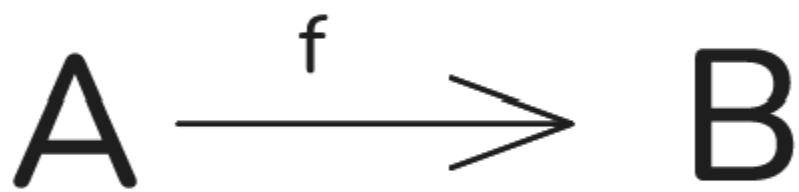
Anticipatory systems (eli5 edition)

(assuming I understood them correctly)

t= 0: Due to an one-time enviromental disturbance A is about to change value

Status: No system yet

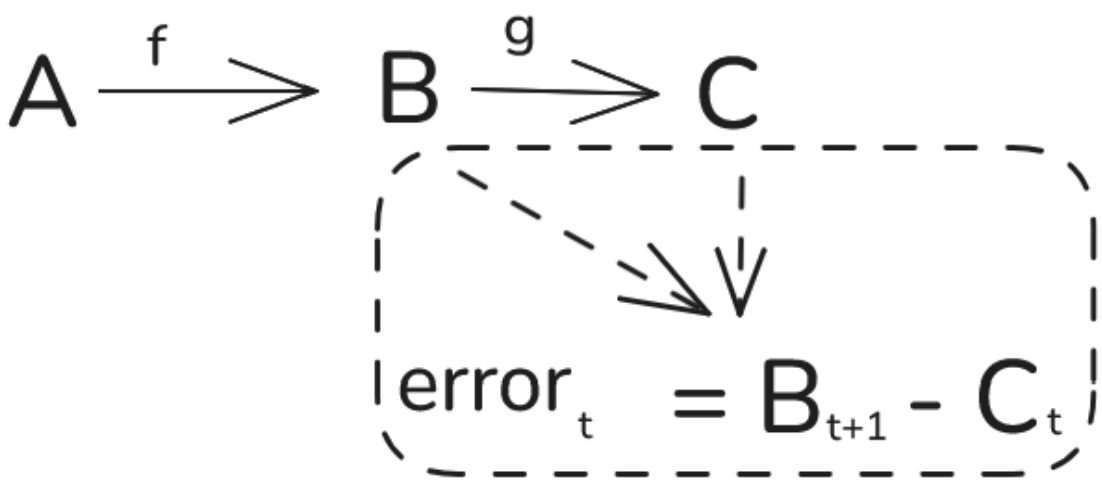
t= t1: A has reached a critical value and starts producing B, (imagine e.g. a chemical reaction that reached activation energy)



Status: This is a purely Reactive "System", (can't even call it that yet).

Cause (A) precedes Effect (B)

t= t2: As A keeps producing it, B has reached a critical value and starts producing C



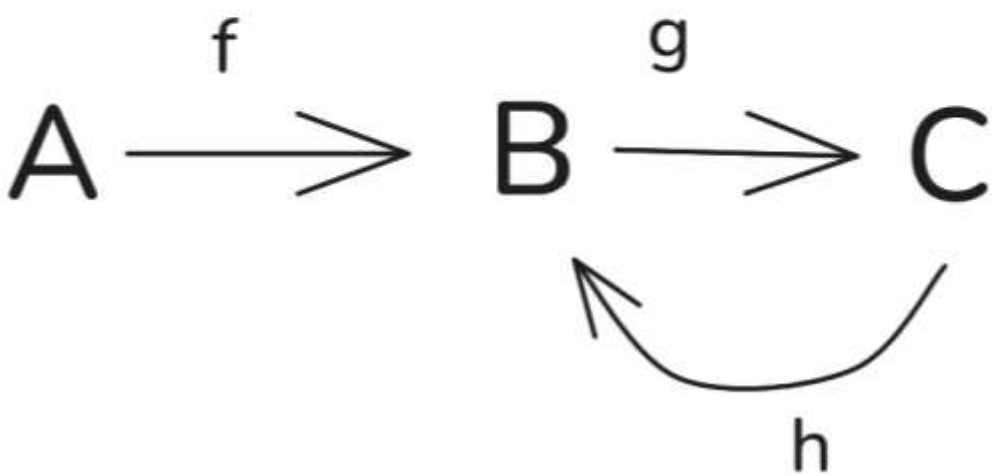
Status: The system is now potentially capable of building an internal representation (a model) of the interaction between itself and the enviroment.

