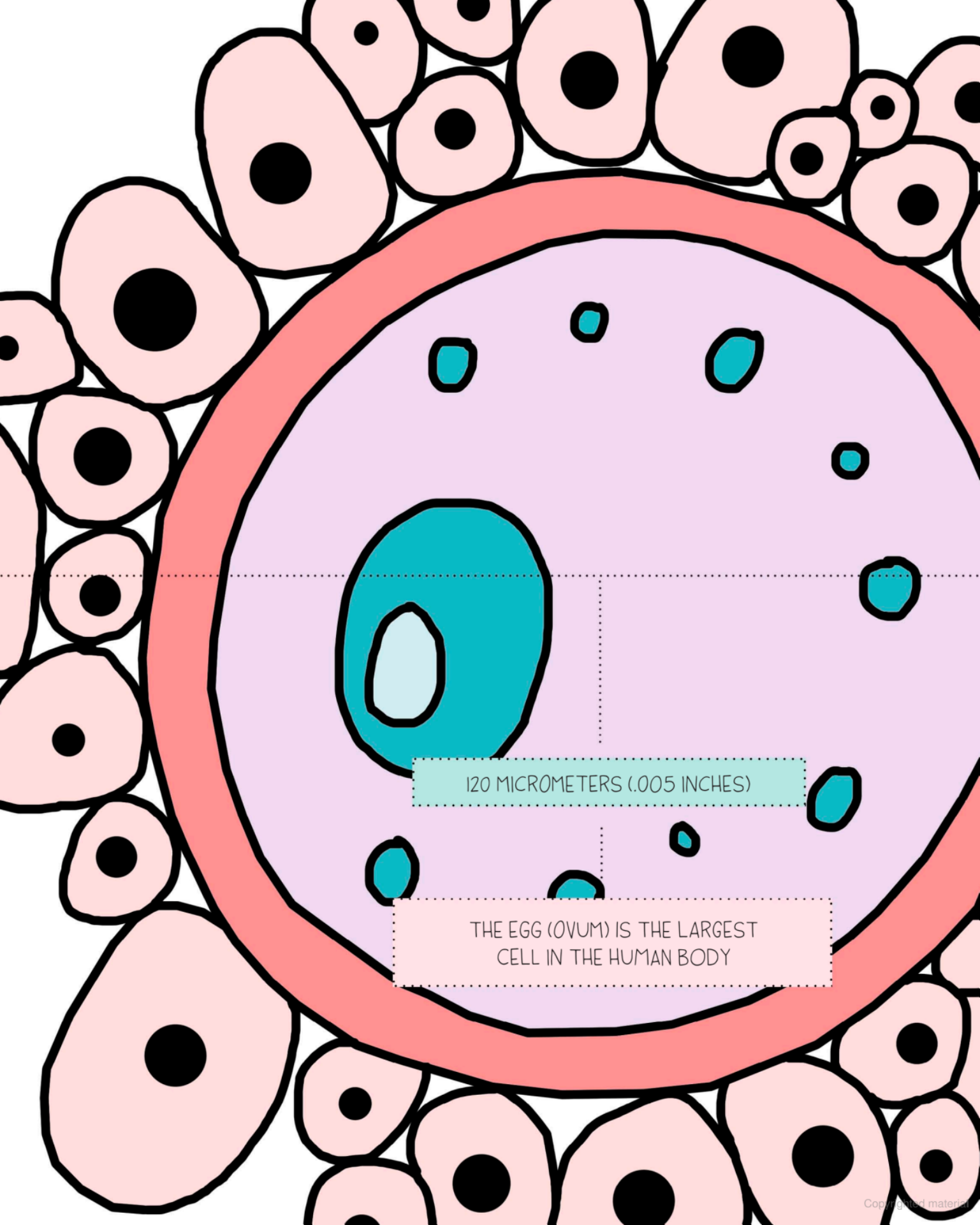
Author **firmly** believes that the egg came before the chicken

