Iconicity and Mental Representation

Gabriel Greenberg, UCLA • 4.16.25

Rutgers Philosophy Colloquium

1. Iconicity and symbolism
2. Semantics
3. Mental representation
4. Iconic and symbolic functions

Iconicity and symbolism

ARBOR

There are likenesses, or **icons**; which serve to convey ideas of the things they represent simply by imitating them… There are **symbols**, or general signs, which have become associated with their meanings by usage.

— Peirce 1894 “What is a Sign?”

ARBOR

The linguistic sign is arbitrary… I mean that it is unmotivated, i.e. arbitrary in that it actually has no natural connection with the signified.

— Saussure 1923 “Course in General Linguistics”

Symbolic representation

Words	Sentences	Mathematical Formalism	Non-Linguistic Emblems

Words

ARBOR

EQUOS

貓

Sentences

nken heraus durch
eicht zu beantwor
g zwiſchen Gegen
Gegenſtände? D
nmen. Die Gr
e: a = a und a =
ntniswerte: a =
ennen, während S
rweiterungen unſ
mmer zu begründ
eine neue Sonne
der folgenreichſten
e Wiedererkennun
icht immer etwas

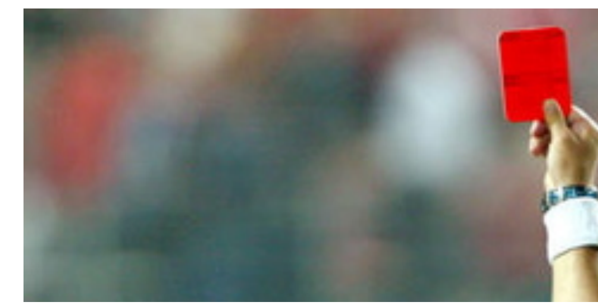
Mathematical Formalism

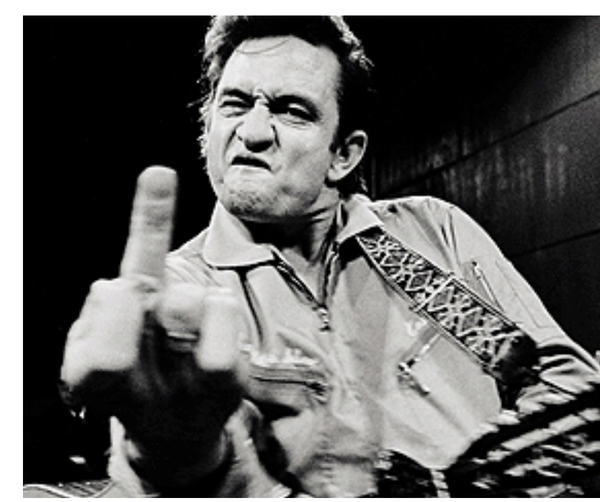
$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\neg p \to (p \to q)$$
$$\neg p \to [p \to (q \wedge \neg q)]$$
$$(p \to \neg p) \to [p \to (q \wedge \neg q)]$$
$$p \to (p \vee q)$$
$$p \to [p \vee (q \wedge \neg q)]$$
$$p \to [(p \wedge q) \vee (p \wedge \neg q)]$$

(1) $x = x$
(2) $\forall y(y \neq x) \to x \neq x$
(3) $x = x \to \neg\forall y(y \neq x)$
(4) $x = x \to \exists y(y = x)$
(5) $\exists y(y = x)$
(6) $\Box\exists y(y = x)$
(7) $\forall x \Box \exists y(y = x)$

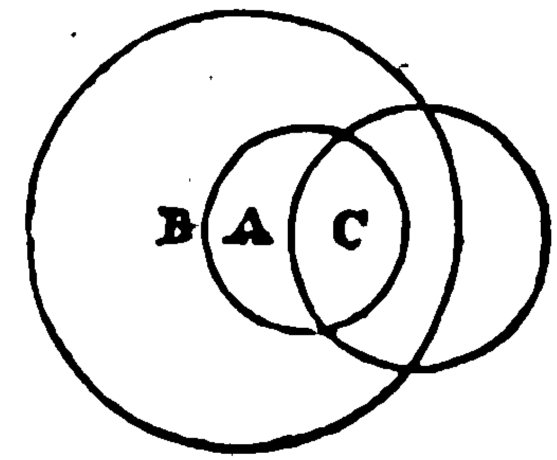
Non-Linguistic Emblems

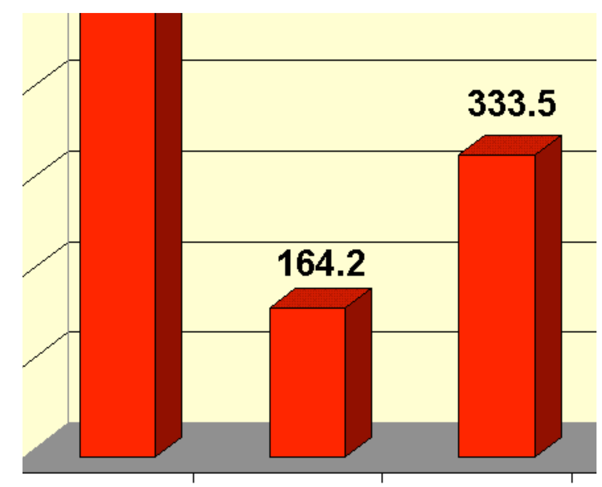


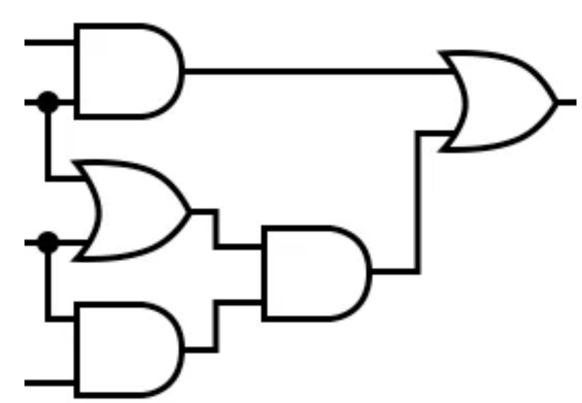


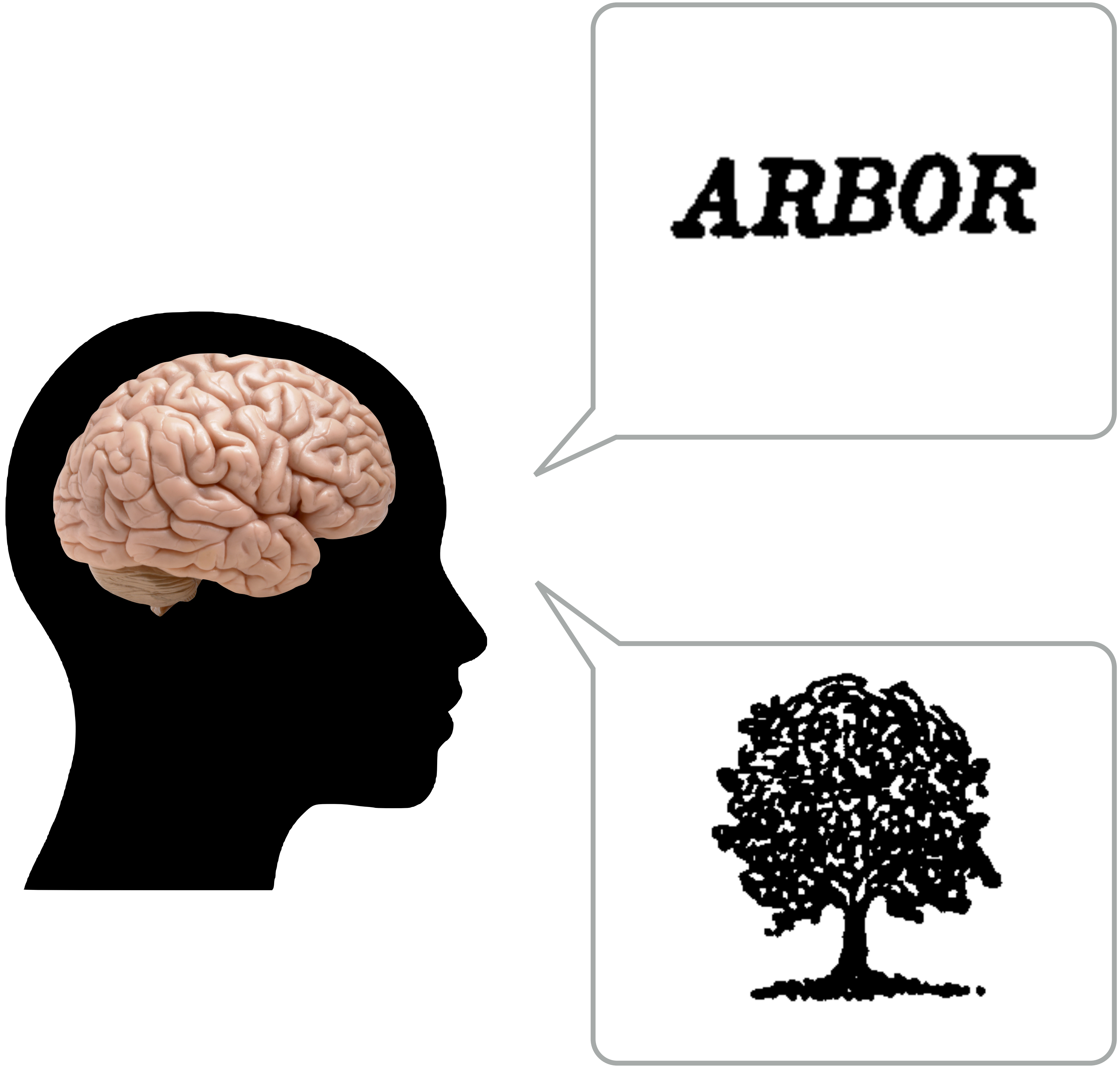
Iconic representation

3D Models	Pictures	Maps	Diagrams





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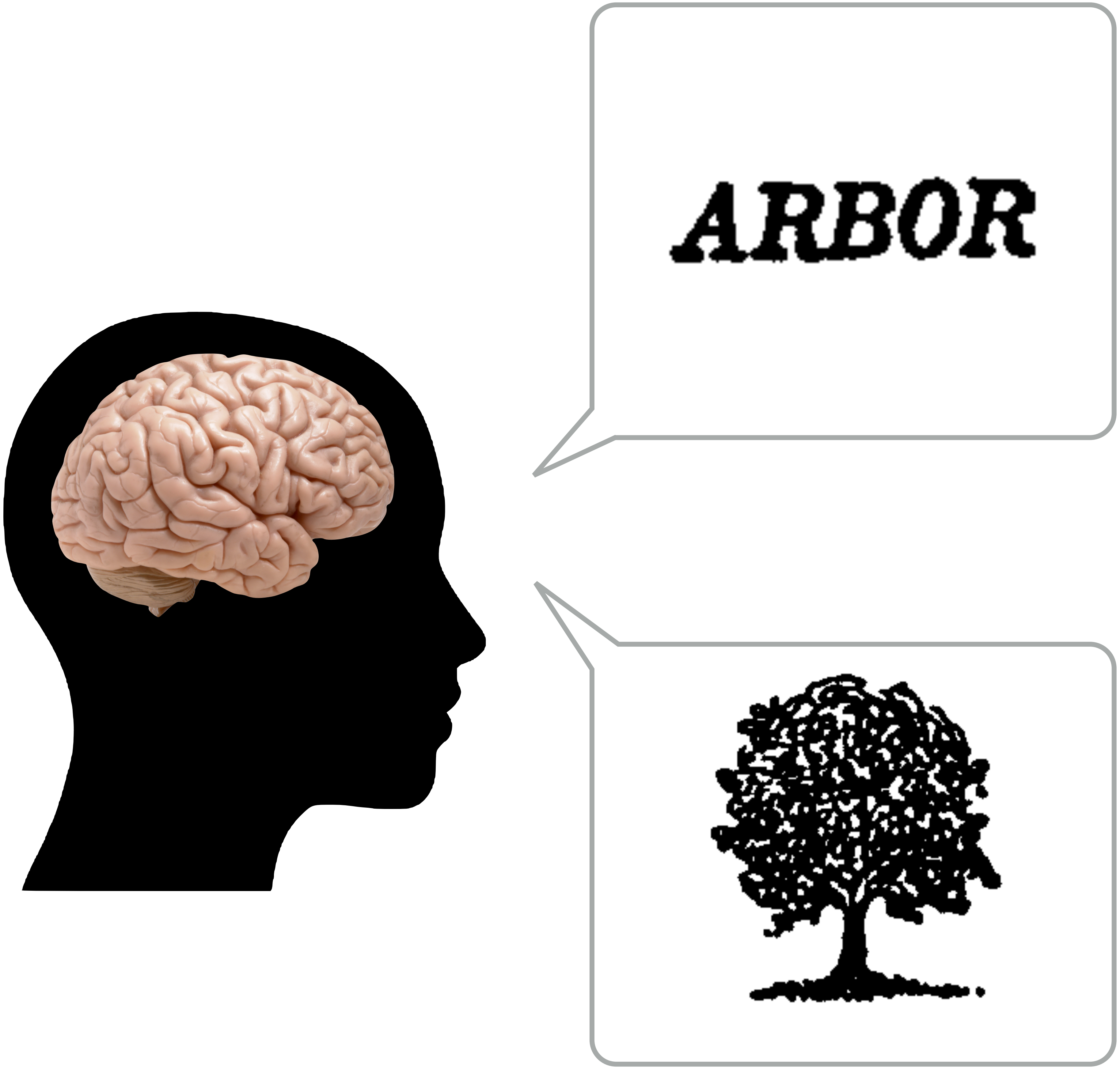
Goals

- Are there iconic and symbolic mental representations?
- It depends on your **theory of iconicity and symbolism.**
  There have been many: isomorphism, parts-principle, holism…
- **Plan:** take a recent semantics-based theory for public representations, and extend it to mental representations.
- **Thesis:** iconic and symbolic representation reflect two basic ways for organisms to functionally encode information about the world.
- **Assumptions:** computationalism, representationalism, externalism.



