

*A brief introduction to*

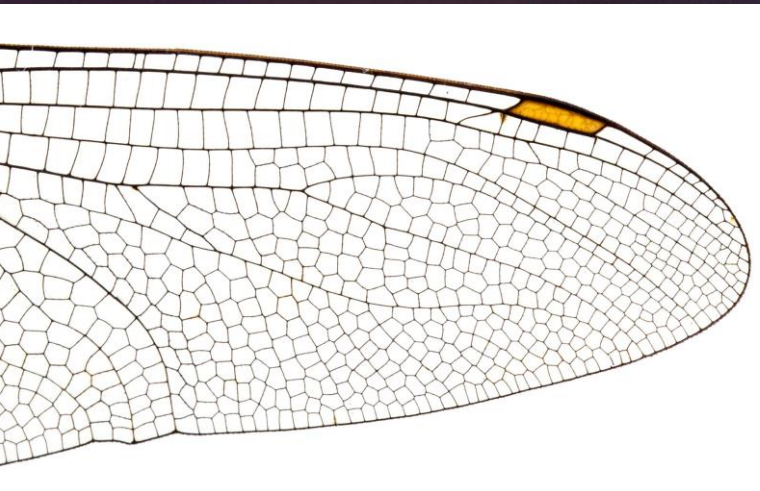
# Turing pattern

*—— something about the organization of organism ——*

Presented by Chang Longxiao

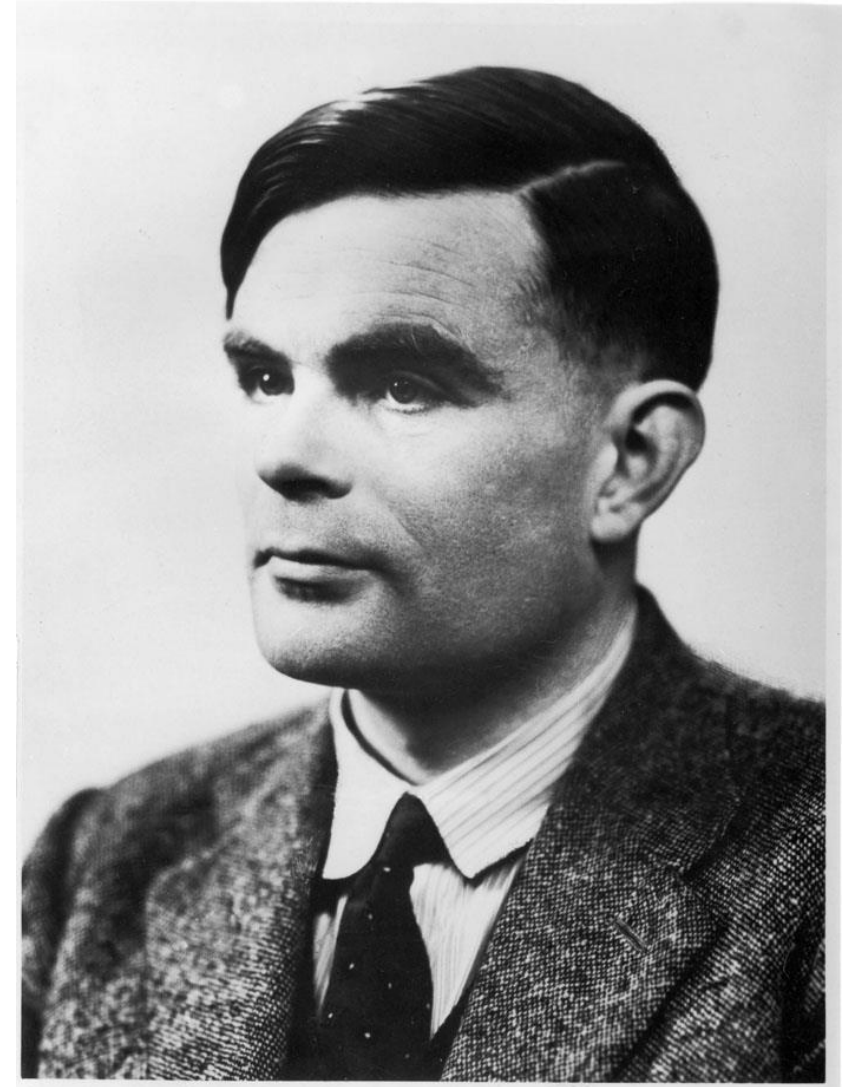
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# Alan Turing

- **Alan Turing** , in full Alan Mathison Turing, (born June 23, 1912, London, England—died June 7, 1954, Wilmslow, Cheshire)
- British mathematician and logician, who made major contributions to mathematics, cryptanalysis, logic, philosophy, and mathematical biology and also to the new areas later named computer science, cognitive science, artificial intelligence, and artificial life.



