

to lose a tooth

.....
An Evolutionary Board Game



NCSE National Center for
Science Education



Hunter-Gatherer

All humans practiced hunting-gathering until about 12,000 years ago. Hunter-gatherer diets eat a variety of seasonally-available foods, including grasses, tubers, fruits, seeds, nuts, and small animals.

pros

- **Varied Diet = Strong immune system**
- **When successful, more leisure time than agricultural societies**

cons

- **Lack of choice in food sources**
- **Unreliable food sources**
- **Smaller population sizes**





Agriculturalist

About 10,000 years ago some groups of humans started establishing permanent residences and tending to crops. Agriculturalist societies could support higher populations because of increased and stable food supply.

pros

- Larger population size
- Diversification of labor

cons

- Lack of dietary diversity
- Famine risk higher
- Sanitation problems from permanent residences





Pastoralist

Pastoralists organize life around herding domesticated livestock. The species of animals vary with the region of the world, but they are all domesticated herbivores.

pros

- Works in dryer environments than agriculture
- Lower risk of drought
- Landscape is less impacted than it is in agricultural society

cons

- Large amount of land required
- Supports a smaller population than agriculturalists





Industrialist

The Industrial Revolution occurred in the 18th century when agricultural and handicraft economies shifted rapidly to industrial and machine-manufacturing-dominated ones. Factories and machines began to produce items faster and cheaper than could be made by hand.

pros

- Less seasonality of food
- Longer food storage
- Less labor per calorie
- Large population size

cons

- Sanitation
- Loss of food nutrition
- Growing economic disparity



impaction

what is it?

An impacted tooth is a tooth that, for some reason, has been blocked from breaking through the gum.

causes

A tooth can become impacted for many reasons, typically when there is not enough space in your mouth.