Language of thought

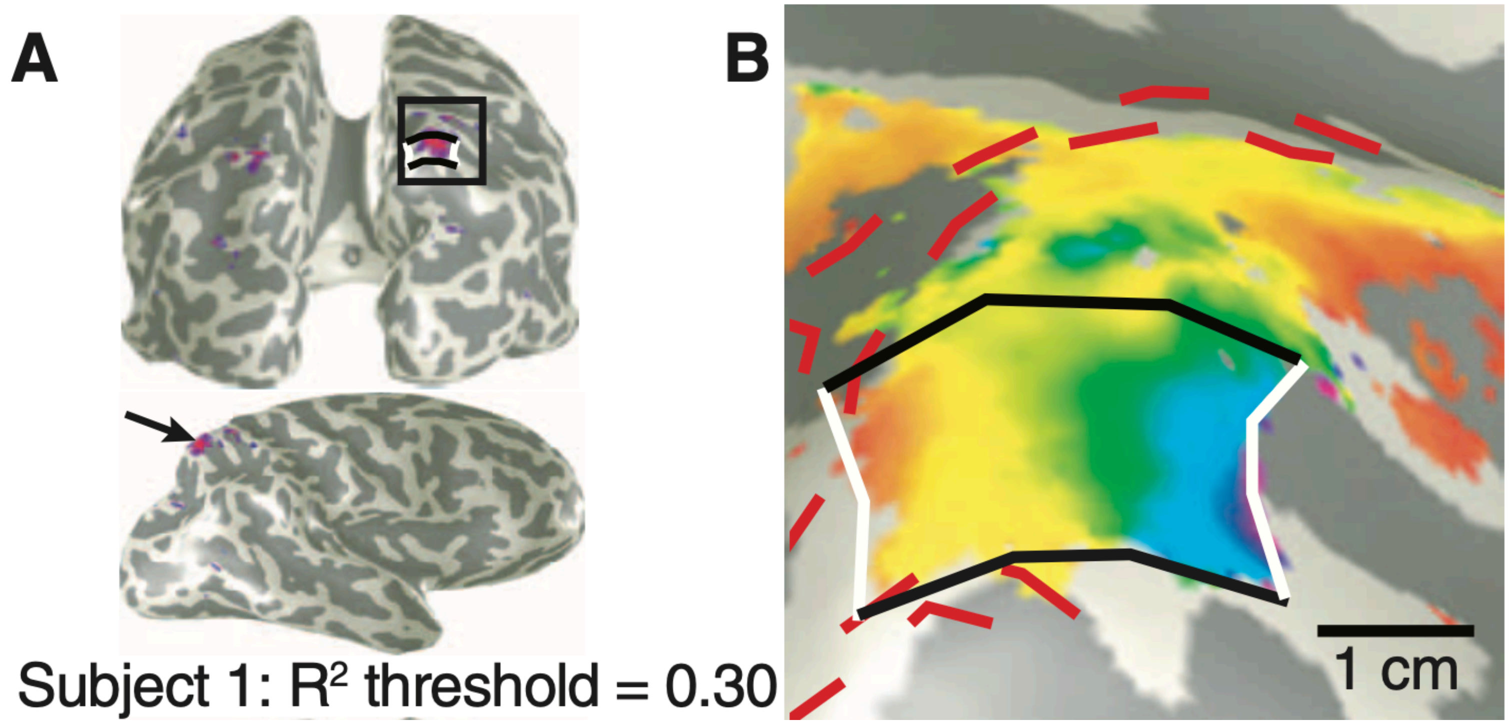
Symbolic computation

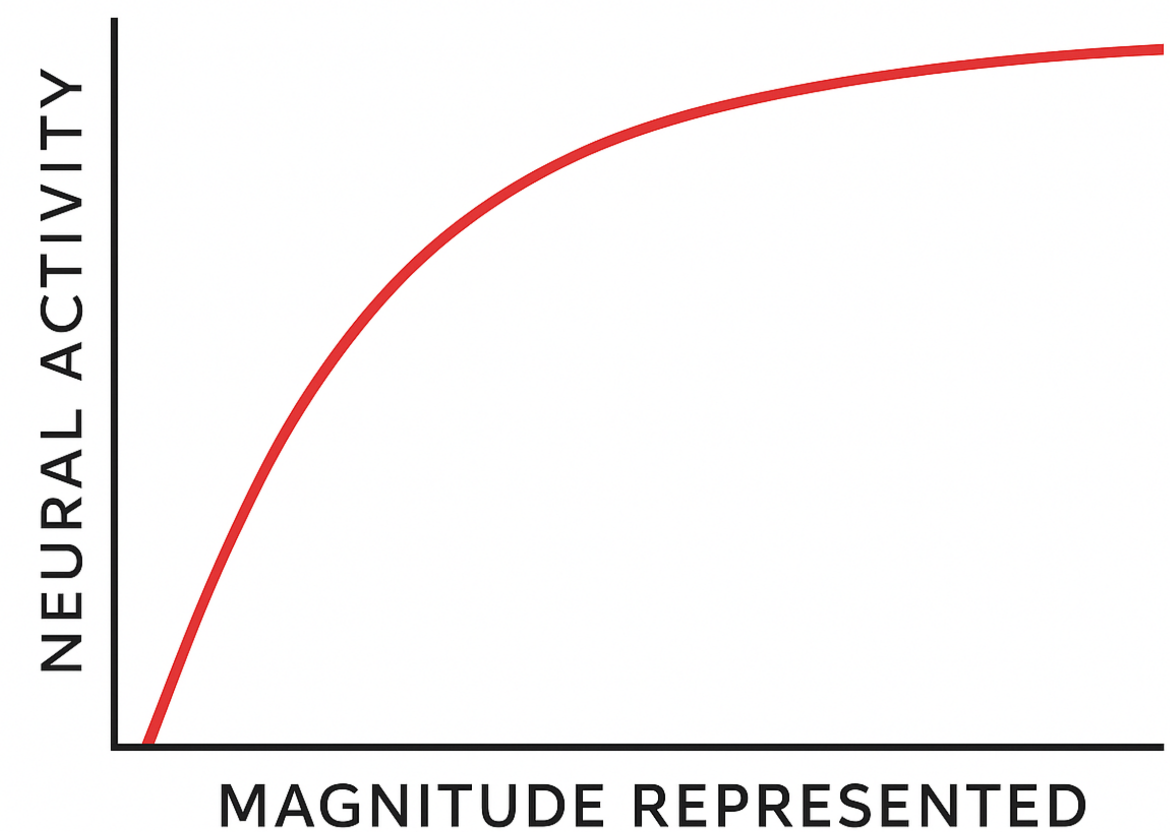
Mental imagery

Mental maps

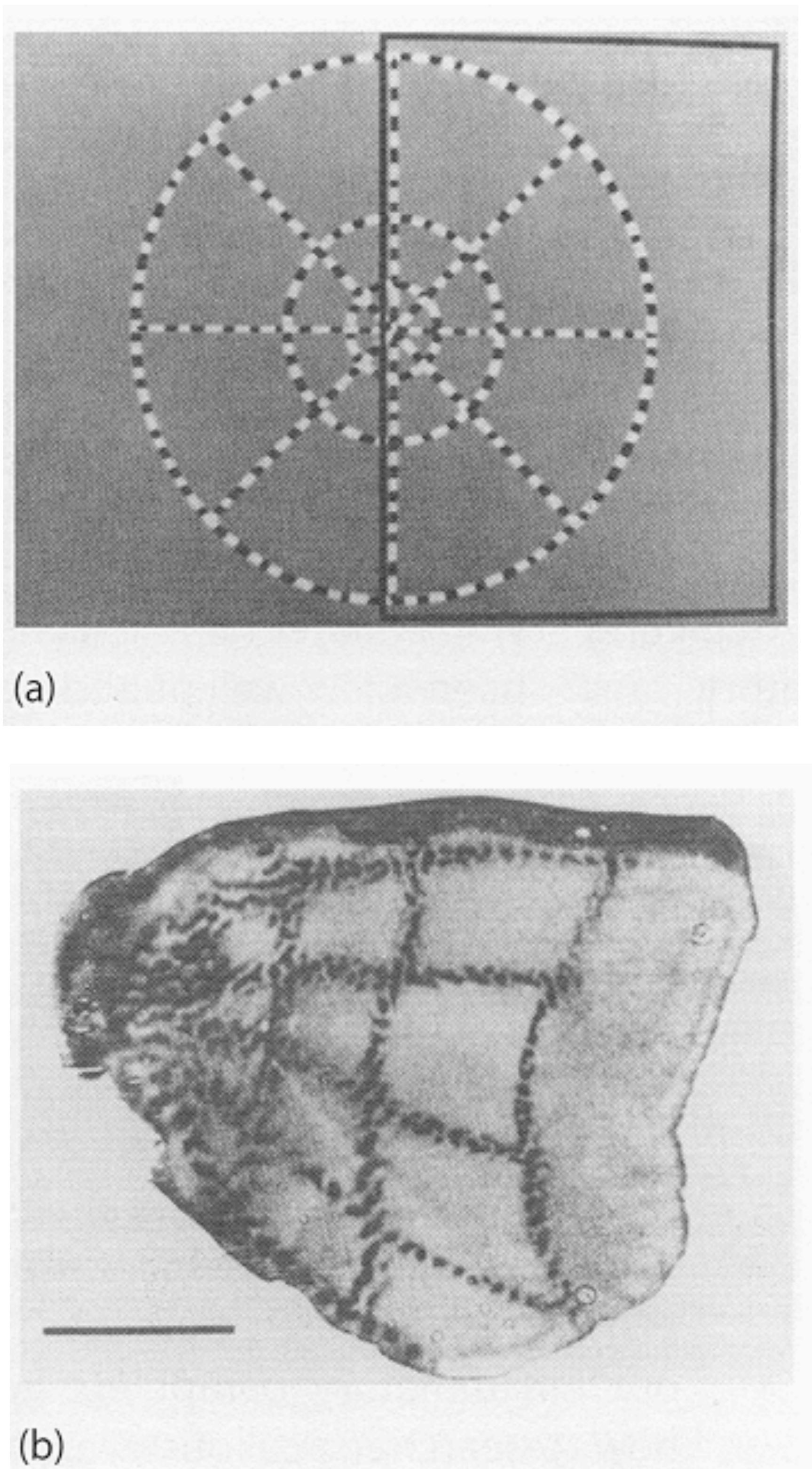
… others?

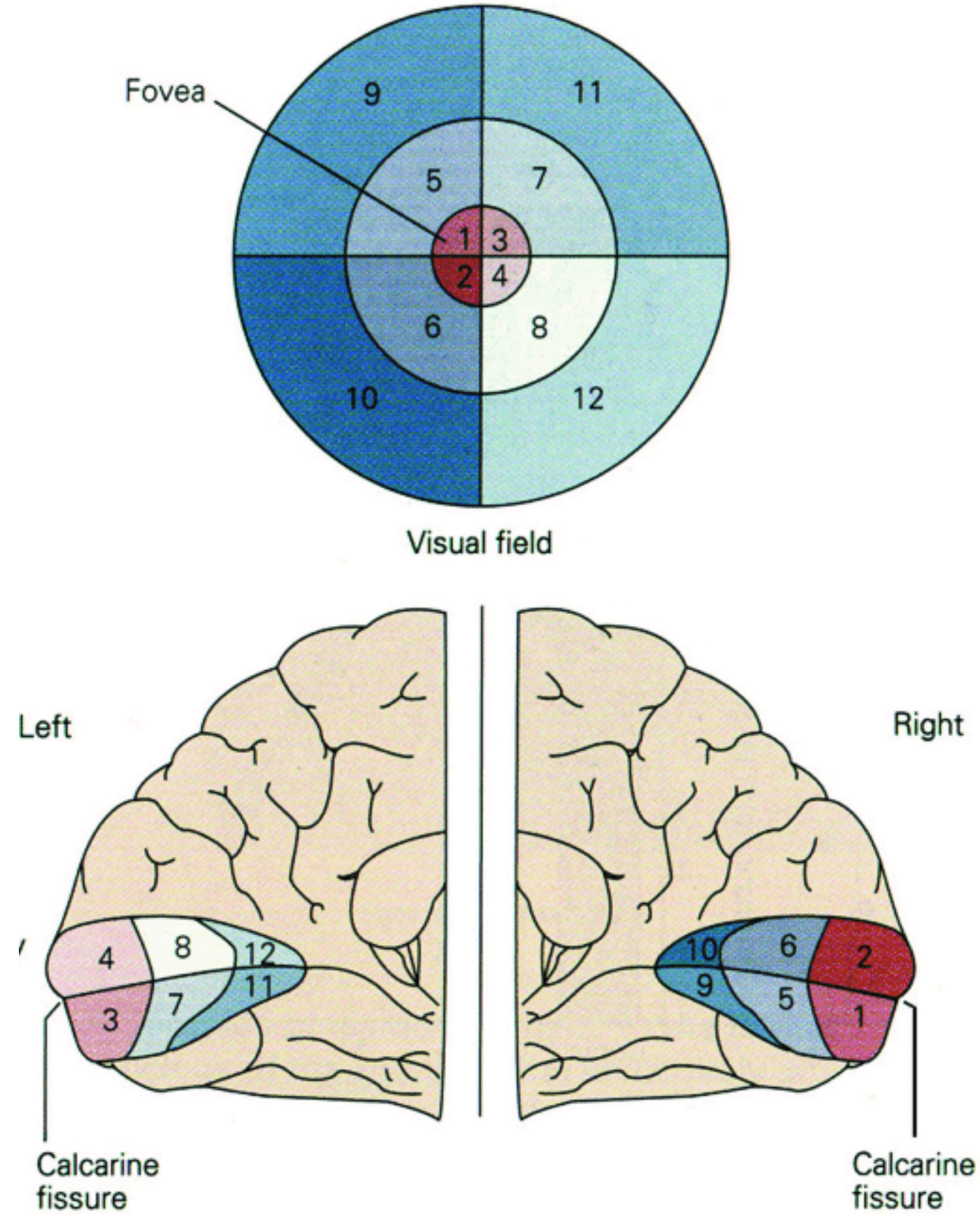
Analog magnitude representations:
neural populations which logarithmically encode environmental magnitudes.