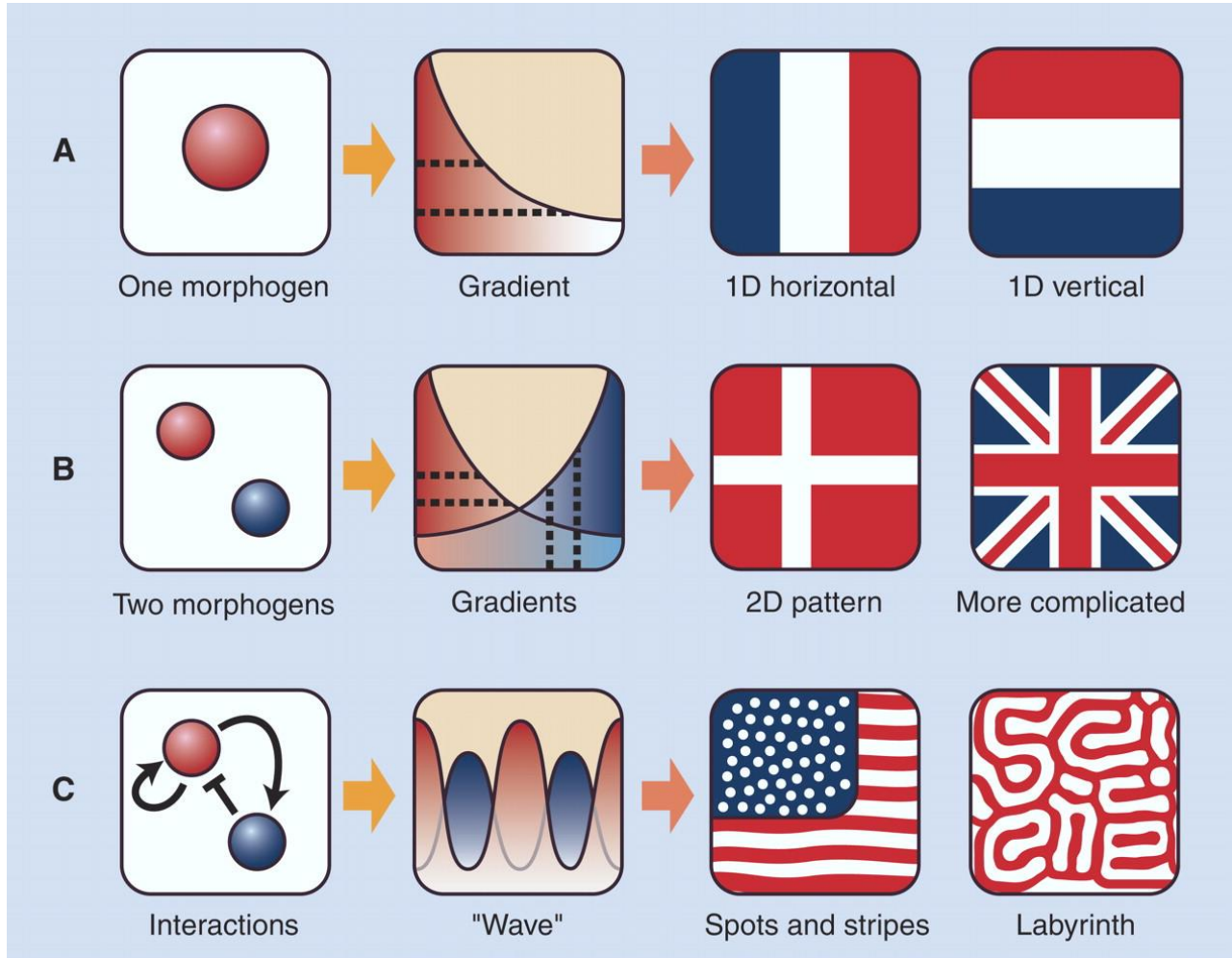
# Turing's model

Diffusion - Reaction

The equation of pattern formation

Model in Chemistry&Biology

# Diffusion and Reaction



Shigeru Kondo, and Takashi Miura Science 2010;329:1616-1620

## Diffusion model

- Independent substance

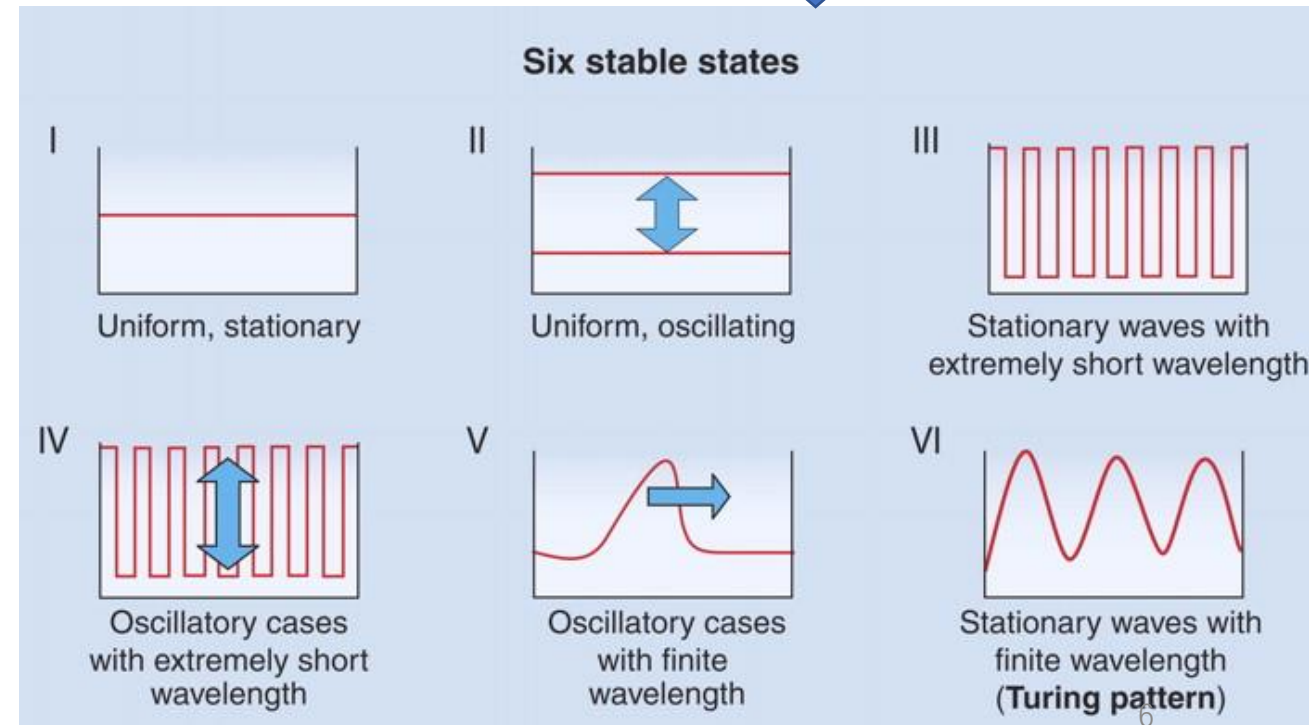