symptoms & complications

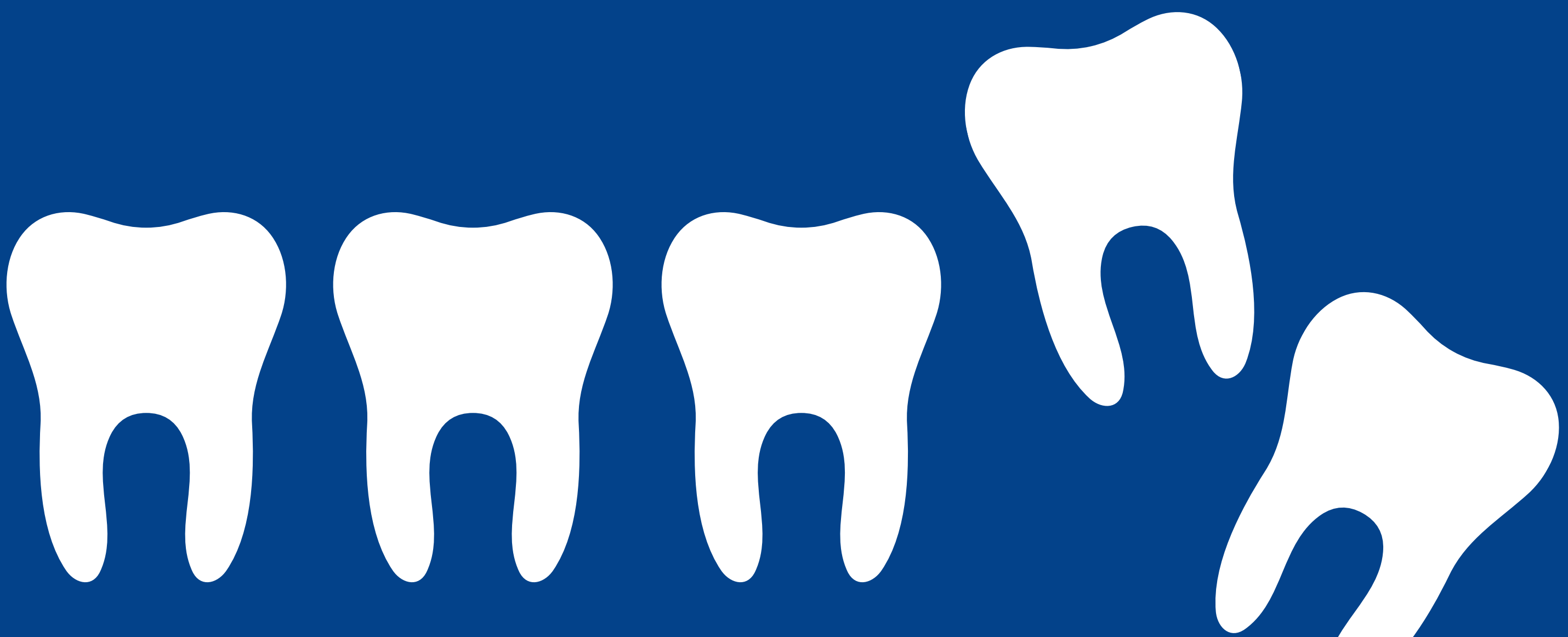
Symptoms

- Swollen or bleeding gums
- Bad breath
- Difficulty opening your mouth
- Pain

Complications

- Cavities
- Decay
- Infection
- Damage to roots of nearby teeth
- Gum disease

impaction



agenesis

what is it?

Tooth agenesis is a condition in which a tooth never forms. It is most common in the third molar and lateral incisors.

causes

Agenesis is heritable, but early childhood trauma can also be a factor.

symptoms & complications

- absence of a tooth or teeth
- if many teeth are missing, chewing may be more difficult
- dentures may be used for cosmetic and functional reasons

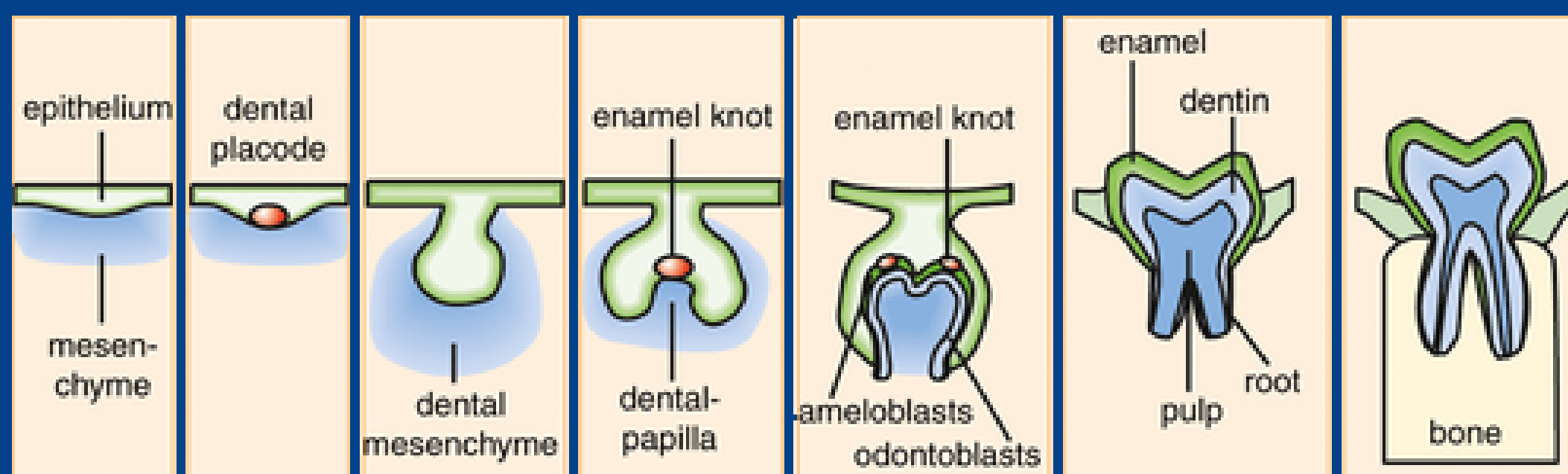
agenesis





genetics of tooth patterning

From your development as an embryo to losing your primary (baby) teeth for adult teeth, your body contains a genetic program that controls how your teeth develop.



