

# Skin Tissue Recovery

## Model Description

This cellular automaton models the recovery of human skin cells after trauma caused by a minor wound, such as a paper cut. In general, these wounds heal in four stages:

1. Bleeding and Clotting (stopping the bleeding): Happens in a few minutes. Blood vessels narrow, platelets stick together and seal the break, and the blood thickens to help create clots to stop the bleeding.
2. Inflammatory stage (cleaning and stabilizing the wound): Usually 4-6 days. Blood vessels near the wound open to give the wound access to fresh blood with oxygen, nutrients, white blood cells and other healing cells to prevent bacteria and infection in the wound.
3. Proliferative stage (rebuilding new tissue): Usually 4-24 days. New tissue starts forming in the wound that is pink and uneven in texture. This pulls the wound in closer, and it gets covered with skin cells.
4. Maturation stage (strengthen and repair tissue): Anywhere from 3 weeks - 2 years. The newly created tissue becomes stronger and the scar that is formed by the new skin tissue gets thinner. Healed wounds are about 80% the strength of uninjured skin. Scar tissue will eventually fade in colour, as well as flatten out.

The time it takes to heal a wound depends on the severity and how deep the wound reaches. Minor wounds take around 2-3 weeks to recover, whereas a deep trauma wound requires stitches and/or surgery, and can take months to years to recover fully. Most wounds tend to leave scars as well, as the new tissue grows back differently from the original tissue.

## The Possible States of a Cell

Representation	Cell Colour	Description
Uninjured skin tissue		This represents skin tissue that is not wounded. Can be one of 5 skin tones as chosen by the user - vanilla, beige, almond, mocha and toffee.
Blood		This represents the blood that comes out from a wound. This is what first comes out when there is a cut in the skin.
Blood Clots		This represents the blood that has started to dry and clot to close the wound with the help of platelets in the blood. It will collect and dry to form a scab.
Inflamed tissue		This represents the tissue with slightly opened blood vessels to allow for fresh blood around the wound once the wound has been closed by the blood clots. This fresh blood brings oxygen and nutrients to the wound to assist the healing process and protect the wound from infection. (colour depends on the skin tone chosen by the user)
New tissue		This is the tissue that fills the wound after the blood clot has completely dried. This is different from the skin tissue that existed before the wound and is in the early stages of a scar. This is what eventually gets stronger and is less flexible than the original skin. (colour depends on the skin tone chosen by the user)
Healed scar tissue		This is the scar tissue that exists after a wound has fully healed and recovered. (colour depends on the skin tone chosen by the user)

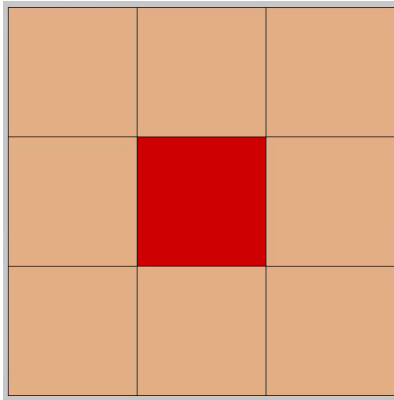
# Evolution Rules

Initially, there are no wounds and the skin is full of undamaged tissue. The user creates a cut by holding and dragging their mouse over a patch of skin.

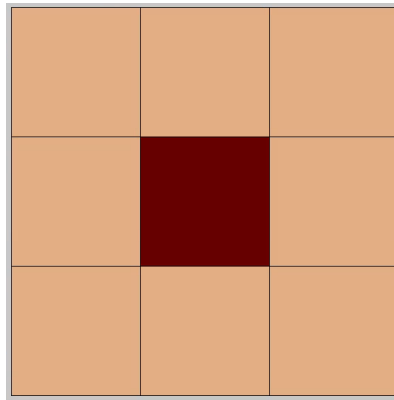
Since the model is based on time, the next generation of a cell is determined by how much time has passed and what stage it is at in the healing process. Once a skin tissue is harmed, it immediately begins the process.

1. Bleeding and Clotting (clotting starts after 2 hours of bleeding)
  - a. The injured tissues are replaced immediately by blood
  - b. Blood clots will start to form with a delay of 2 hours
2. Inflammation (duration: 2-36 hours)
  - a. This will begin once the clots have formed
  - b. The neighbouring uninjured tissue will gradually turn into inflamed tissue
3. Building of new tissue (duration: 36-80 hours)
  - a. After the inflammation has finished, new tissue will gradually replace the blood clot scabs
  - b. The neighbouring inflamed tissue will gradually return to normal skin
4. Strengthening (duration: 80+ hours)
  - a. New tissue will be gradually replaced by healed scar tissue until all the tissue in the wound is covered in scar tissue

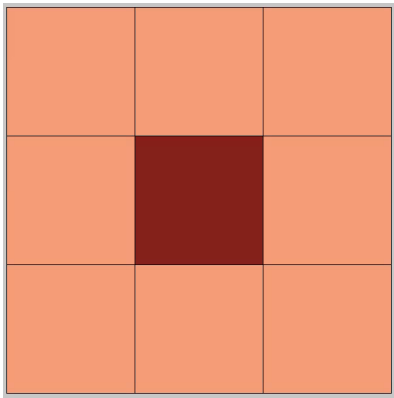
## Sample Evolution



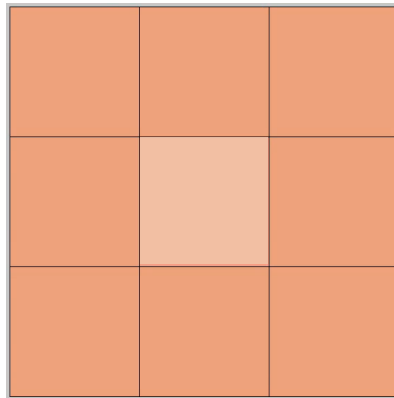
A bleeding cell



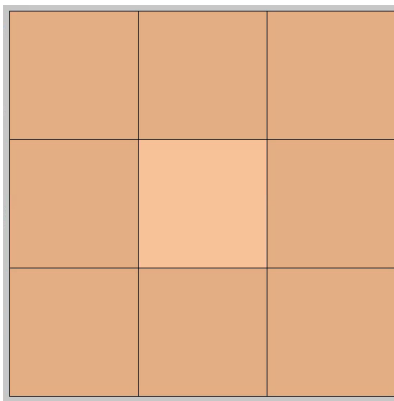
Turns into a blood clot after 2 hours



Skin cells around the clot get inflamed in 2-36 hours



Blood clot turns into new tissue and inflammation reduces in 36-80 hours



New tissue turns into scar tissue and inflammation is gone for the rest of the simulation

# Strengths and Limitations

## Correct Predictions:

1. Tissues go through the four stages that a wound requires to heal
2. The skin colour can vary so the inflammation and tissue colours are relative to each skin tone
3. Follows the general amount of time it takes the wound to heal
4. Updates the colours of the tissues gradually and not abruptly to make the model more realistic (eg. inflammation of the skin occurs and decreases gradually, and new tissue turns into scar tissue slowly over time)

## Simplifying Assumptions:

1. Wound depths are not taken into consideration (deeper wounds, in reality, take longer to heal but there are no cell depths in the model)
2. A wound in the healing process or scar tissue cannot be cut again
3. Does not account for external and internal factors that may affect the recovery process (eg. infections, temperature, humidity and blood flow)
4. The wound does not require additional resources (eg. band-aids) to assist in healing