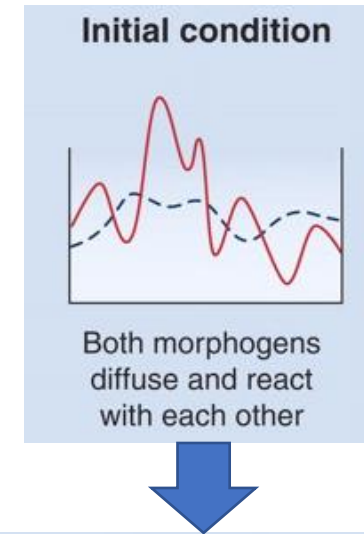
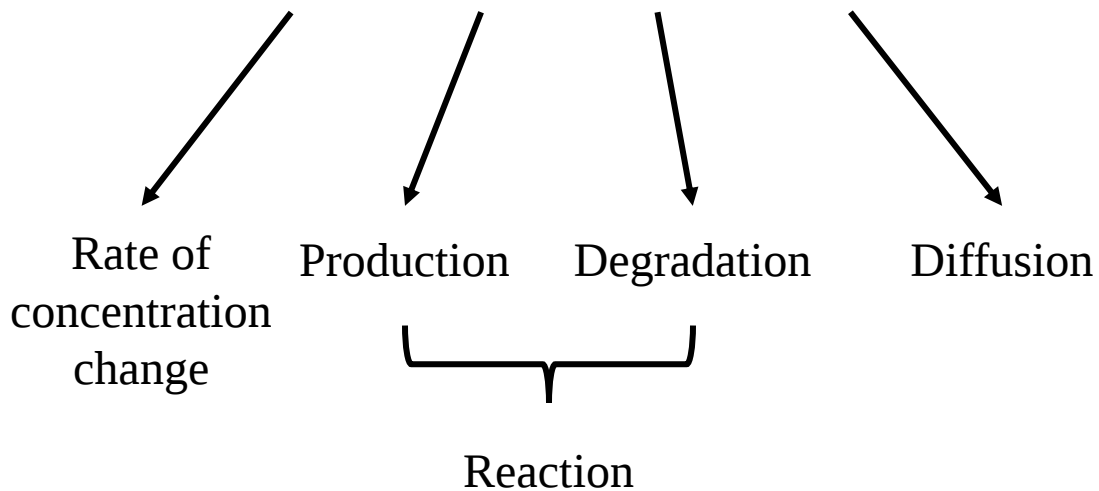
## Reaction-diffusion model

- An activator;
- An inhibitor;
- The reaction that produce both substance;

# The formula of Turing Pattern

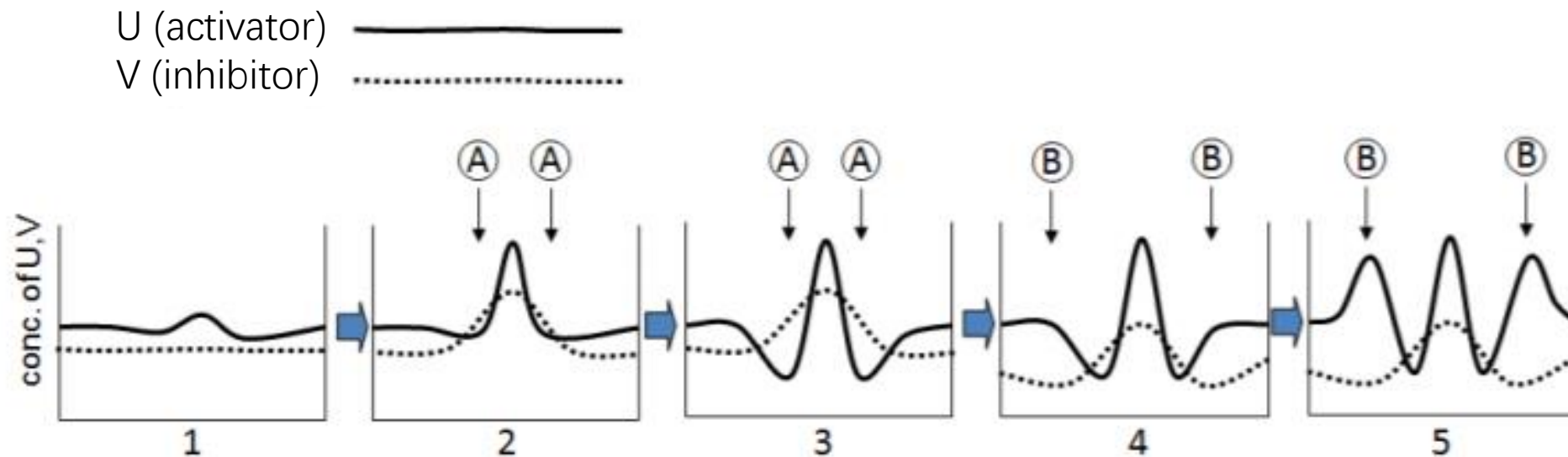
$$\frac{\partial u}{\partial t} = F(u, v) - d_u u + D_u \Delta u$$