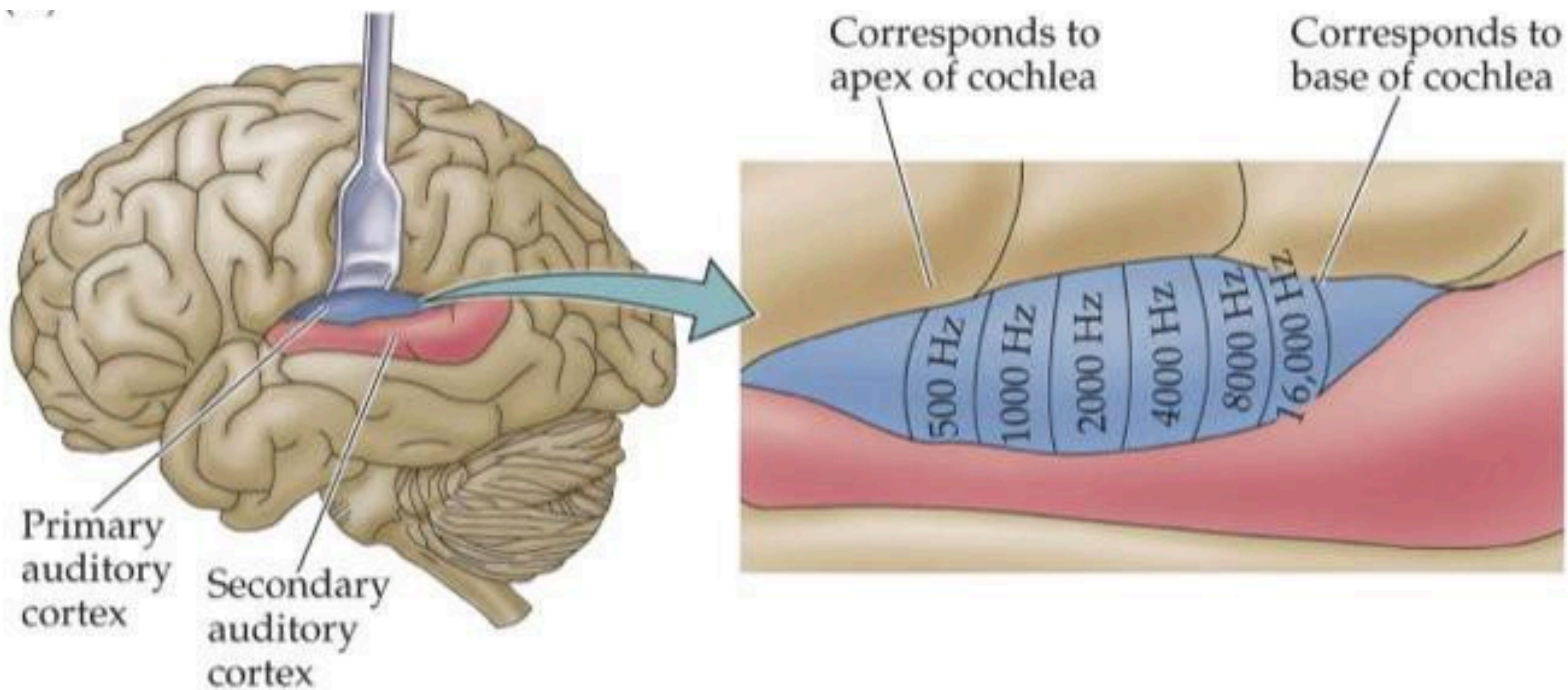


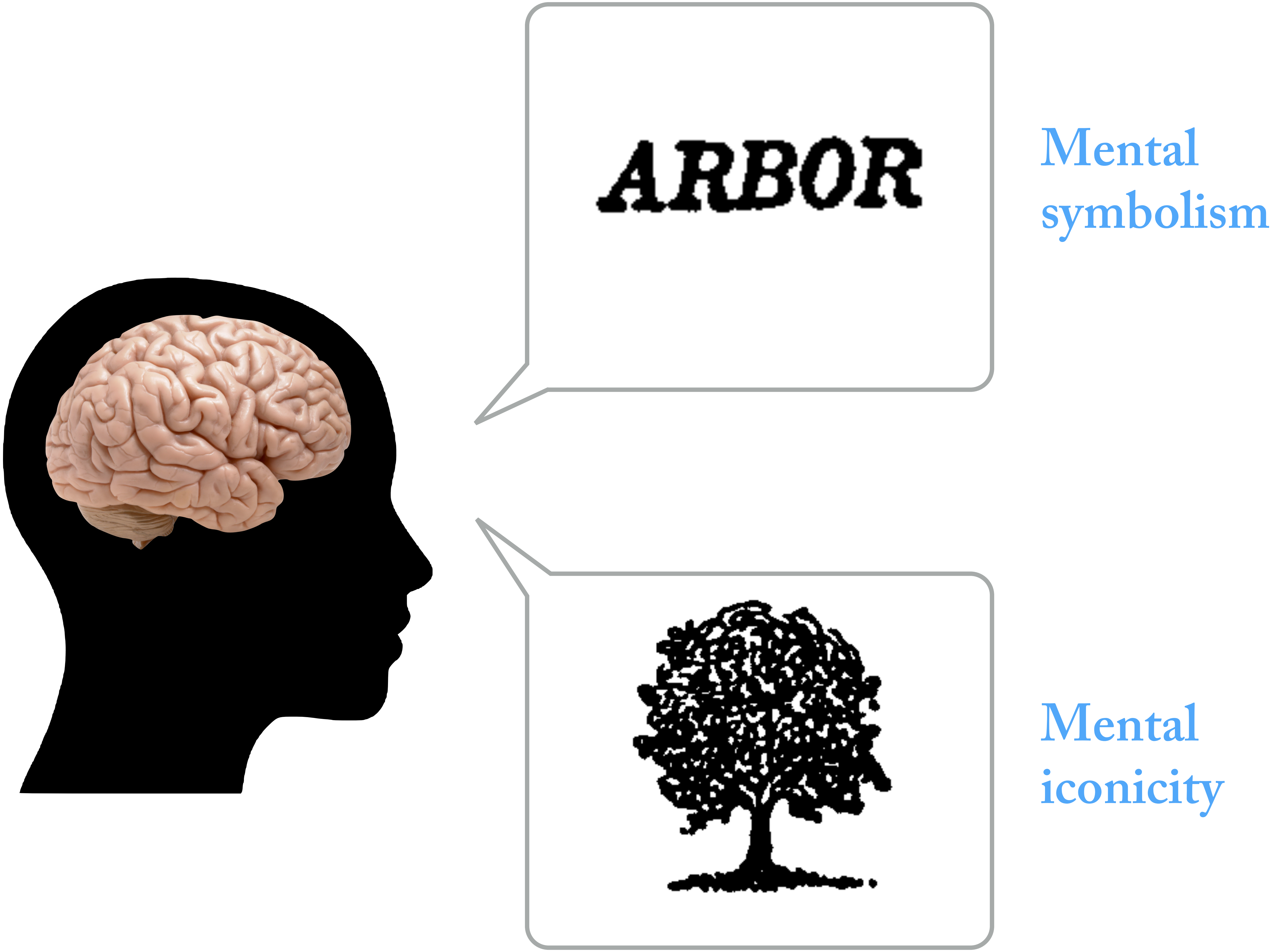
Retinotopy: areas of visual cortex in which spatial layout on the cortical sheet mirrors the spatial layout of visual space.





Tonotopy: in the primary auditory cortex, the spatial layout of the cortical sheet mirrors the gradient of sound frequencies.

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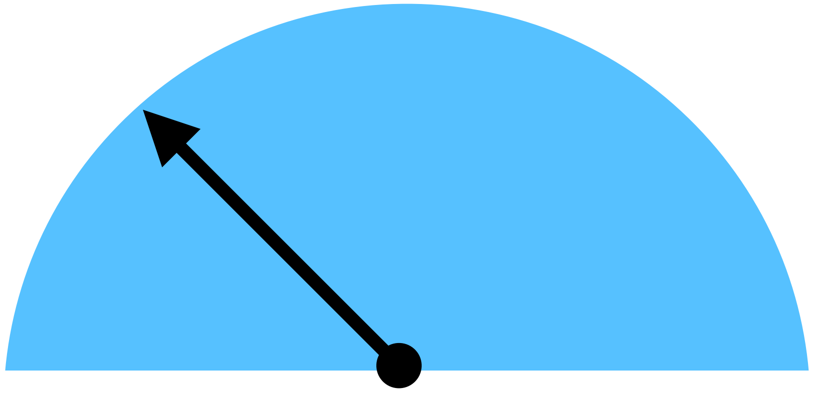
Mental symbolism
Mental iconicity

Semantics

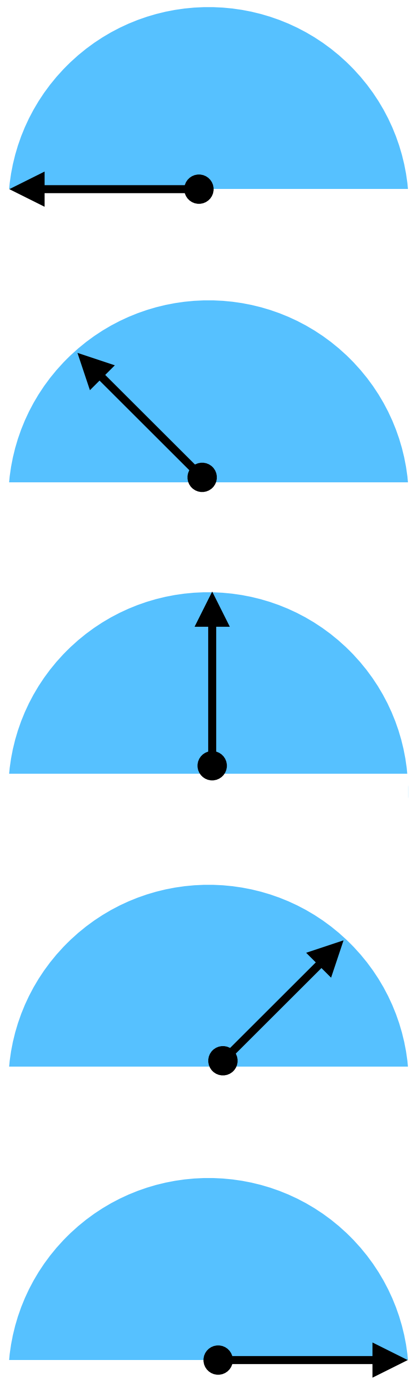
I need to signal to you how many gallons of water are in a tank.

All I've got is this simple dial…

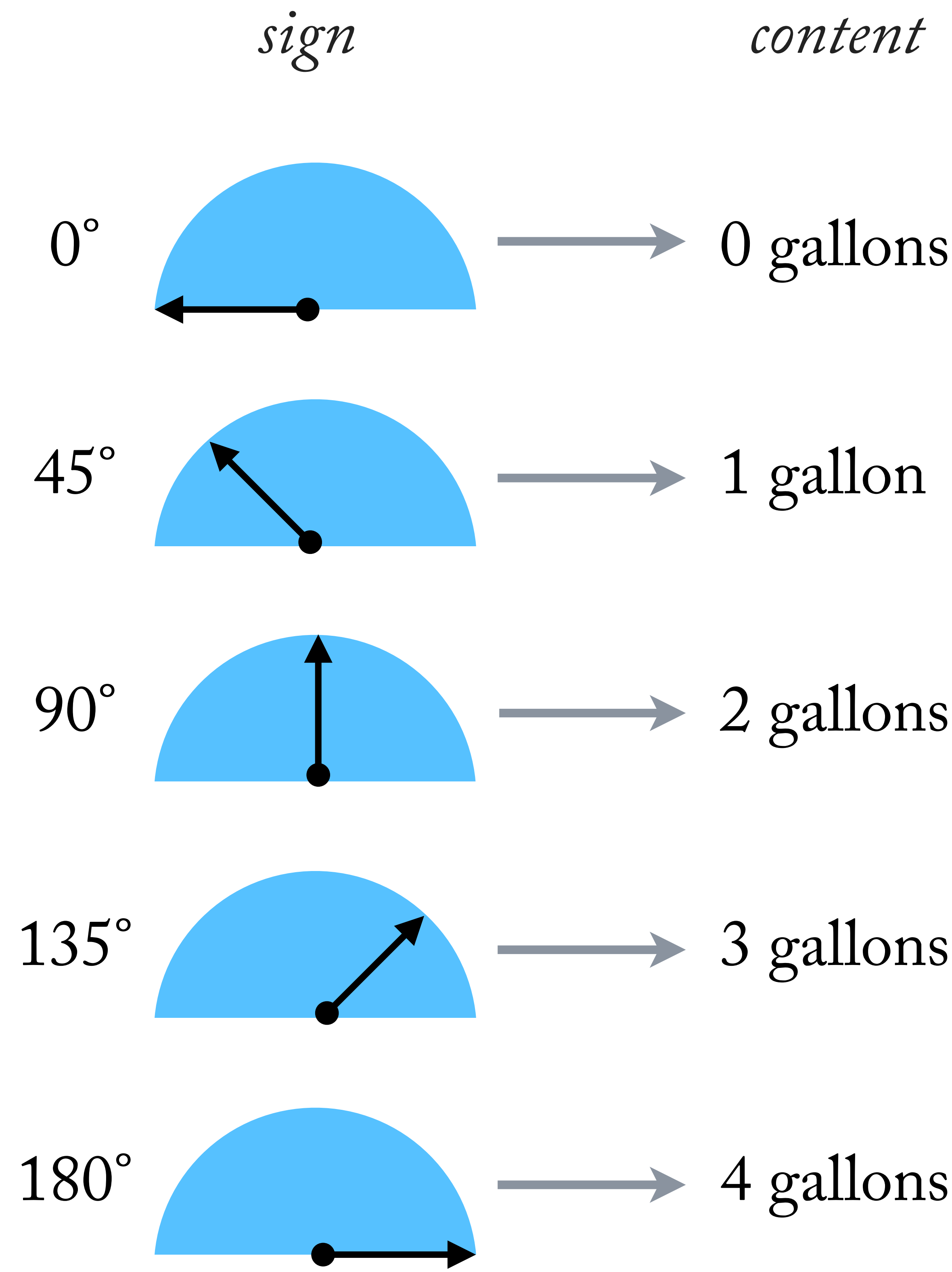


… with five possible settings

… for five possible volumes of water in the tank.