Source: Thesleff 2013

1

Genes signaling pathways such as Wnt, SHH, BMP, and FGF control tooth development (Bei 2009)

2

The cells in your body respond to these gene signaling pathways, which can activate and/or inhibit cellular actions. (Salazar-Ciudad and Jernval 2002)

3

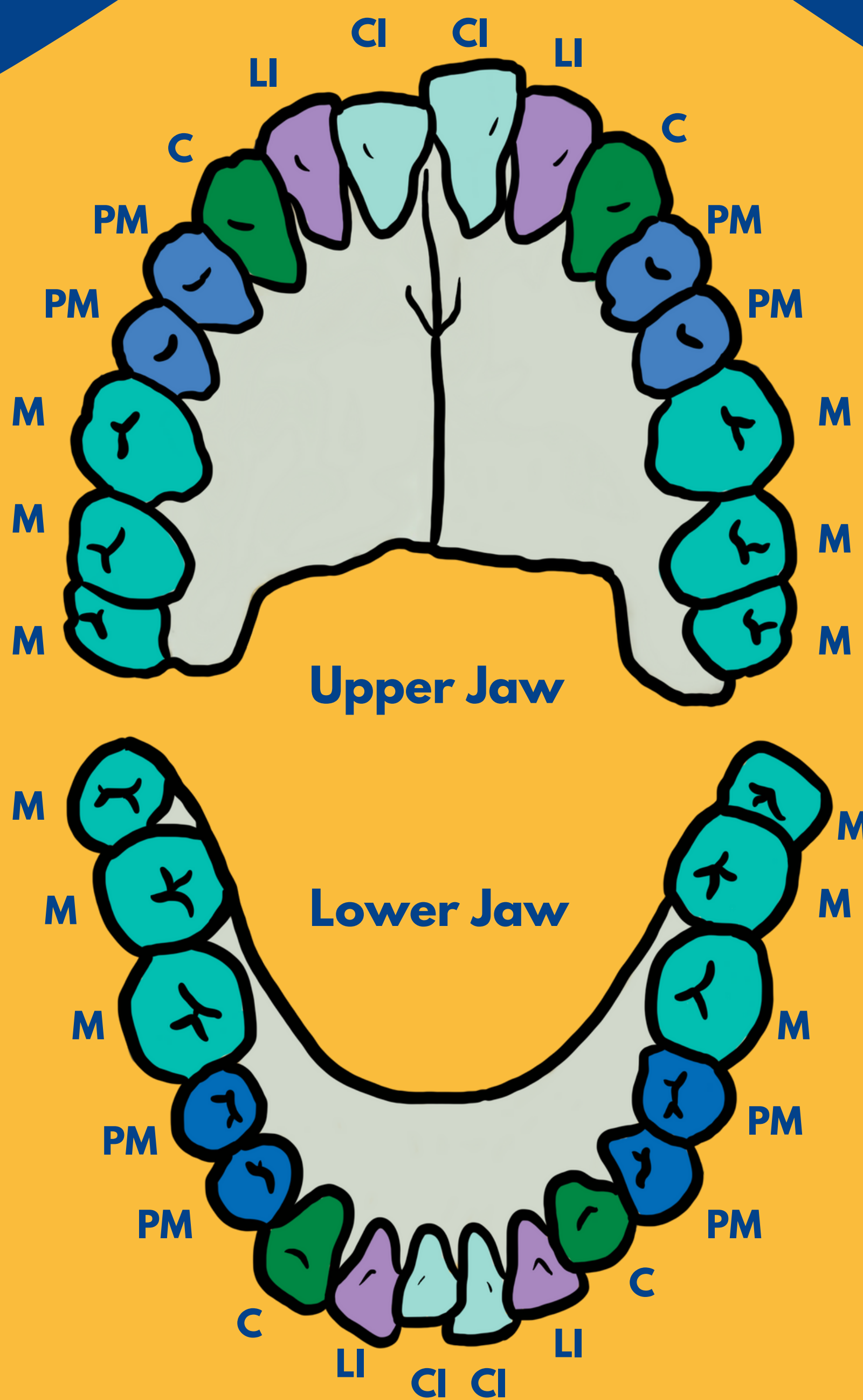
In the development of your teeth, some gene pathways are inhibitory and promote growth, while others are activatory and result in cellular differentiation. (Salazar-Ciudad and Jernval 2002)