$$\frac{\partial v}{\partial t} = G(u, v) - d_v v + D_v \Delta v$$



# A qualitative explain

- Condition: The inhibitor diffuses **faster** than the activator



Shigeru Kondo, and Takashi Miura Science 2010;329:1616-1620

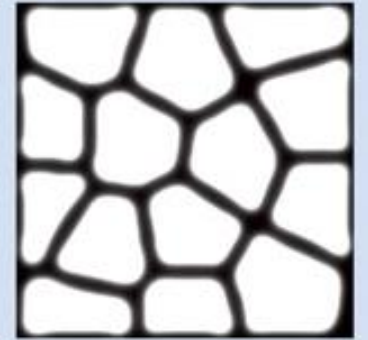
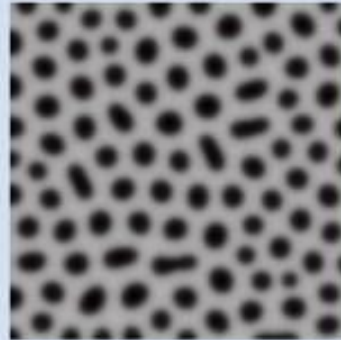
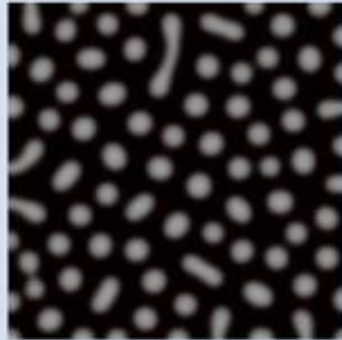
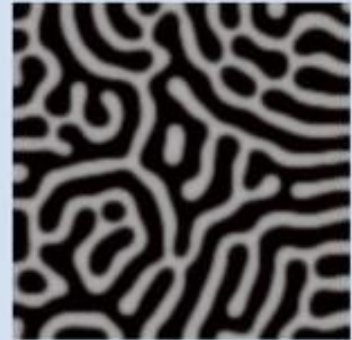
- periodic

# Some generated patterns

Case V



Case VI (Turing pattern)