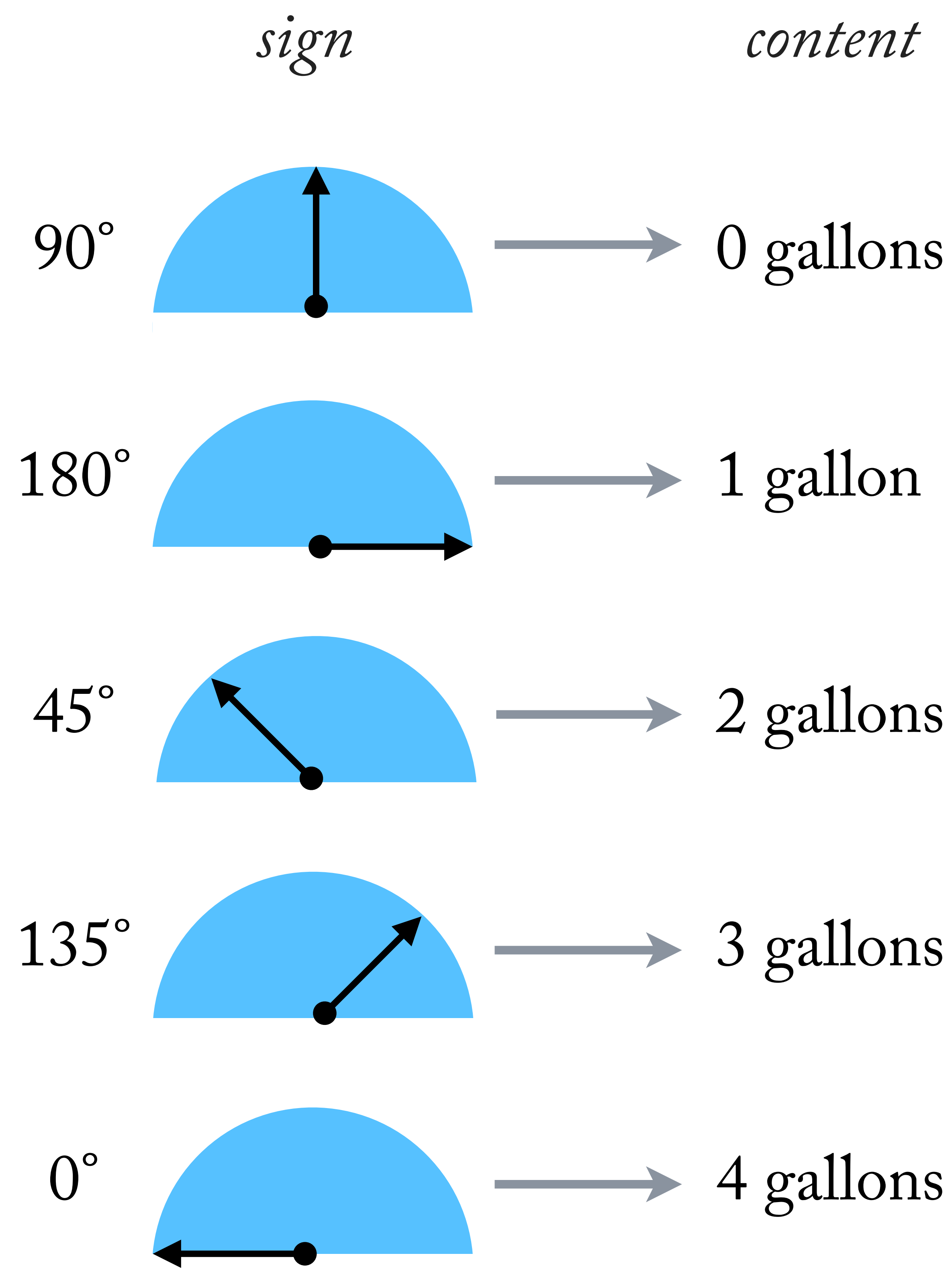


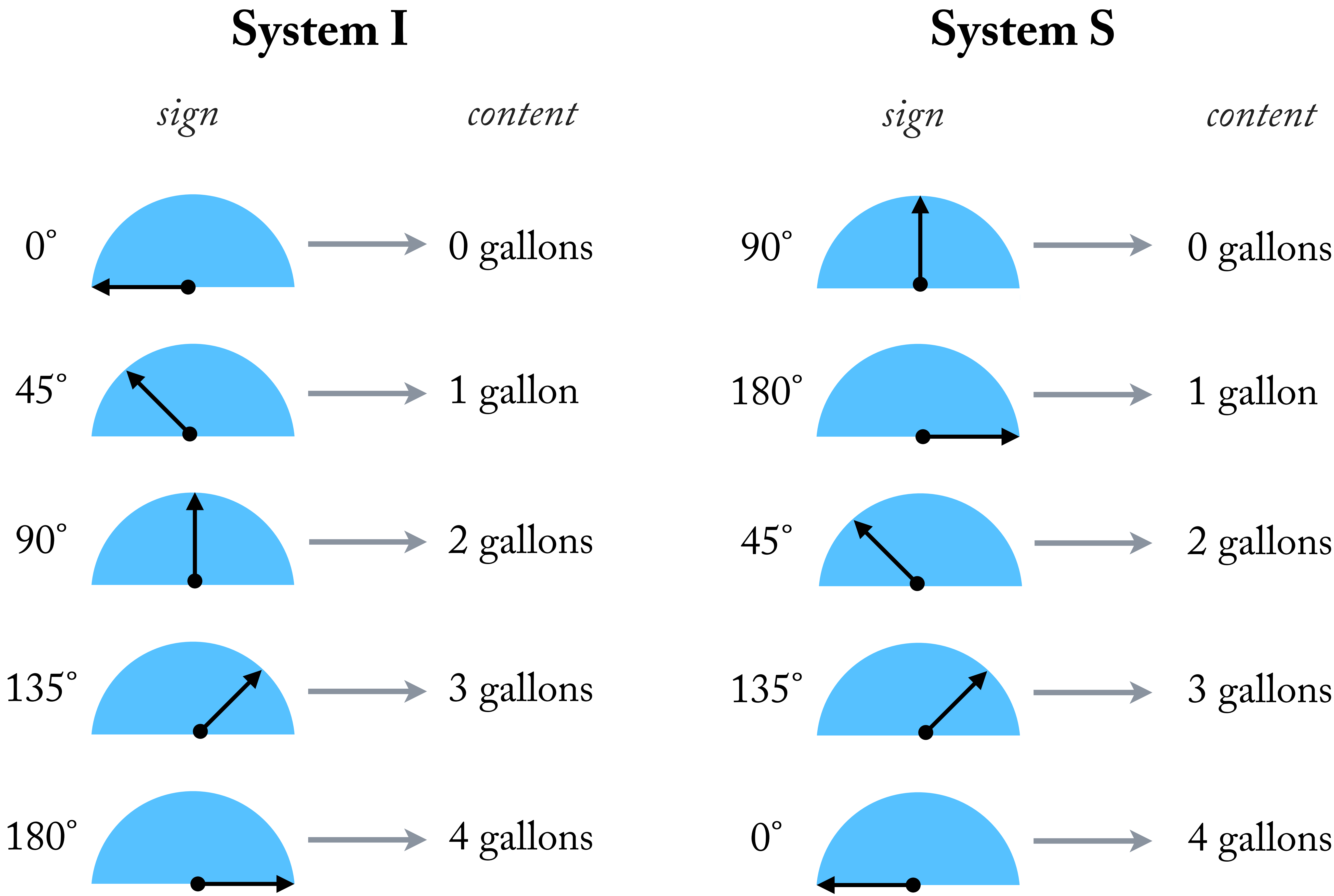
System I


sign
content
0°
0 gallons
45°
1 gallon
90°
2 gallons
135°
3 gallons
180°
4 gallons

System S

… decided by
the roll of a die




System I
sign
content
0°
0 gallons
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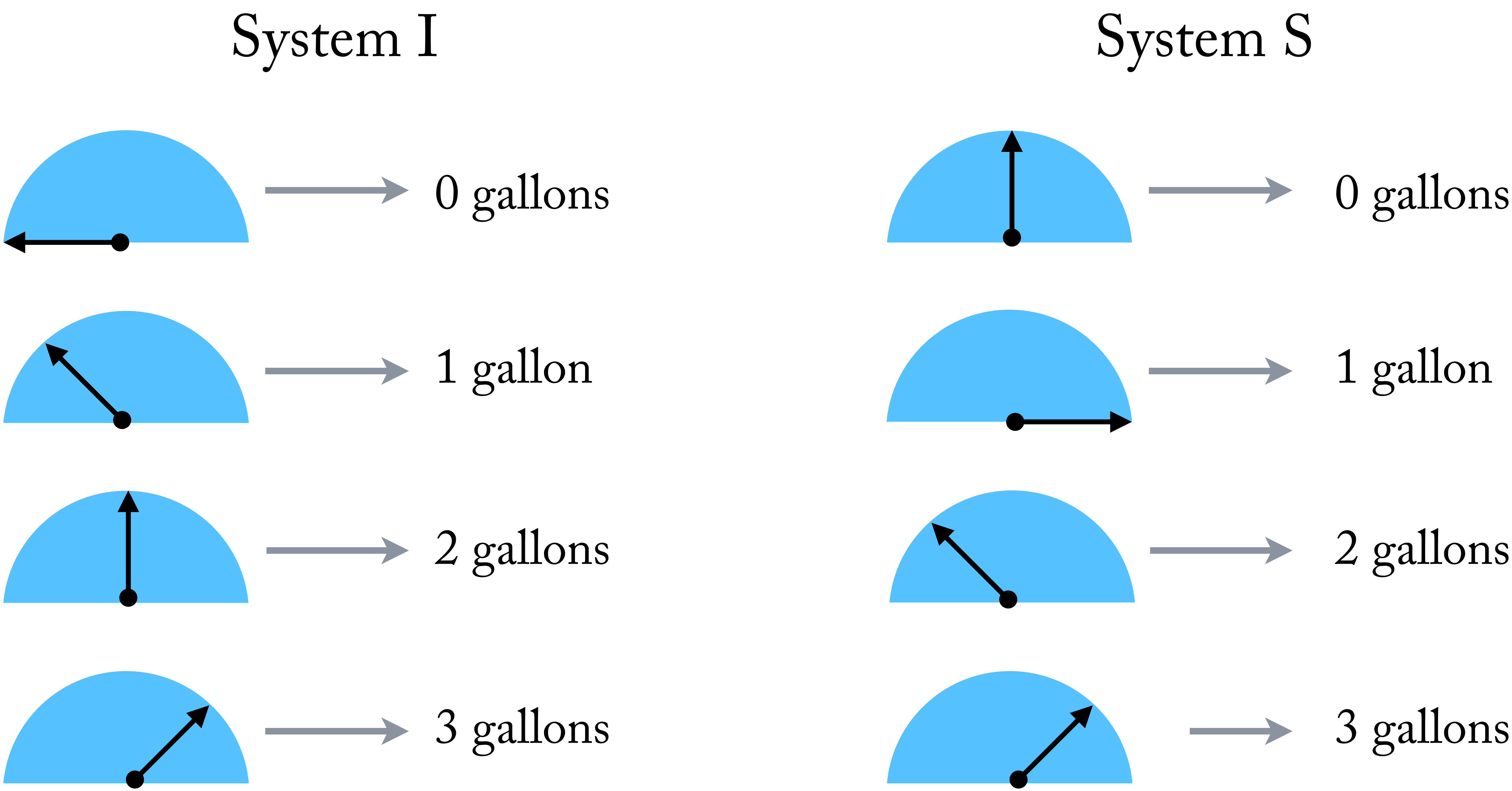
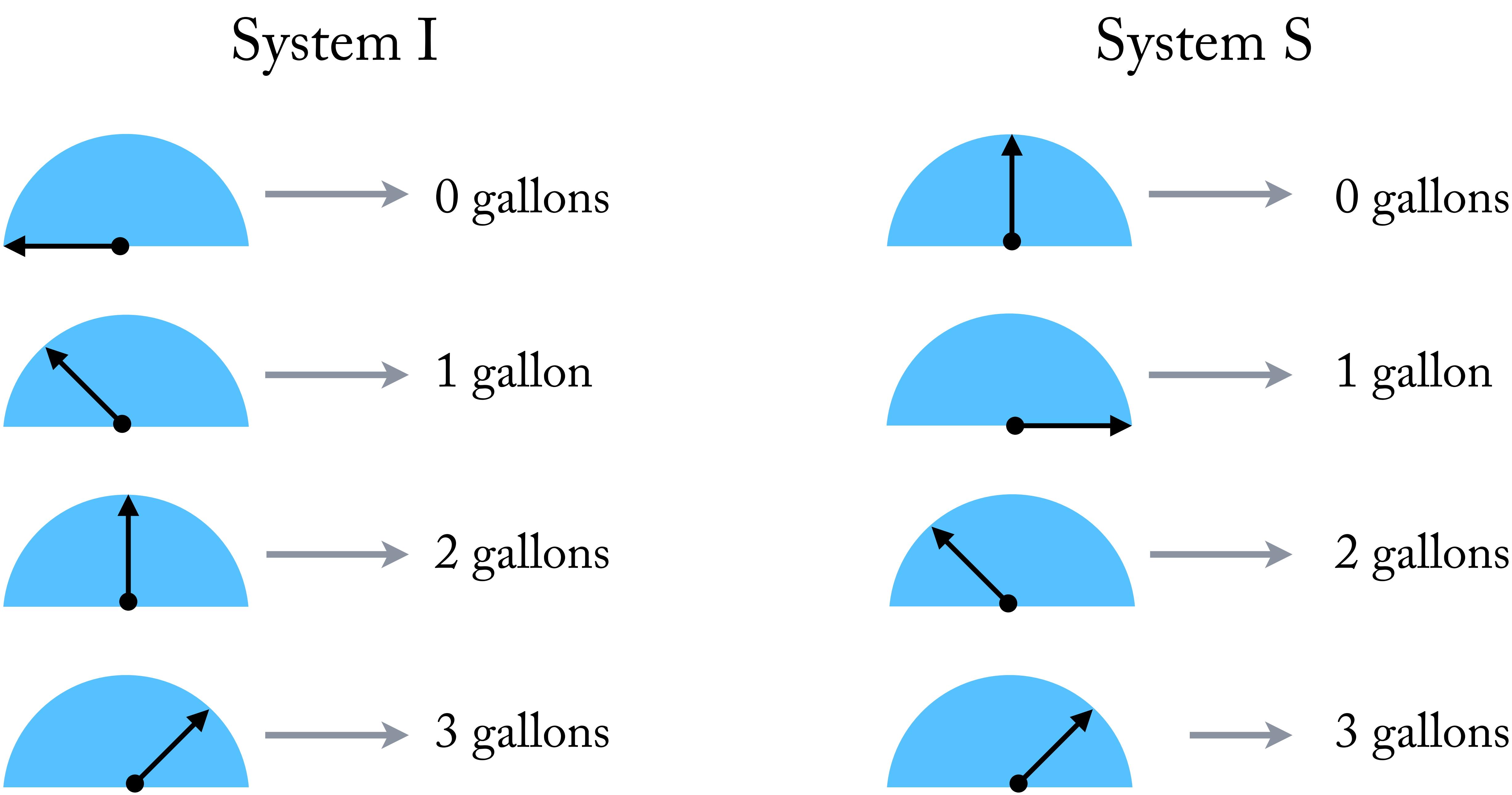
3 gallons
180°
4 gallons
System S
sign
content
90°
0 gallons
180°
1 gallon
45°
2 gallons
135°
3 gallons
0°
4 gallons