Eventually, your body produces the teeth you have today through genetic regulation. These genes control how your teeth look and the order in which they develop!

dental anatomy

Human teeth change once in our lifetime; children have 20 teeth while adults have 32. Humans are heterodont, meaning we have teeth of different types. This includes incisors, canines, premolars and molars. Check out the graphic below to learn more about dental anatomy.



Key

- CI = Central incisor
- LI = Lateral incisor
- C = Canines
- PM = Premolars
- M = Molars

How many teeth do you see? Is this an adult or child?

Which tooth is the third molar?



over time, some groups of people learned how to farm



hunter-gatherers

Hunter-gatherer diets eat a variety of foods, including grasses, tubers, fruits, seeds, nuts, and small animals. Many populations got most of their dietary energy from animal fat and protein. Because carbohydrates are not abundant, less tooth decay is observed in prehistoric human hunter-gatherer remains.

About 10,000 years ago some groups of humans moved towards agriculture. This was not a universal change in human populations, and some contemporary groups remain hunter-gatherers.



agriculturalists

Agriculturalists grow crops for subsistence, including corn and wheat. By farming food, there was a more stable food supply. Human molars were important for grinding plant products during chewing, though these agriculturalist teeth showed different wear patterns than hunter-gatherers because the food was often ground or prepared before consumption (Smith 1984)



population dynamics

how have human choices affected the evolution of our teeth over time?

The Industrial Revolution of the 18th century brought rapid change to agricultural and livestock production. New technologies brought about mass production of food, however industrial processes can have harsh effects on the environment and other detrimental ecological and social effects.

In some geographical areas, domesticated herbivores can be more reliable food sources than crops. These animals provide both milk and meat, making pastoralism an advantageous subsistence practice for many.



industrialists

In an industrial society, large scale agriculture and livestock production are prevalent. Processed foods are commercially prepared for ease of consumption. Vitamins exist to supplement modern diets, alongside the field of dentistry to maintain dental health. Many of the foods eaten in industrial societies are 'soft' because they have been processed for consumption. Industrial diets create less wear on teeth and increased risk for cavities due to an abundance of carbohydrates in processed food.

pastoralists

Pastoralists organize life around herding domesticated livestock. Pastoralist diets include products such as milk and meat. In particular, milk can be available daily and supplies important nutrients such as calcium. Teeth from pastoralist communities generally show a lesser degree of wear, as they consume a less abrasive diet.

Print At Home Guide



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An Evolutionary Board Game



Young Learners Exploration Grid

Match jaws by color and pair teeth on the jaws to explore the societies. Print out 1 page for each young player.