You can use C(t) as a prediction, (however faulty it may be), of the value of B(t+1)

There are conditions such that, the error of the prediction, (B(t+1) - C(t)), converges "close enough" to 0 as t grows.

It's maybe worth getting into the weeds of when this actually happens later but for now all we care about is that this is mathematically possible at all and that it is.

t= t3: C has reached a critical value and starts producing B



Status: The system is now not only anticipating the future, (via guessing B(t+1) through C(t)), it is potentially also able to use that prediction to control/course correct the value that B(t+1) will take.

(At this point the model is coming together as A is staring to play the role of the state of the enviroment, B of the state of an organism, C of the state of the internal model the organism builds of its enviroment.)

Let's assume C(t) is initially a "good enough" prediction of B(t+1).

let's also assume, (again because this is the interesting case), that:

f: A -> B doesn't change too much for h: C -> B to be able to anticipate and course correct B(t+1) and that

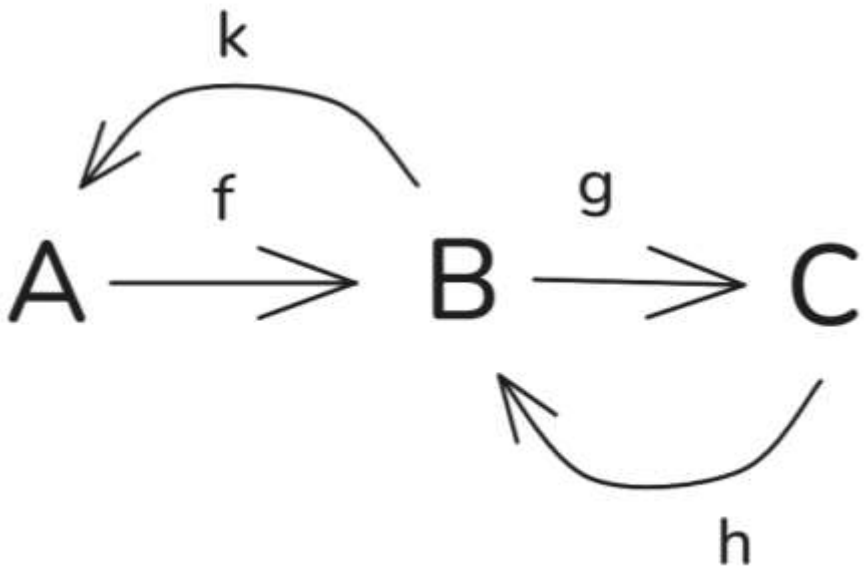
dB/dC >> dB/dA is not true, i.e. the system is not prone to "become delusional by only listening to its internal model"/ B(t+1) continues to be affected to a non negligible degree by the flow A -> B, the enviroment has veto power over the state of the organism.

Then anticipation becomes a positive,(self-reinforcing), feedback loop:

C(t) predicts B(t+1) -> C acts to course correct B(t+1) -> C(t+1) predicts B(t+2) even more accurately by design/control -> repeat

so as t grows C(t) indeed becomes a good enough prediction of B(t+1)

t= t4: B has reached a critical value and starts producing A



Status: The system is now no longer just reacting to the world, it is using an internal prediction (C) to control the world (A) indirectly through itself (B).

Anticipatory Systems cannot be emulated by Turing Machines. You can take an anticipatory system, map it to a program/simulation, run the simulation, decode the output and predict (to some degree) the future behaviour of the system, (using recursion), but you cannot emulate their behaviour, (they do incursion).

In a simulation, the code for C is just data. It cannot entail the future behavior of B unless the simulator (the computer) runs faster than the system (which is impossible if the simulation is the system) or unless the "future" is hard-coded (which is physically not possible).

https://www.sciencedirect.com/science/article/pii/S0303264725002503

https://link.springer.com/article/10.1007/s11229-026-05455-7

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(See Robert Rosen and company for a better more rigorous and formal understanding)