Intuitively, there is something **natural** about System I, and something **arbitrary** about System S.



Claim: System I is an exemplar of **iconic** representation and System S is an exemplar of **symbolic** representation.

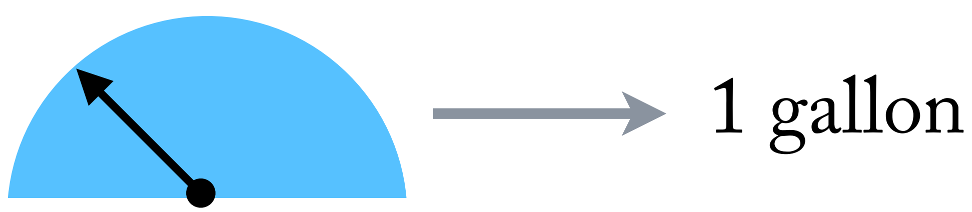


But then the difference between iconic and symbolic can't be…

… the types of signs involved,

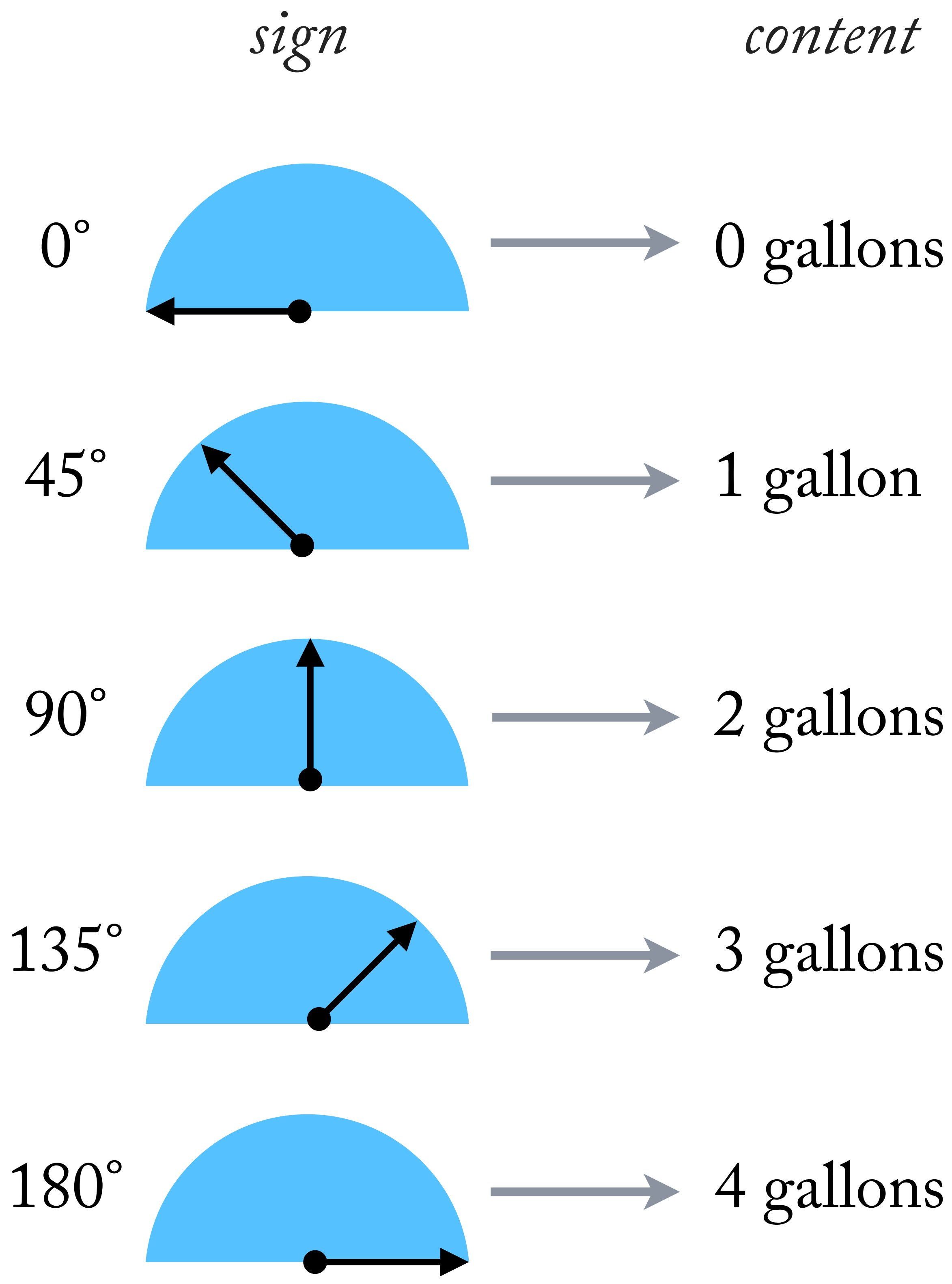
… or the types of contents expressed.

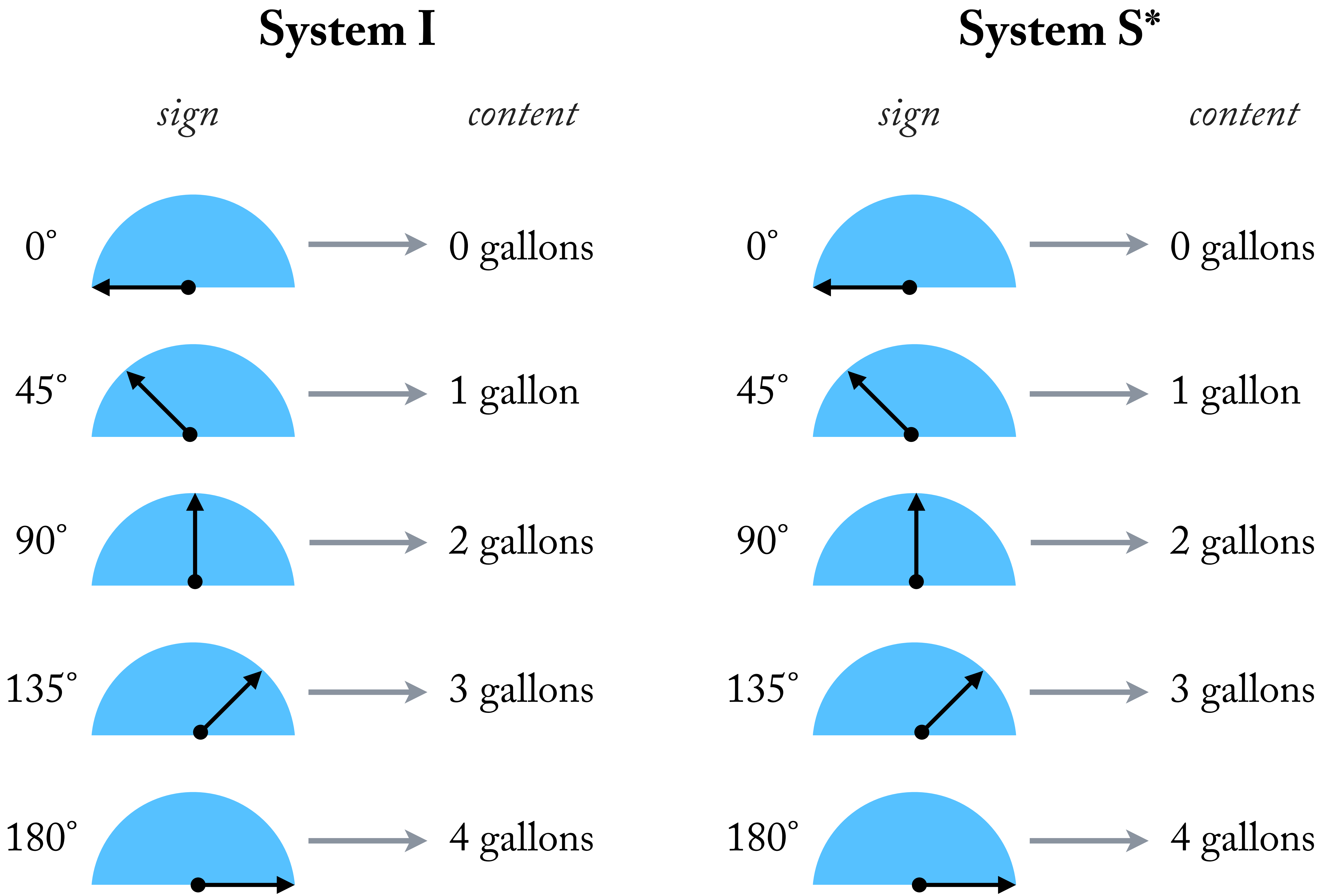
It has to be in the *way* that signs are connected contents.



System S*

… decided by
the roll of a die




System I
sign
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0°
0 gallons
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1 gallon
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180°
4 gallons
System S*
sign
content
0°
0 gallons
45°
1 gallon
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2 gallons
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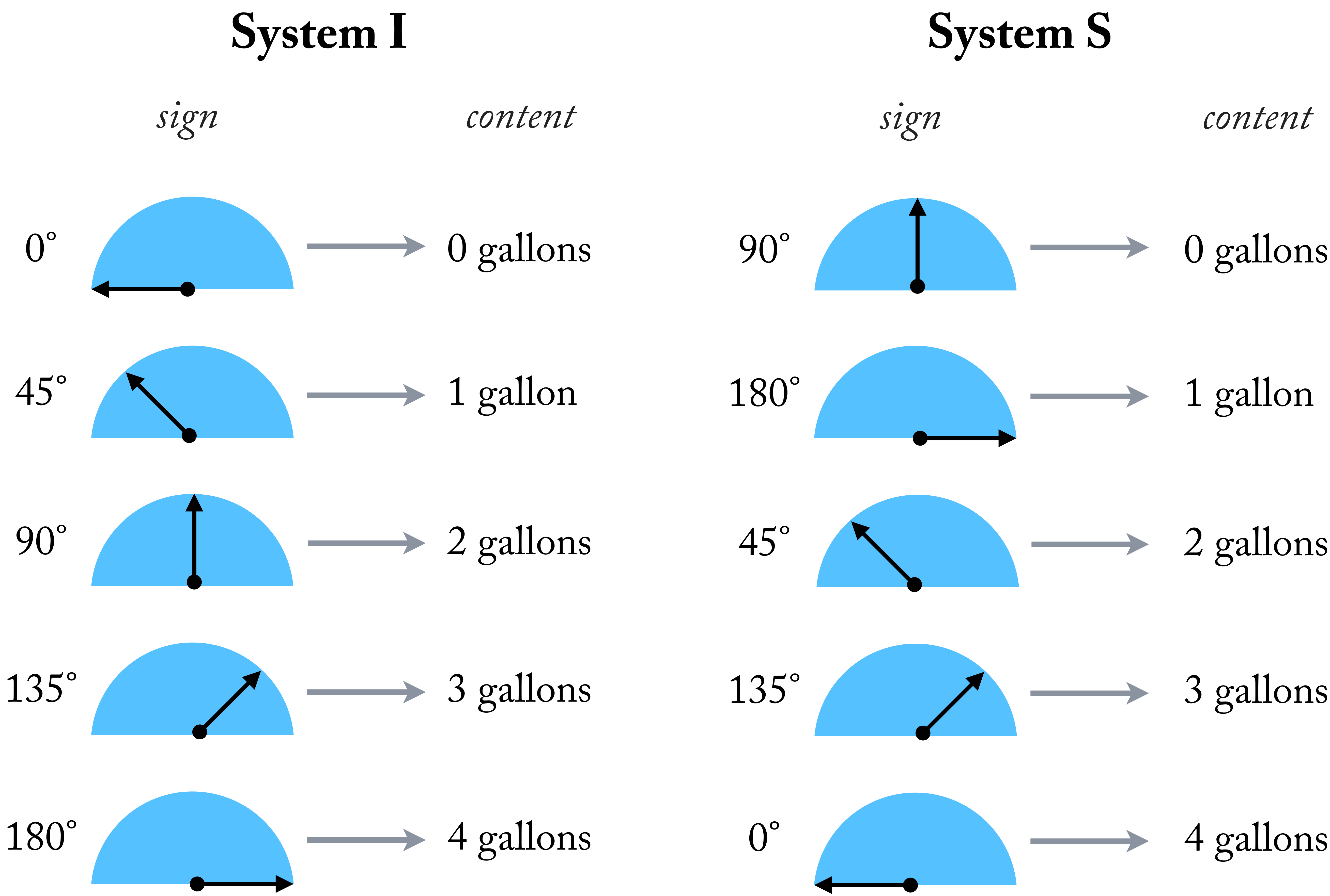
180°
4 gallons

Semantic Proposal:

We need to look "under the hood" at the semantic machinery.