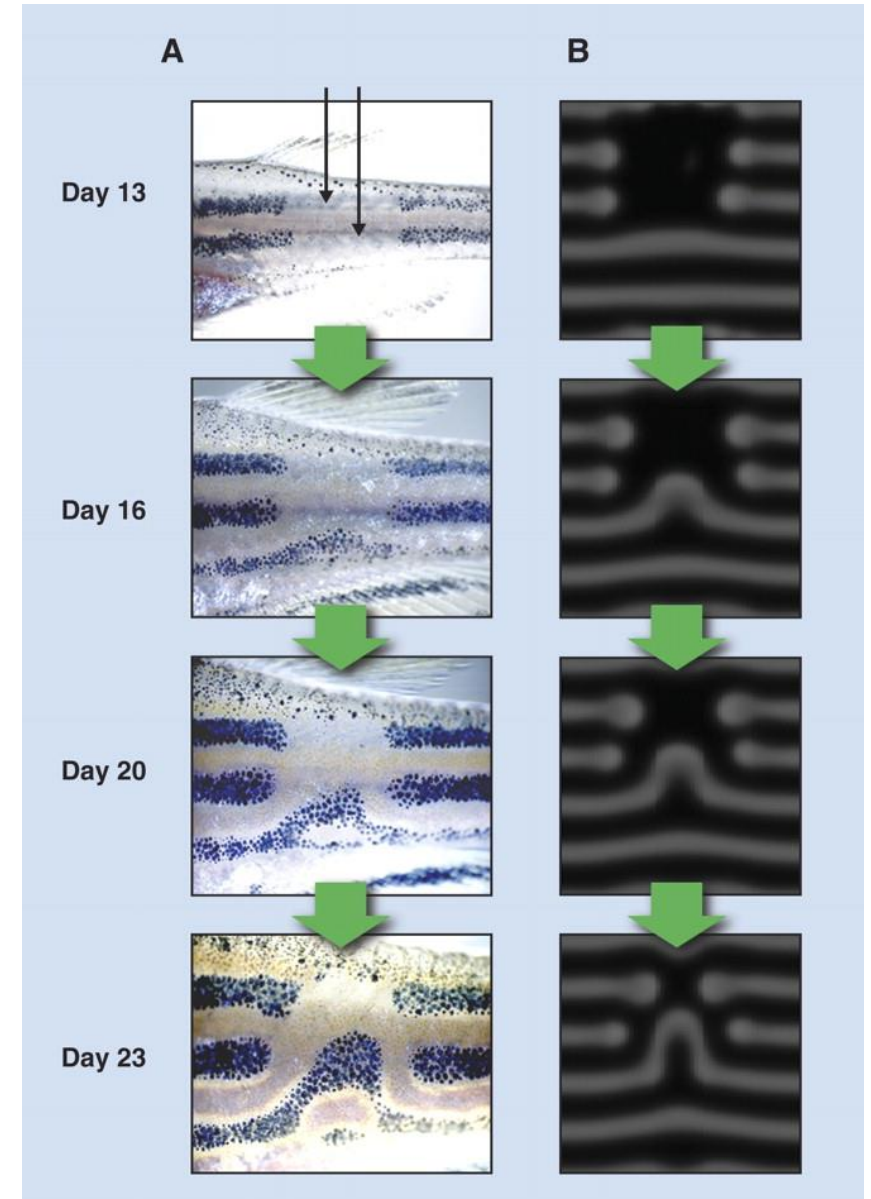
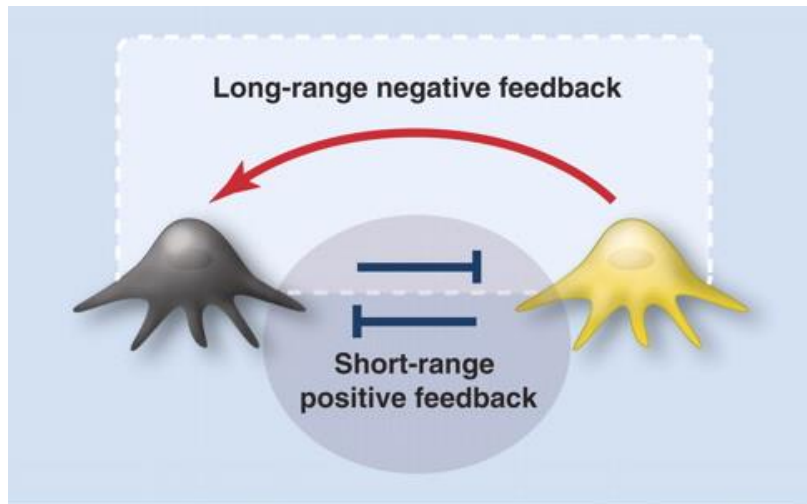
# Real pattern formation

Animals

Plants

# Animal skin

- Laser ablation of pigment cells
- In zebrafish
- M.Yamaguchi et al.,2007



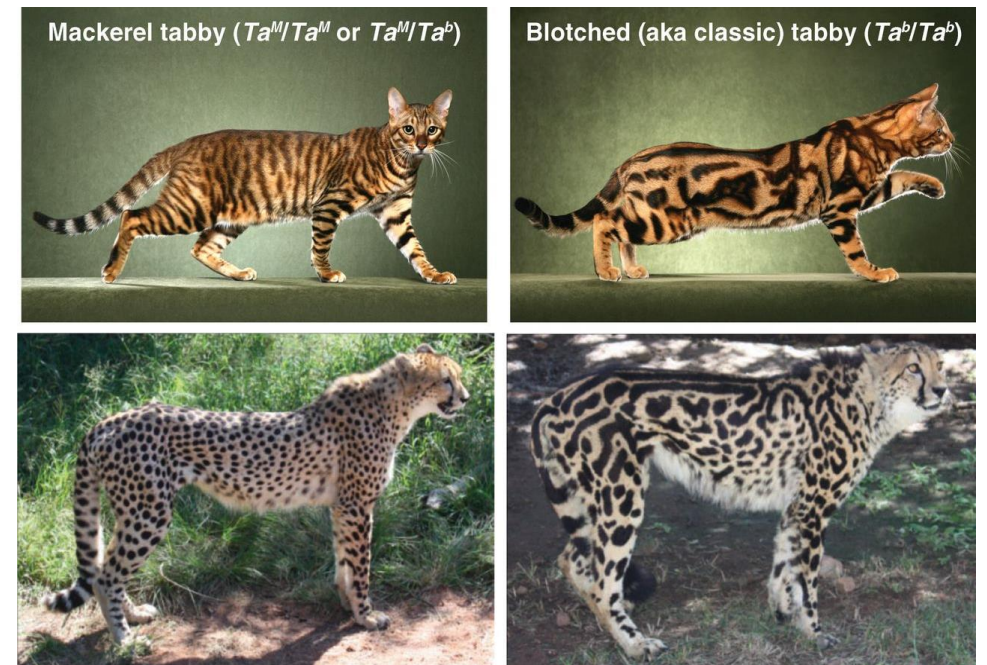
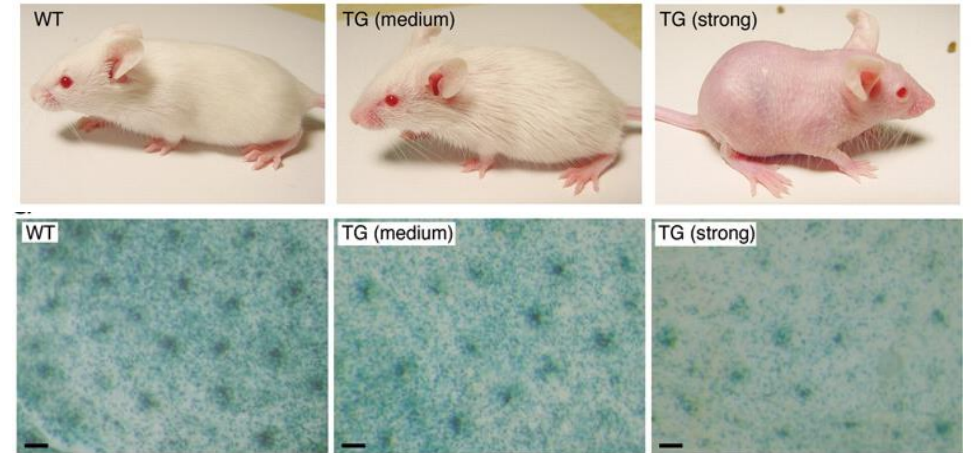
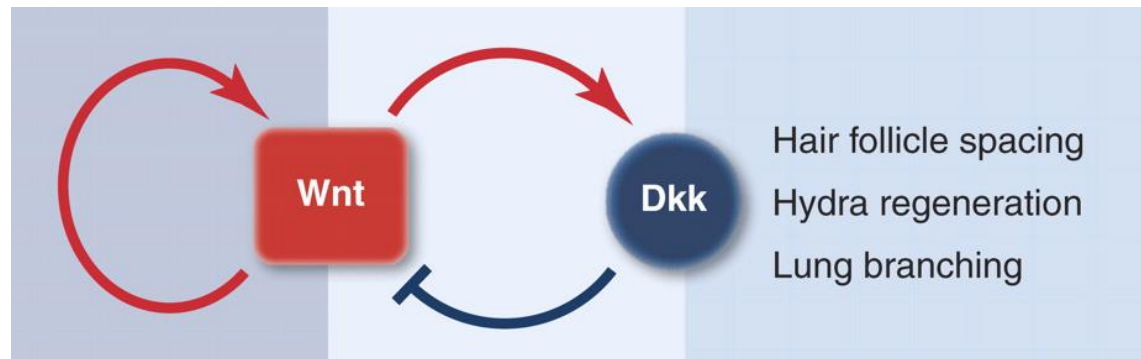
# Animal skin