Hunter-Gatherer



Agriculturalist



Pastoralist



Industrialist



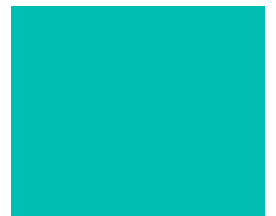
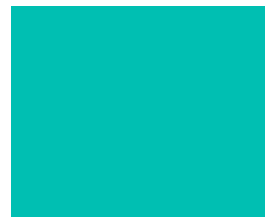
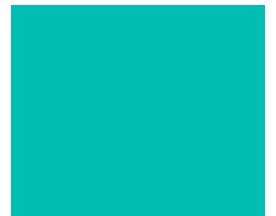
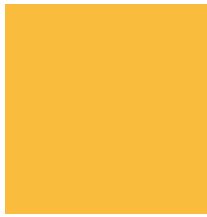
to lose
a tooth

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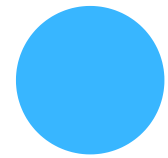
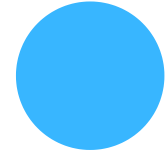
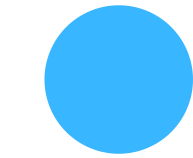
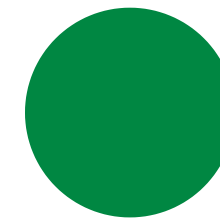
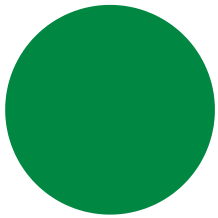
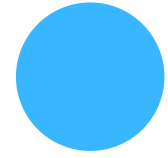
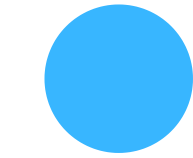
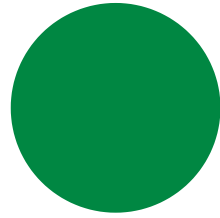
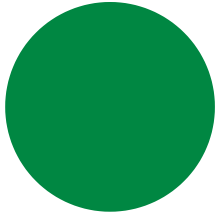
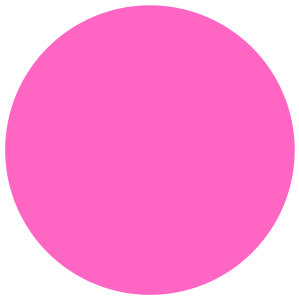
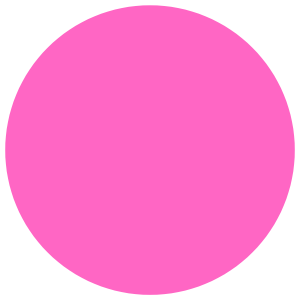