The difference between iconic and symbolic representation has to do with the kinds of **semantic rules** that map signs to contents.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1 gallon
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2 gallons
135°
3 gallons
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4 gallons

Semantics for System I

For any sign *s* in I:

$$\textit{Content}(s) = \left(\textit{angle}(s) \times \frac{1}{45}\right) \textit{ gallons of water in the tank}$$

Semantics for System S

For any sign *s* in S:

- if *angle(s)* = 90, *Content(s) = 0 gallons of water in the tank;*
- if *angle(s)* = 180, *Content(s) = 1 gallon of water in the tank;*
- if *angle(s)* = 45, *Content(s) = 2 gallons of water in the tank;*
- if *angle(s)* = 135, *Content(s) = 3 gallons of water in the tank;*
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Semantics for System I

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$$\mathit{Content}(s) = (\mathit{angle}(s) \times \frac{1}{45})\ \textit{gallons of water in the tank}$$

semantic clause

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selection clause

content clause

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Observation 1: Conditionality

- System I is **uniform**: there is a single semantic clause for all sign types; it treats all sign types in the same way.
- System S is **itemized**: there is a separate semantic clause for each sign type; it treats each sign type differently.

Semantics for System I

For any sign *s* in I:

$$\textit{Content}(s) = (\textit{angle}(s) \times \frac{1}{45})\ \textit{gallons of water in the tank}$$

Iconic rules

- Uniform

Semantics for System S

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Symbolic rules

- Itemized

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Iconic rules

- Uniform

Symbolic rules

- Itemized

Observation 2: form-dependence

- System I is **form-dependent**: the form of the sign plays an essential role in the content clause.
- System S is **form-independent**: properties of the sign do not appear in the content clause.

Semantics for System I

For any sign *s* in I:

$$Content(s) = (angle(s) \times \frac{1}{45})\ \textit{gallons of water in the tank}$$

Semantics for System S

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Iconic rules

- Uniform
- Form-dependent

Symbolic rules

- Itemized
- Form-independent

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Iconic rules

- Uniform
- Form-dependent

Symbolic rules

- Itemized
- Form-independent

Observation 3: natural dependency

- System I implies a relationship of **natural dependency** between the form of a sign and its content.
- System S merely **juxtapose** signs with contents, with no mediating dependency.

Iconic rules are (i) **uniform** and (ii) **form-dependent**.

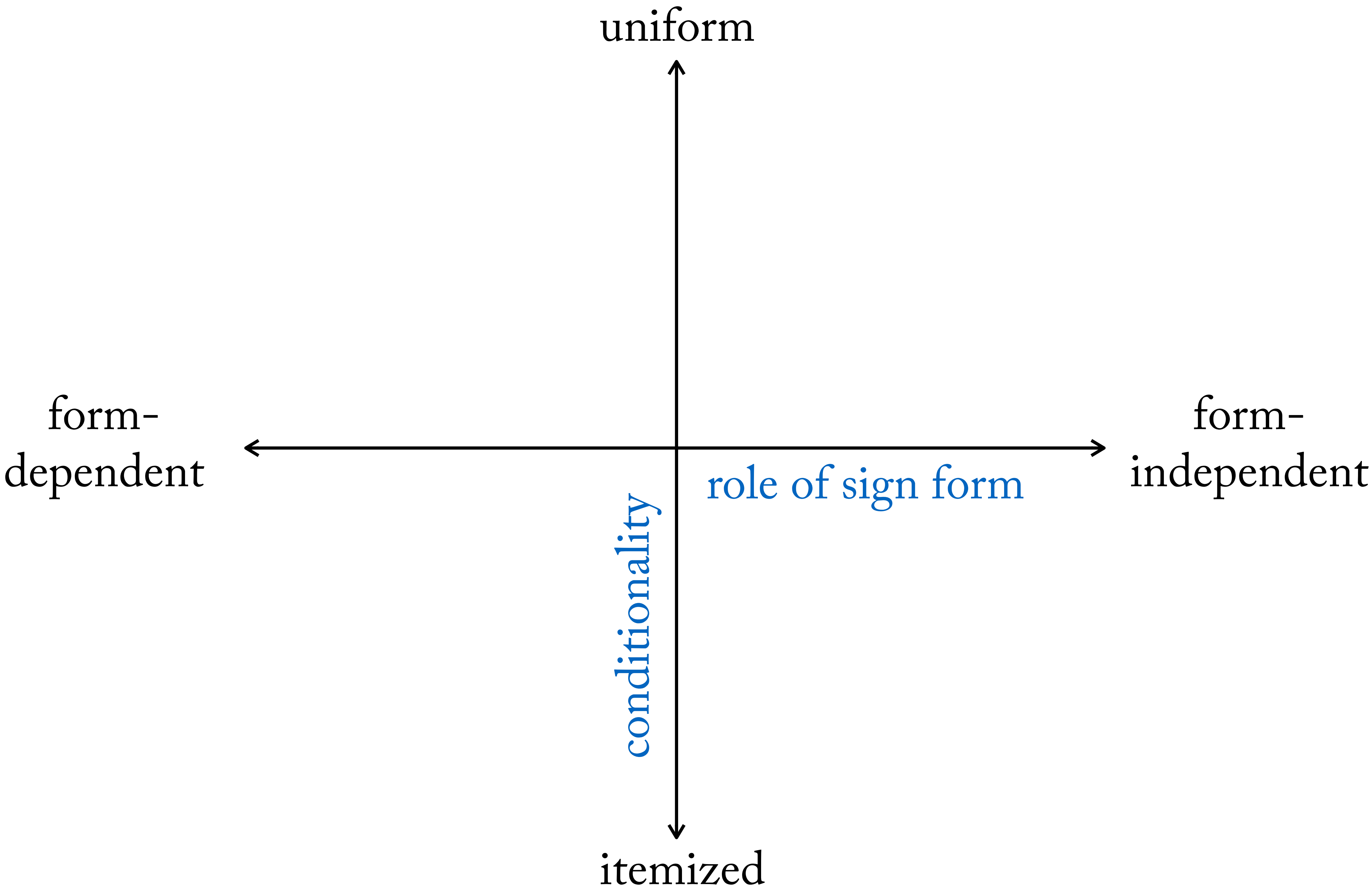
(i) **Uniform:** all sign-types are interpreted in the same way.

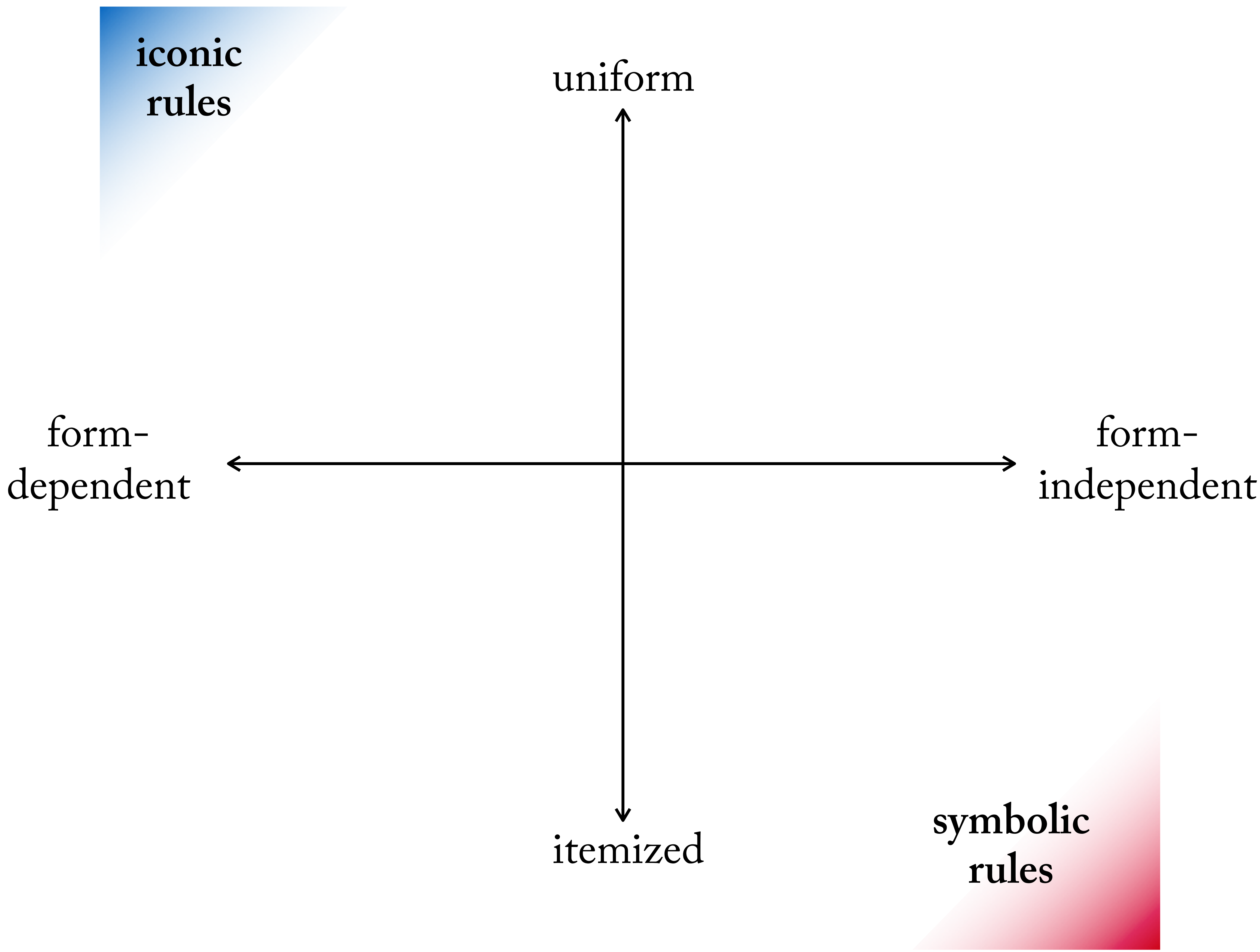
(ii) **Form-dependent**: the content of the sign bears a natural dependency to the form of the sign.

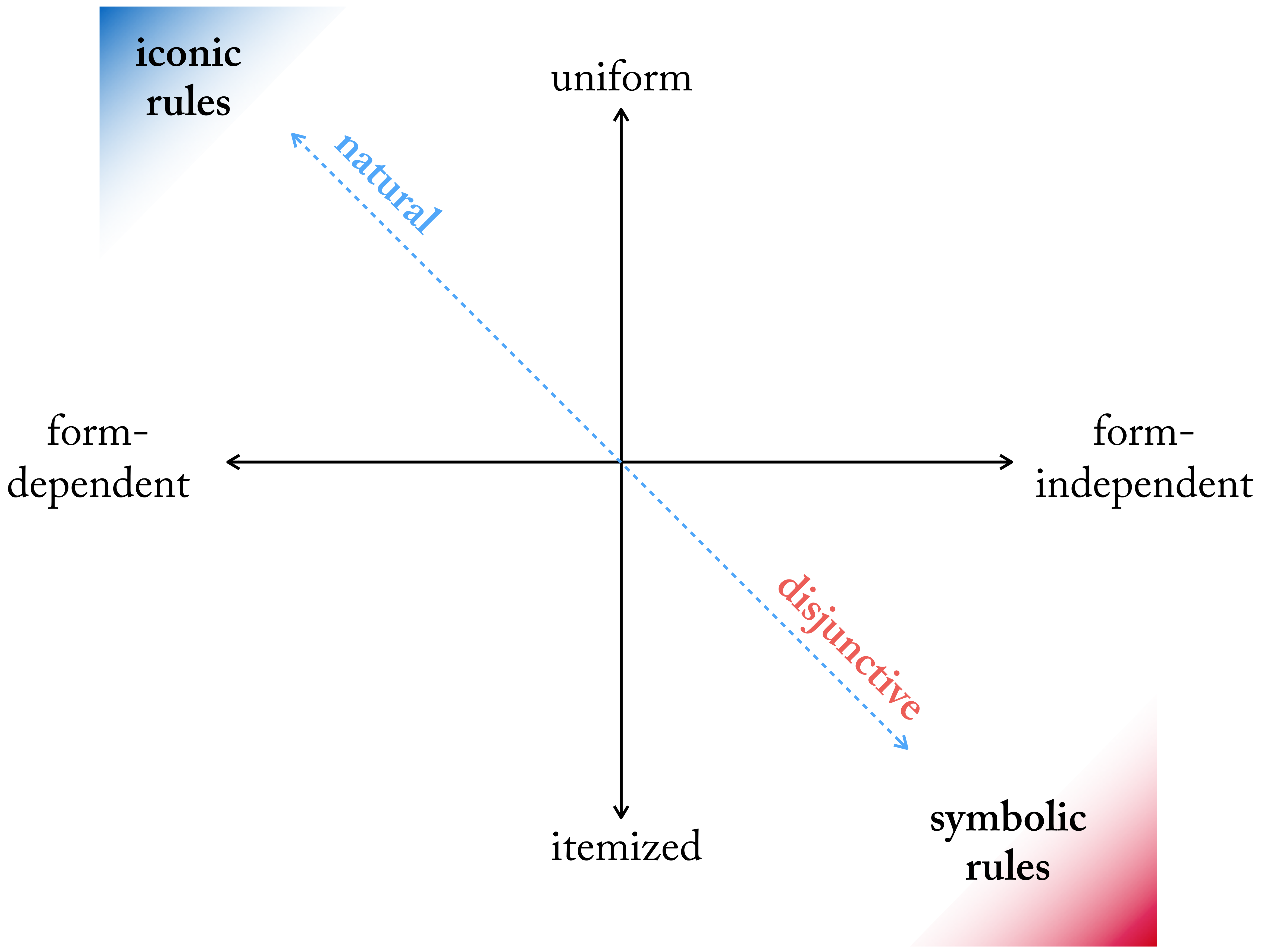
Symbolic rules are (i) **itemized** and (ii) **form-independent.**

(i) **Itemized**: each sign-types is interpreted in a different way.