- Wnt-Dkk4 in mice hair follicles

S.Sick et al.,2006

- Tabby in cats and cheetahs

C.Kaelin et al.,2012

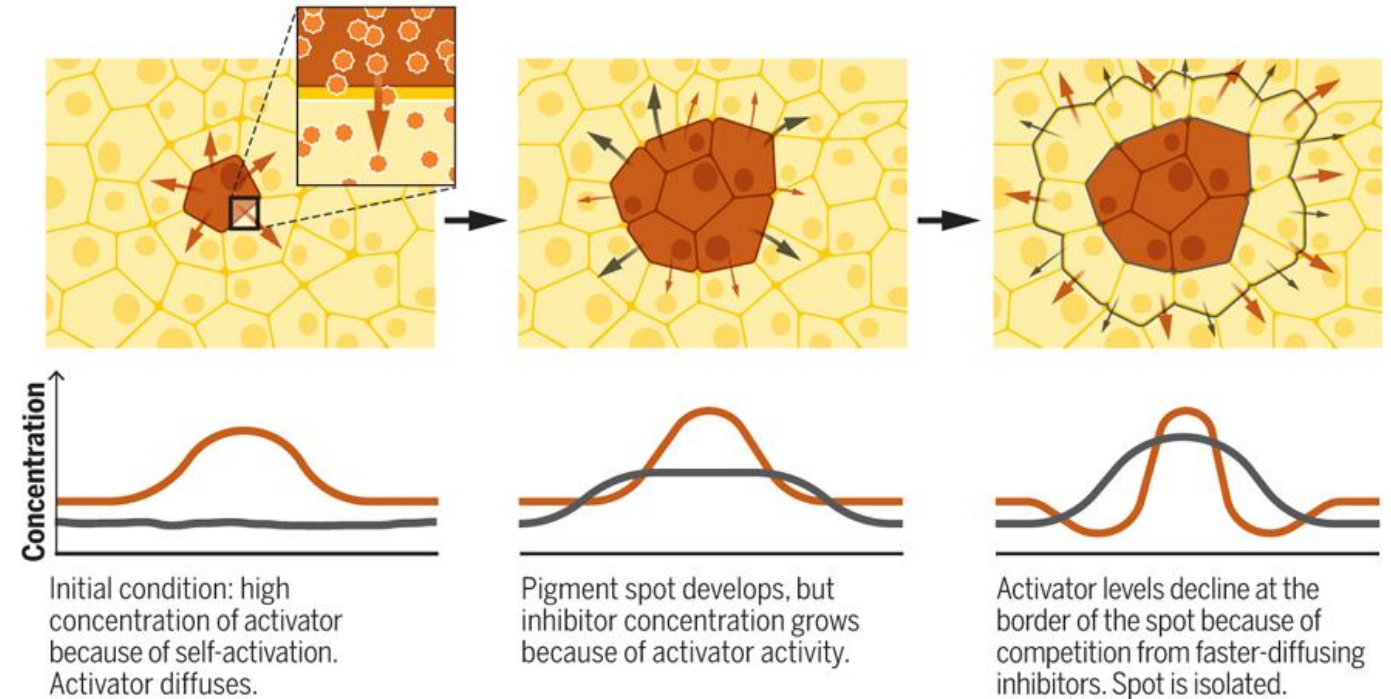


# Plants

- Monkeyflower
- Y.Yuan et al,

## Spot on

Unimpeded by the inhibitor, an activator colors a cell and spreads to and colors nearby cells. The inhibitor quickly diffuses away from the colored cells, causing a nonpigmented halo to form. As this process repeats throughout the tissue, multiple spots form, resulting in a periodic pattern.