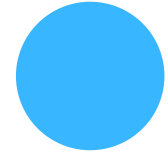
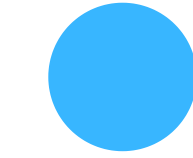
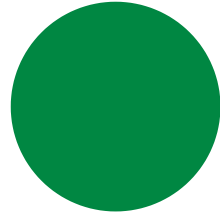
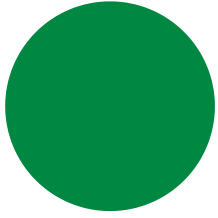
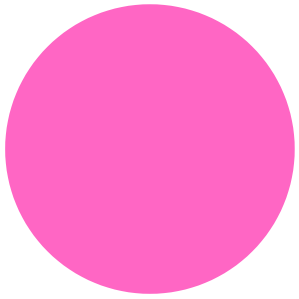
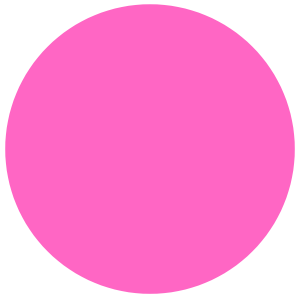
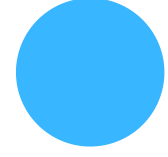
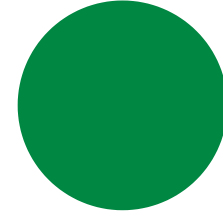
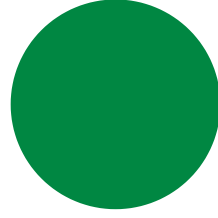
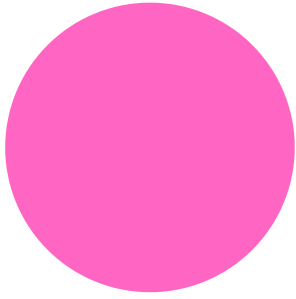
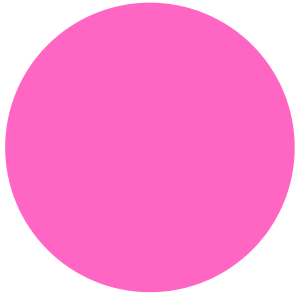
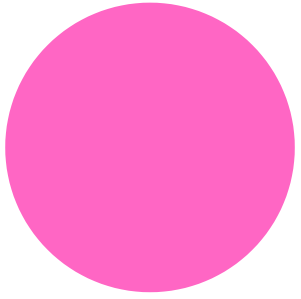
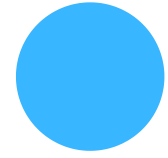
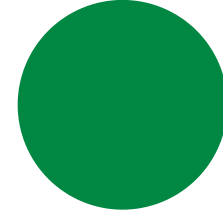
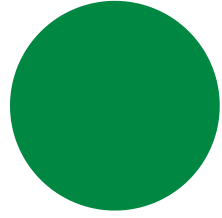
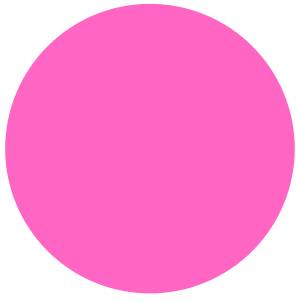
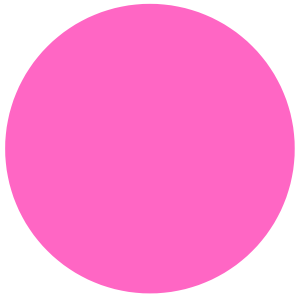
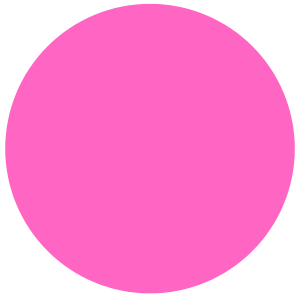
Jaws