(ii) **Form-independent:** the content of the sign does not depend on the form of the sign.


uniform
form-dependent
form-independent
role of sign form
conditionality
itemized


iconic rules
uniform
form-dependent
form-independent
itemized
symbolic rules


iconic rules
uniform
natural
form-dependent
form-independent
disjunctive
itemized
symbolic rules

Mental representation

Iconicity and symbolism in the mind

- If iconic and symbolic representation are distinguished by **semantic rules**, how is iconic and symbolic **mental** representation possible?
- There is **no homunculus** or privileged observer to interpret mental representation or encode their semantics.
- **Proposal:**
  - Semantic rules for representations in the brain are grounded in **functions to carry information**.
  - **Iconic and symbolic functions** are two different ways of functioning to carry information.
- **Plan:** Identify mental counterparts of I, S, and S*

Informational teleosemantics

- **Informational teleosemantics:** content is grounded in functions to carry information.
- **Progenitors:** Millikan, Papineau, Shea, Neander, Godfrey-Smith, et al.
- **For now:** a working framework for informational teleosemantics.
    - **Naturalistic ambitions**: grounding, not reducing.
    - **Semantics:** building a bridge between semantics and teleosemantics.
    - **Domain**: first-order representations in perception and lower cognition. For now…

Informational teleosemantics, a framework

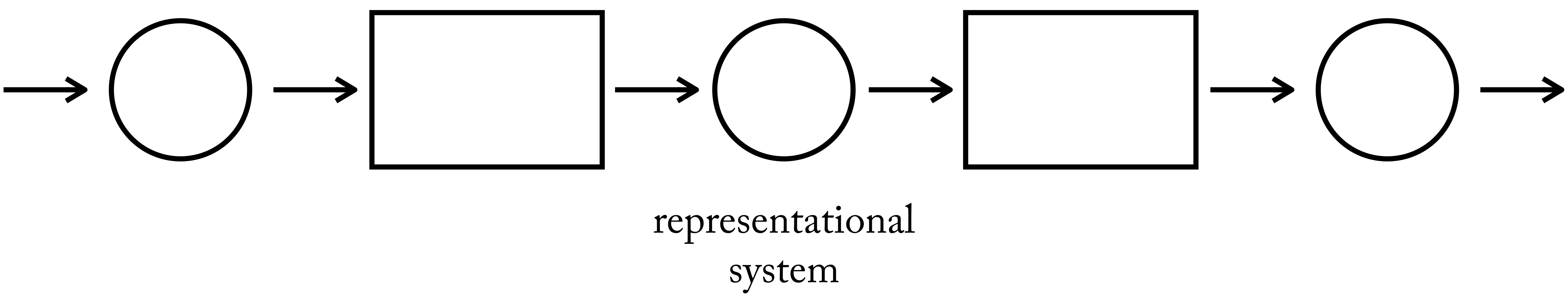
- **Functions**, roughly: the **function** of a system S is the **effect** that S was **selected** for.

- **Information**, roughly: an internal state **carries information** about an external state by standing in a relationship of **counterfactual covariation** to it.

- **Informational functions: representational systems** function to produce internal state types that counterfactually covary with environmental state types.

Representation and computation

- **Representational systems** function to token internal states that covary with external states.
- **Computational systems** function to compute mappings by transforming input states into output states.
- Cognitive processes can be idealized as **computational graphs**, made up alternating activations of representational and computational systems.



computational graph

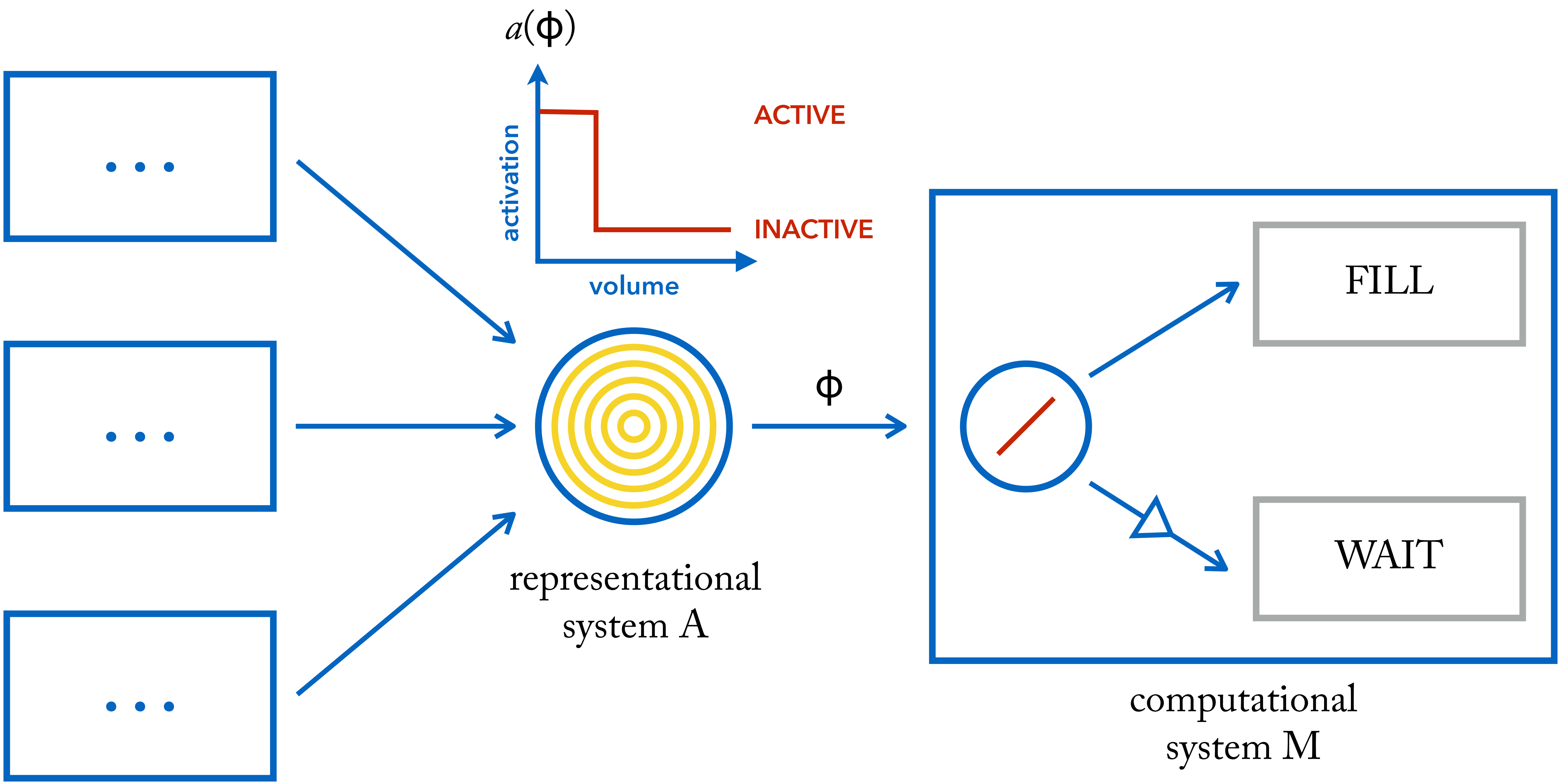
Case study: System A

- **Organism O** must refill a **fluid reserve U** when it is empty in order to survive and reproduce.

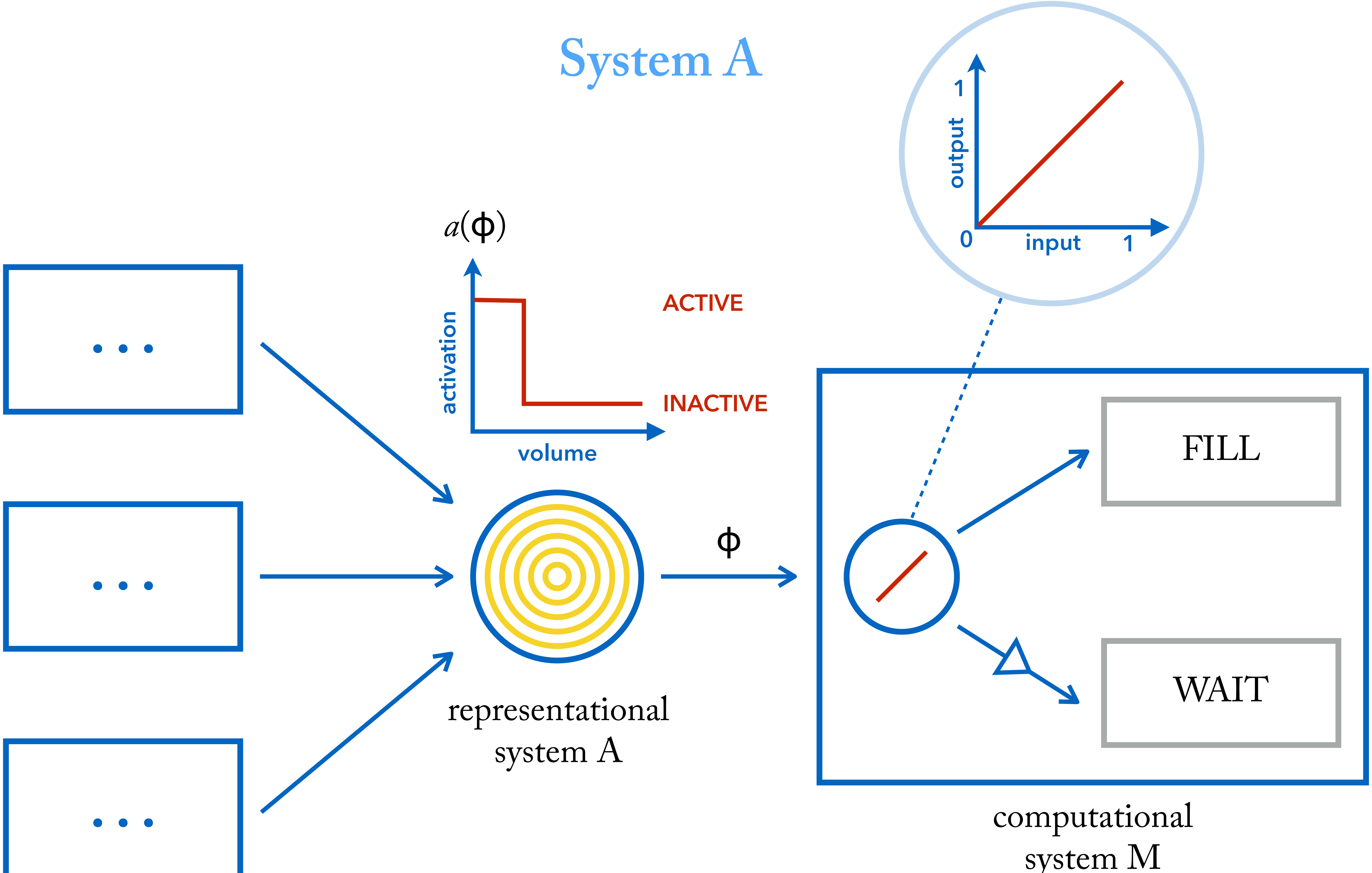
- **Representational system A** enters into two states: **active** and **inactive**.