## Patterns galore

Monkeyflower hybrids mix different species' activators and inhibitors, altering petal speckle patterns.



# More than stripes and spots

Limbs: Digit or fin

Branch: Kidney & lung

Others: Compound eyes

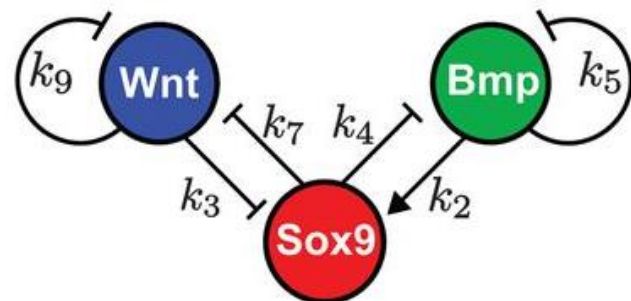
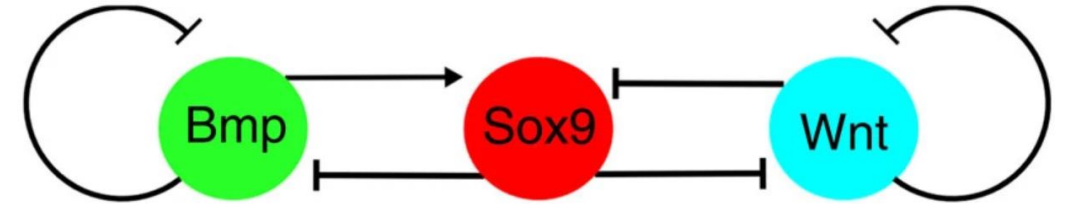
# Organ formation

- Bmp-Sox9-Wnt Turing network

Development of digits and fins

J.Raspopovic et al.,2014

K.Onimaru et al.,2015



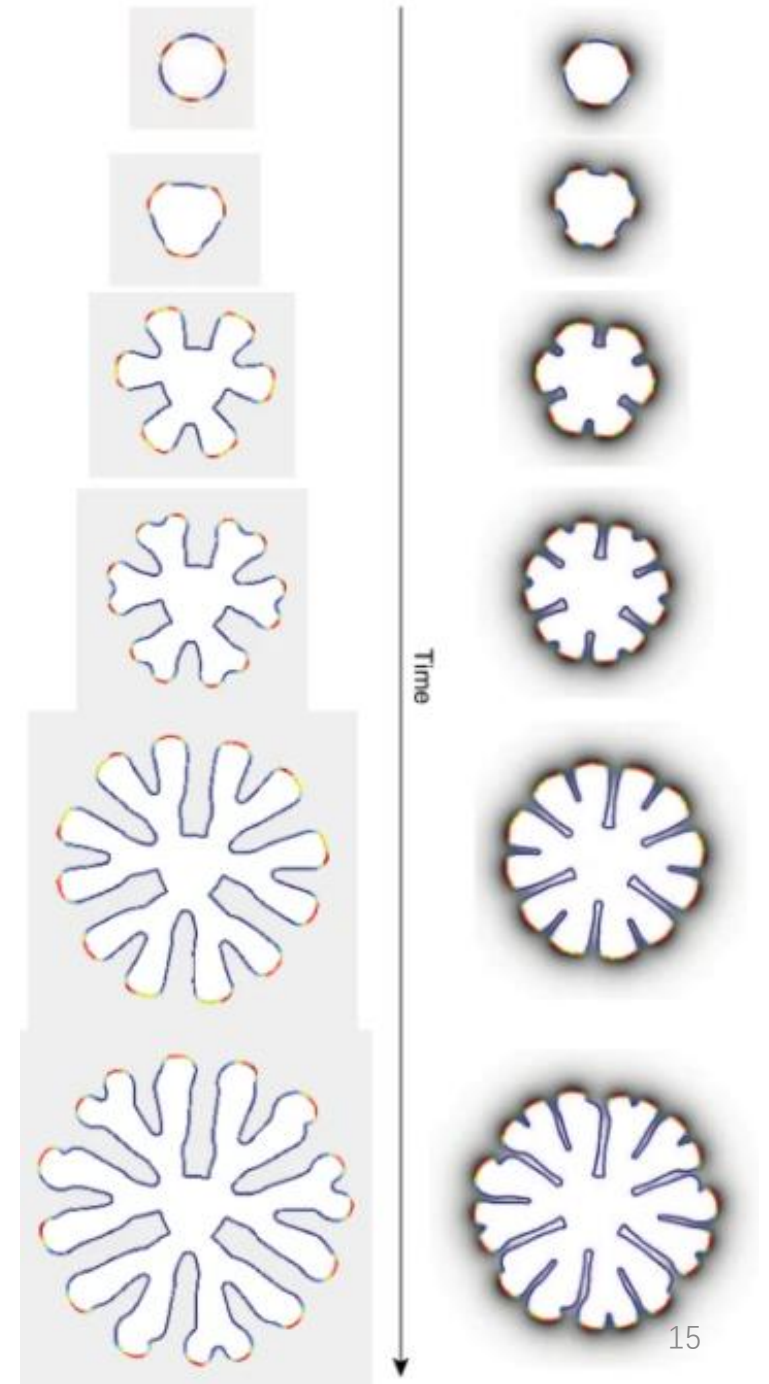
$$\frac{\partial sox9}{\partial t} = \alpha_{sox9} + k_2 bmp - k_3 wnt - sox9^3$$