50 MICROMETERS (.002 INCHES)

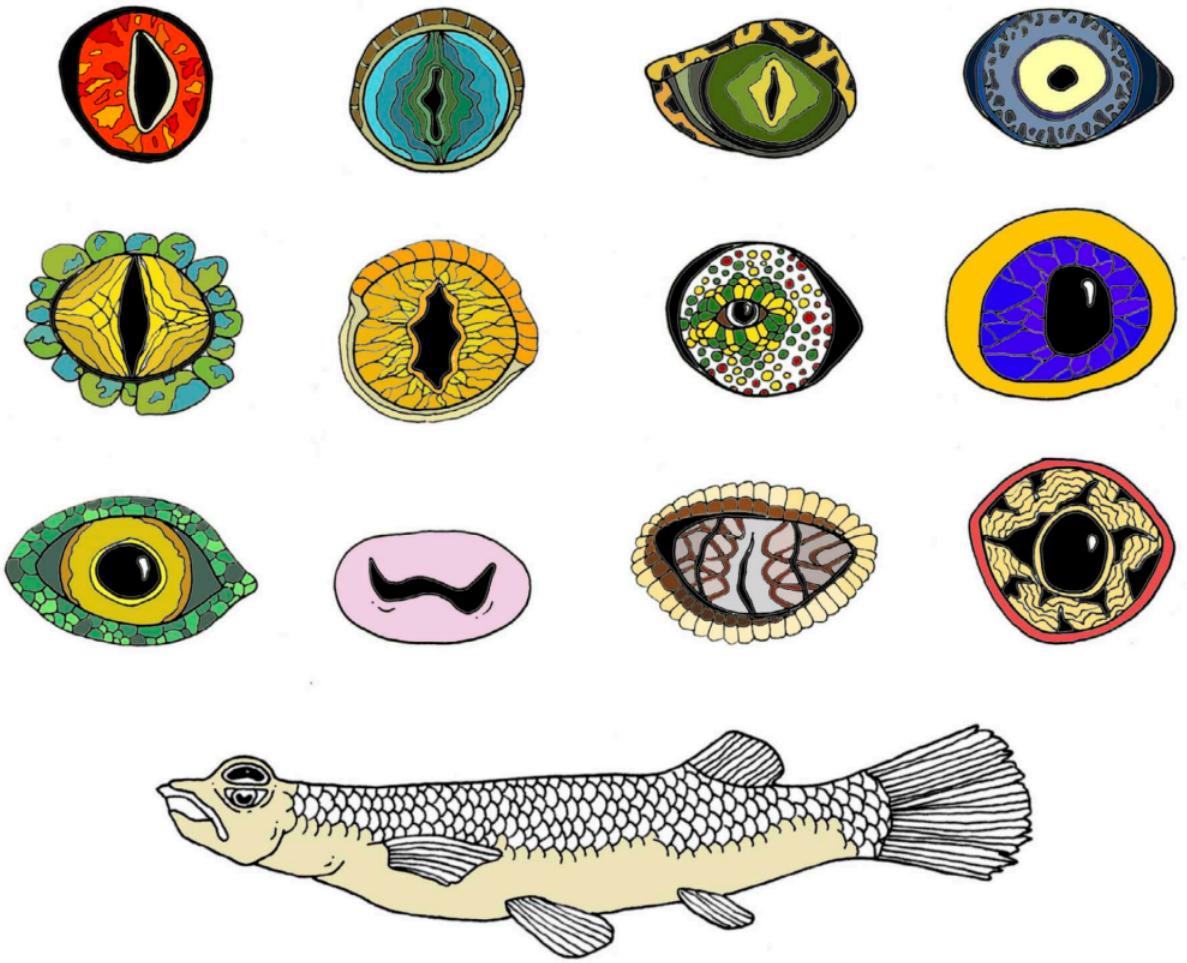
SPERM IS THE SMALLEST CELL IN THE HUMAN BODY



*NOT DRAWN TO SCALE



Eyes
Are in the head of the beholder



THE FOUR-EYED FISH HAVE DIVIDED EYES WITH TWO PUPILS TO SEE ABOVE AND BELOW THE WATER. THE LENS CHANGES IN THICKNESS TO ACCOUNT FOR THE DIFFERENCE IN REFRACTION OF AIR AND WATER.

ANIMALS ONLY HAVE THE LEVEL OF EYE DEVELOPMENT THAT THEY NEED. IF A SPECIES' SURROUNDINGS CHANGE TO REQUIRE A LESS COMPLEX VISION (CAVE DWELLERS), THEIR EYES WILL EVOLVE TO A LESS COMPLEX, ENERGY-CONSUMPTIVE STRUCTURE.