Print out 2 pages of
jaw pieces



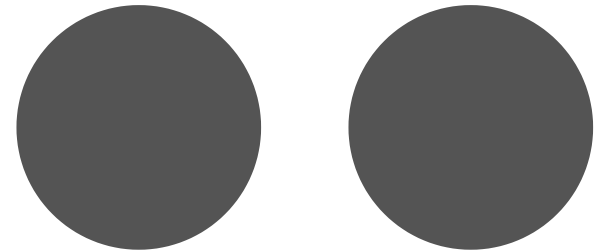
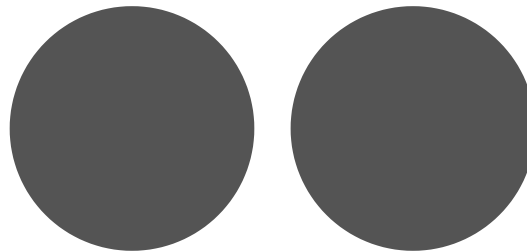
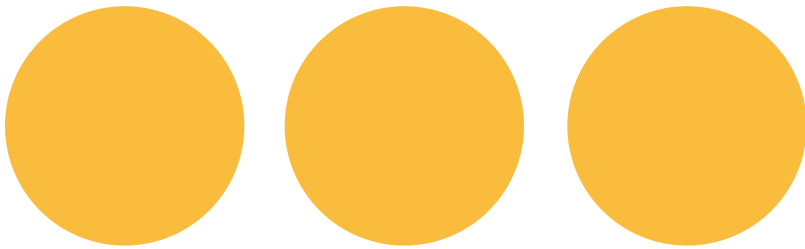
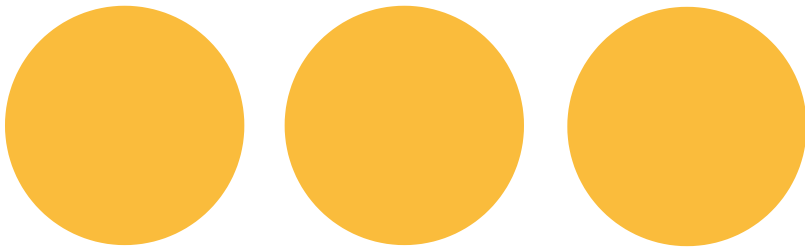
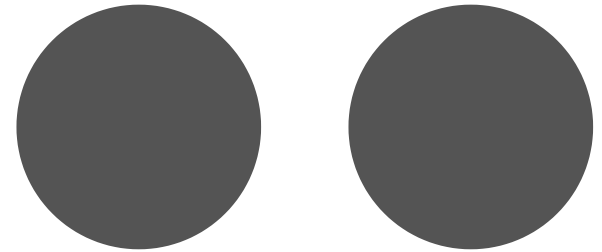
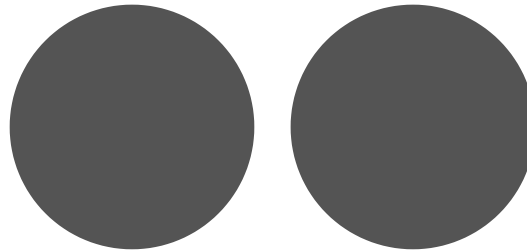
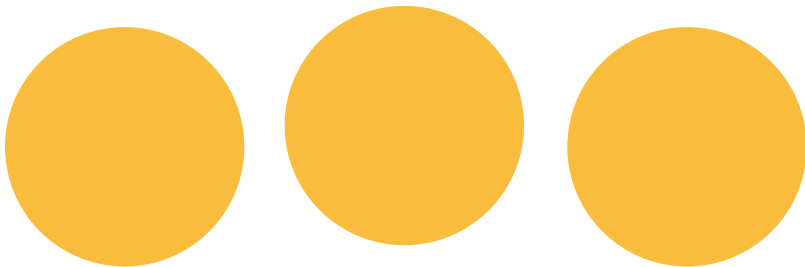
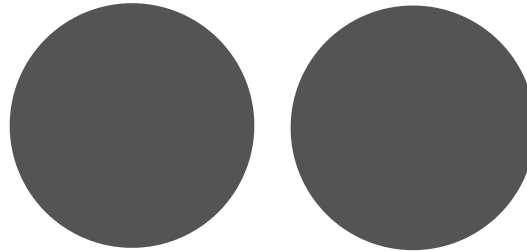
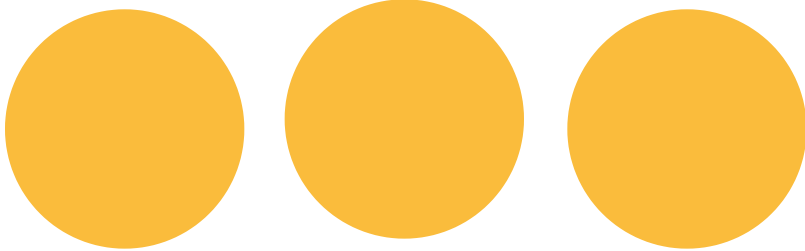
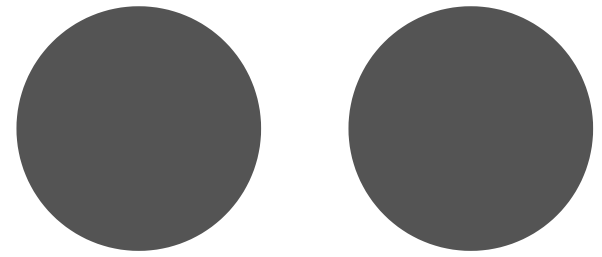
Teeth

Print out 1 page of
pink/green/blue/red
teeth



Teeth

Print out 1 page of
yellow and agenesia
teeth



agenesia teeth



Hunter-Gatherer Tiles

Cut out 4 tiles. You will need 1 per player.