$$\frac{\partial bmp}{\partial t} = \alpha_{bmp} - k_4 sox9 - k_5 bmp + d_b \nabla^2 bmp$$

$$\frac{\partial wnt}{\partial t} = \alpha_{wnt} - k_7 sox9 - k_9 wnt + d_w \nabla^2 wnt$$

# Other organ formation

- Branching of kidney and lung
- Even in the development of compound eyes



# Reference

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# Turing pattern

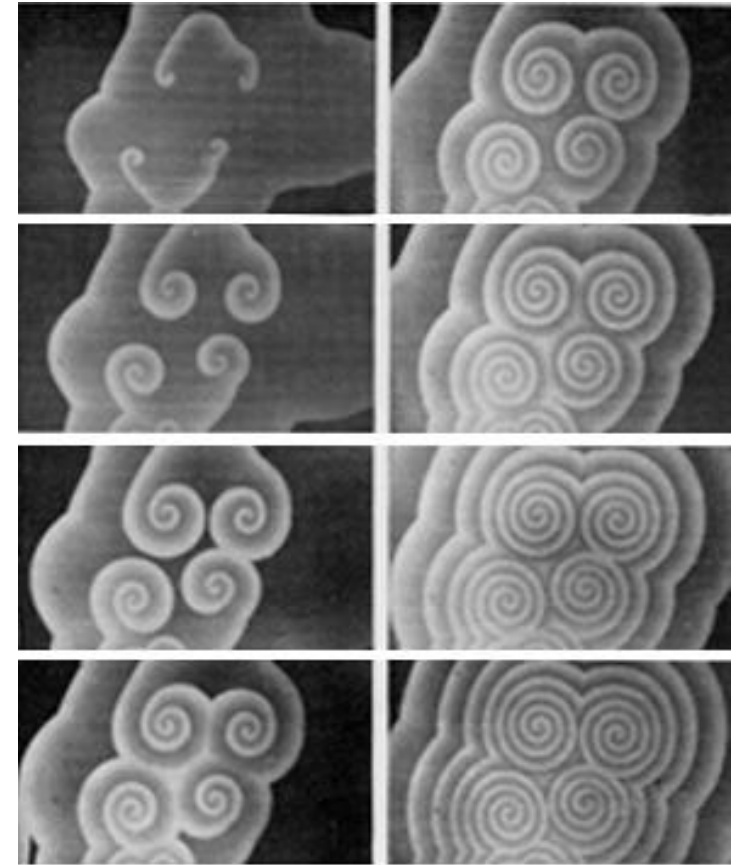
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# Models in chemistry

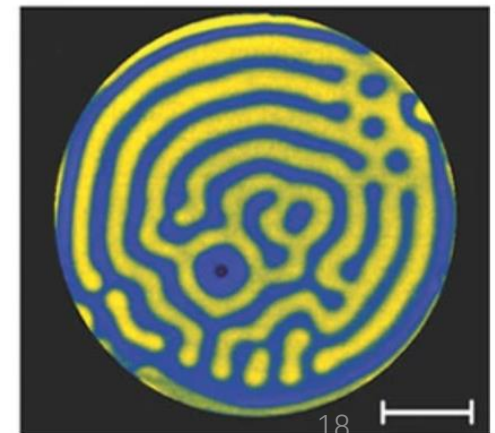
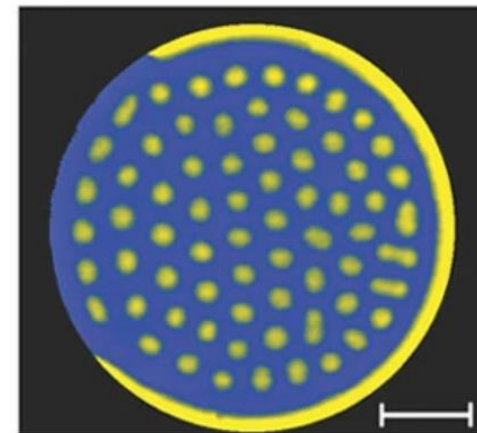
- The Belousov-Zhabotinsky (BZ) reaction

A family of oscillating chemical reactions

During these reactions, transition-metal ions catalyze oxidation of various, usually organic, reductants by bromic acid in acidic water solution.



- Usage of open gel reactor



# Models in biology

- **two diffusible ligands**,  $u$  and  $v$ , and receptors for them
- ligands **diffuse** at their specific diffusion constants
- bind to the receptor  
**enhance (or repress)** the production of themselves.