Agriculturalist Tiles

Cut out 8 tiles. You will need 2 per player.





Pastoralist Tiles

Cut out 4 tiles. You will need 1 per player.





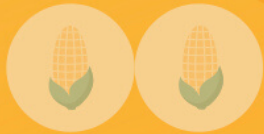
Industrialist Tiles

Cut out 12 tiles. You will need 3 per player.





hunter-gatherer
cc:4



agriculturalist
cc:6



**to lose
a tooth**



pastoralist
cc:5



industrialist
cc:8

one

two

three

four

five

six

seven

eight

Board Game

Print out 4 board games.

You will need 4 in total, 1 for each player.

to lose a tooth



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infection

Impacted third molars lead to infection in your pre-antibiotic society, an often fatal condition. Roll for each impacted member of your population. If you roll less than 4, remove them from the population.

Shin et al. 2016



genetic diversity

Small population sizes without migration can lead to inbreeding and health problems. Every population with less than 3 members should roll. If you roll below 3, remove one member from your population.

Hawks, 2008



hygiene

Impacted third molars cause inflamed and swollen gums, increasing the risk of secondary infection. Roll for each impacted member of your population. If you roll less than 3, remove them from the population.

McArdle et al. 2018



migration event

Your society expands near the boundaries of another group, leading to gene flow. If another society has the same technology as you, you may exchange up to two members of your respective societies.

Kulhwilm et al., 2016



borrowed tools

Agriculture requires land and many hunter-gatherers adopted agricultural practices of invading people. Any society may now adopt agricultural technology at the cost of one individual.

Robb and Miracle, 2007



conflict

Interactions between groups were not always positive. The society (or societies) with the most individuals may each choose another society to attempt to conquer. If they roll 2 or fewer, the smaller society forfeits half their population.

Estabrook, 2014



impaction

Impacted teeth can cause infection, leading to reduced productivity. Roll for each impacted member of your population. If you roll below 3, remove that individual from your population.

Shin et al., 2016



mate choice

In this pair-bonded society, both partners need to be able to actively provide food. Any impacted society member cannot mate on this round.

Kaifu et al., 2003



jaw growth

Soft food stimulates less jaw growth. Non hunter-gatherers should swap out any teal jaw pieces for orange jaw pieces.

Cramon-Taubadel 2011



jaw growth

Soft food stimulates less jaw growth. Non hunter-gatherers should swap out any blue jaw pieces for orange jaw pieces.

Cramon-Taubadel 2011



jaw growth

Soft food stimulates less jaw growth. Non hunter-gatherers should swap out any teal jaw pieces for yellow jaw pieces.

Cramon-Taubadel 2011



jaw growth

Soft food stimulates less jaw growth. Non hunter-gatherers should swap out any blue jaw pieces for yellow jaw pieces.

Cramon-Taubadel 2011



famine

Industrialization prevents against famine. Non-industrial societies should roll. If the roll is 2 or 3, lose 1 member of the society. If the roll is 1, lose 2 members.

Szreter, 2004



caries

Cavities (caries) became a big problem in agricultural and industrial societies, though often not enough to be fatal. No one may add an individual to their population during this round.

Cremaschi et al., 2015



body size

First molar size corresponds well with body size. The largest member of each society (judging by first molar size) is more reproductively successful. If this person mates next round, add two members to your society.

Wood, 1979



impaction

Impacted third molars lead to so much pain that often those with them could not survive on their own. No impacted member of a society may migrate this round.

Larsen, 1995



impaction

Impacted third molars cause overcrowding of other teeth, leading to plaque build-up and gum disease. Roll for each impacted member of your population. If you roll below 2, remove that individual from your population.

Bharathi et al., 2018