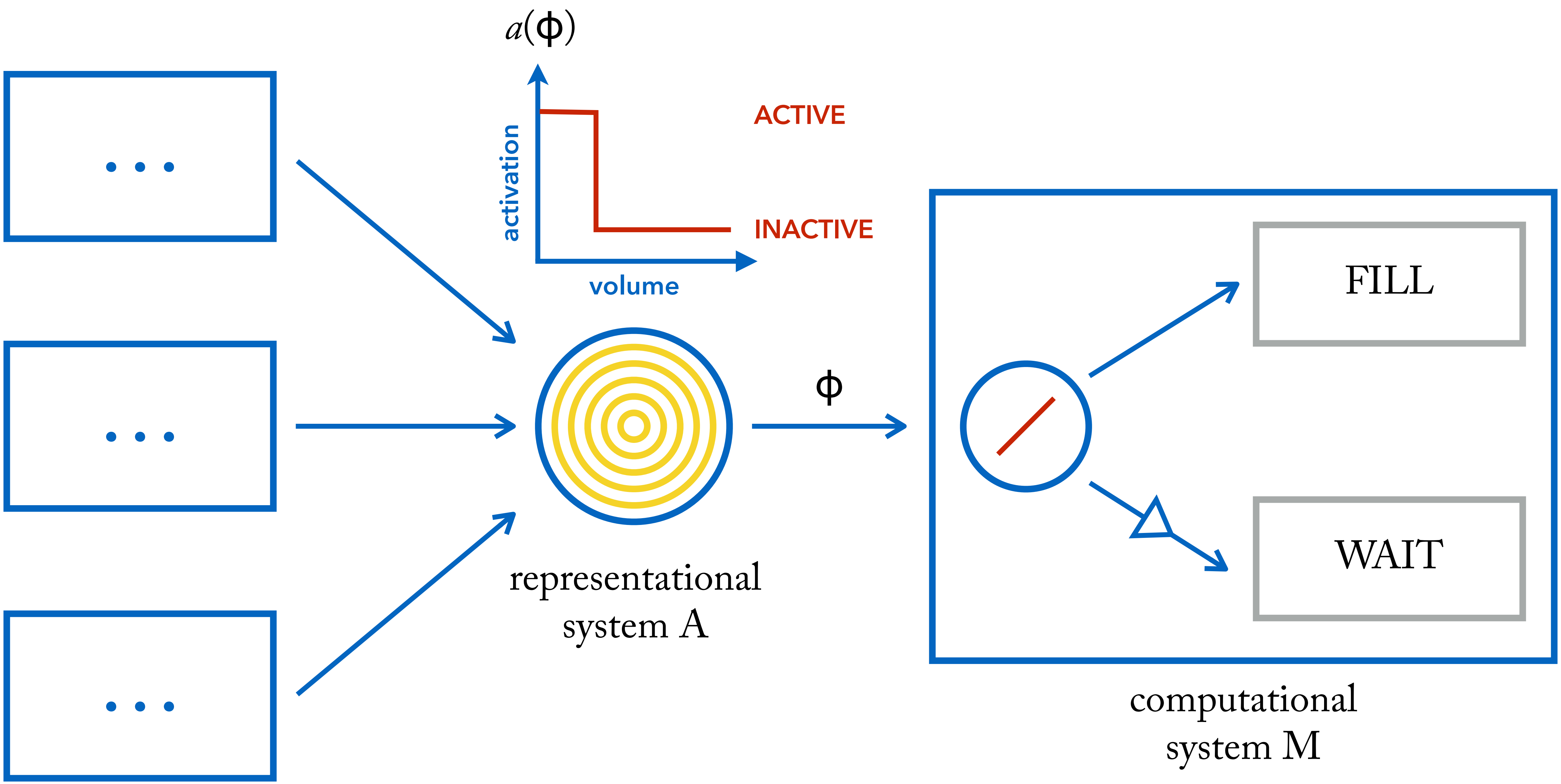
- **Computational system M** takes inputs from A (active, inactive) and outputs motor actions: **fill**, **wait**.

System A



. . .
. . .
. . .
a(ϕ)
activation
volume
ACTIVE
INACTIVE
ϕ
representational
system A
FILL
WAIT
computational
system M


System A
a(ϕ)
activation
volume
ACTIVE
INACTIVE
output
input
1
0
1
ϕ
FILL
WAIT
representational
system A
computational
system M

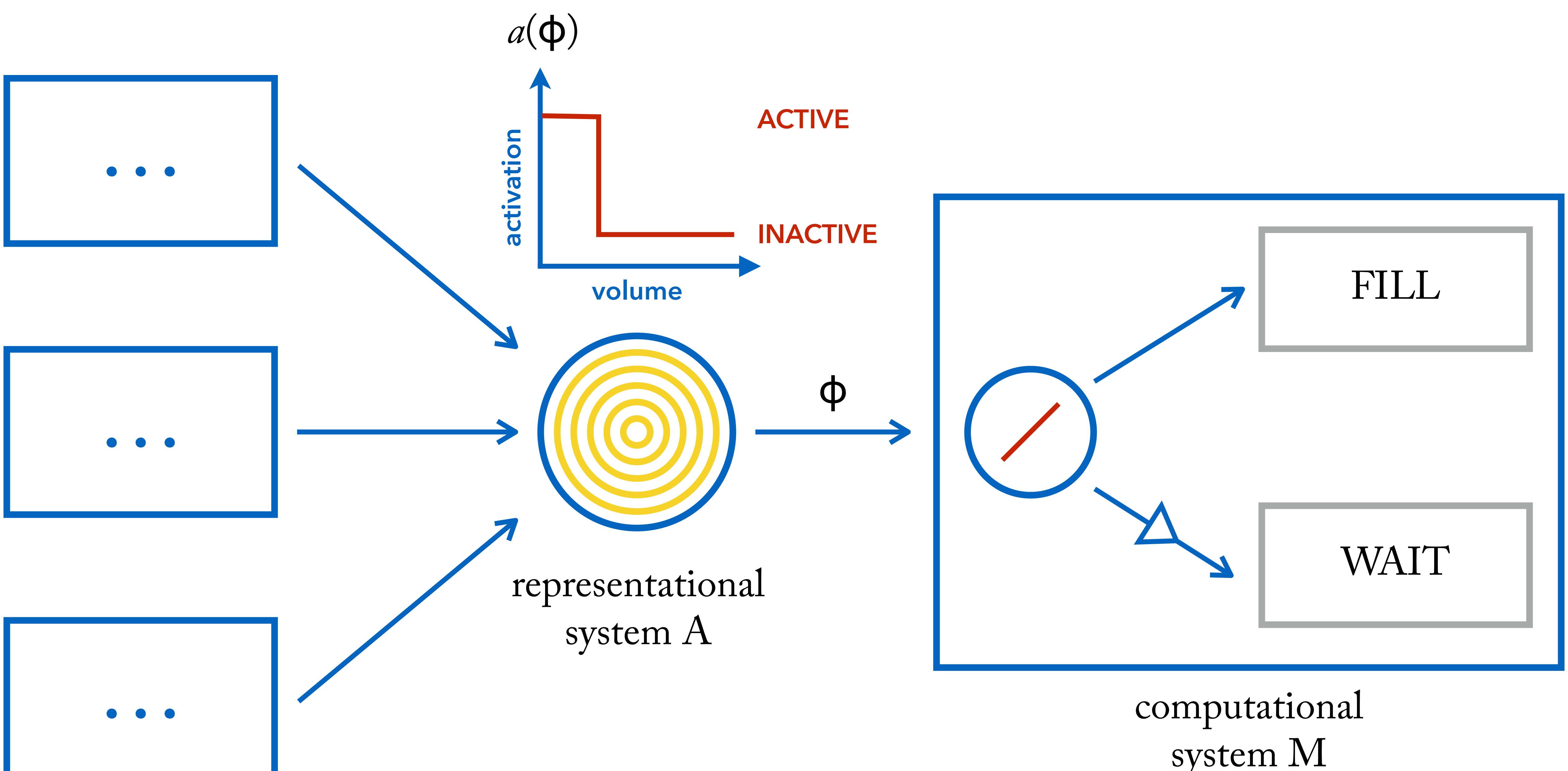


$a(\phi)$
activation
volume
ACTIVE
INACTIVE
. . .
. . .
. . .
ϕ
representational system A
FILL
WAIT
computational system M

The function of A is satisfied only if
if A produces ϕ:

if $a(\phi) = 1$, then *Empty*(t);

if $a(\phi) = 0$, then *Not-empty*(t).



Information as weak covariation

- A system functions to carry information about a target situation.
- A **target** *t* typically determines a world, time, viewpoint, or object.
- S functions to **carry information** about target *t* ≈
  - S functions to produce internal states *i* that **covary** with external states *e* of *t*.
- **Covariation** is counterfactually supported (reliable) co-occurrence of state types.
  - **Strong:** *i* occurs if and only if *e* occurs.
  - **Weak** (**indication**)**:** *i* occurs only if *e* occurs.
- I'll use "covariation" to mean **weak covariation** (≈ Dretske's "indication").

From informational functions to content

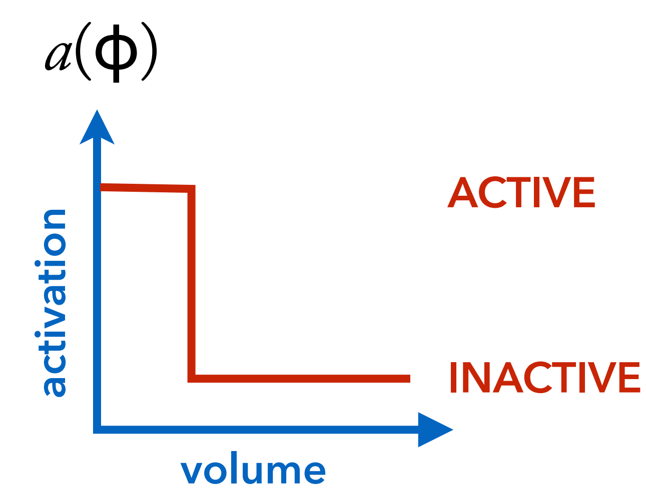
- **The content of a representation** is the set of conditions that tokens of the representation must covary with in order for its system to function properly.
- **Content** as an abstraction over the functional information carried by individual representations.
- **Abstraction principle:**

$$Content_S(\phi) = \beta \quad \Leftarrow \quad \text{the function of } S \text{ is satisfied only if } S \text{ tokening } \phi \text{ covaries with } \beta \text{ } (target_c)$$

- **Derived functions:** the abstraction principle doesn't look at what a system functions *to do* (direct function), but what *must be the case* when a system is functioning properly (derived function).

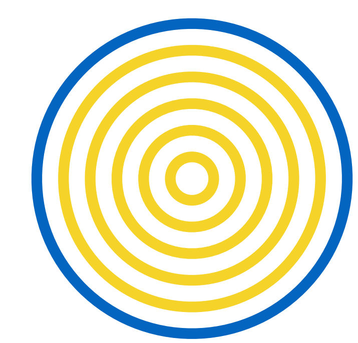
System A's informational function

- The function of system A is satisfied in context c only if
  - for any state ϕ produced by A in *c*:
    - if *activation*(ϕ) = 1, then *Empty*(t_c);
    - if *activation*(ϕ) = 0, then *Not-empty*(t_c).



Content in System A

- *Content*(1) = *Empty*( );
- *Content*(0) = *Not-empty*( ).



representational system A

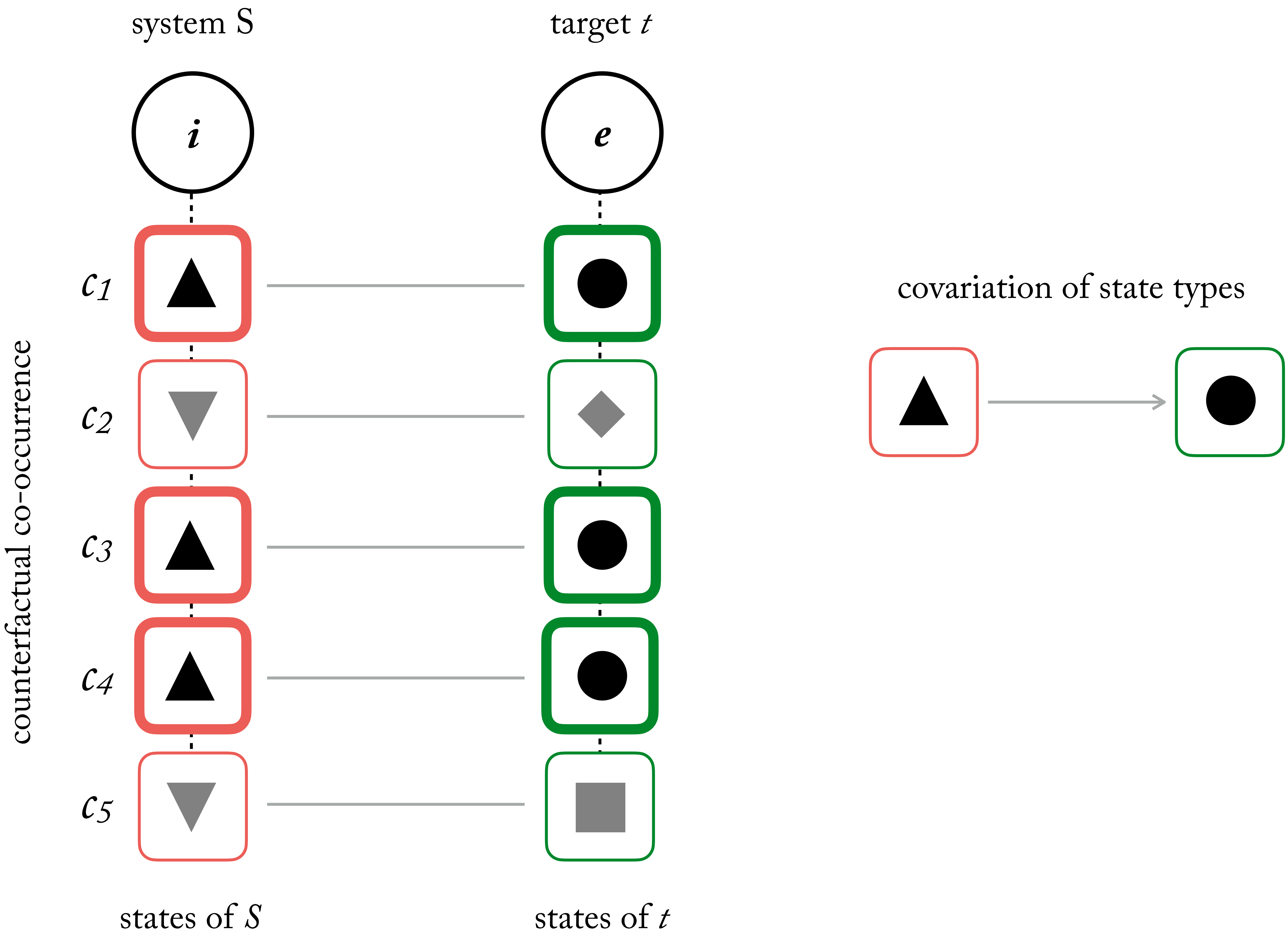
Iconic and symbolic functions

Iconic and symbolic functions

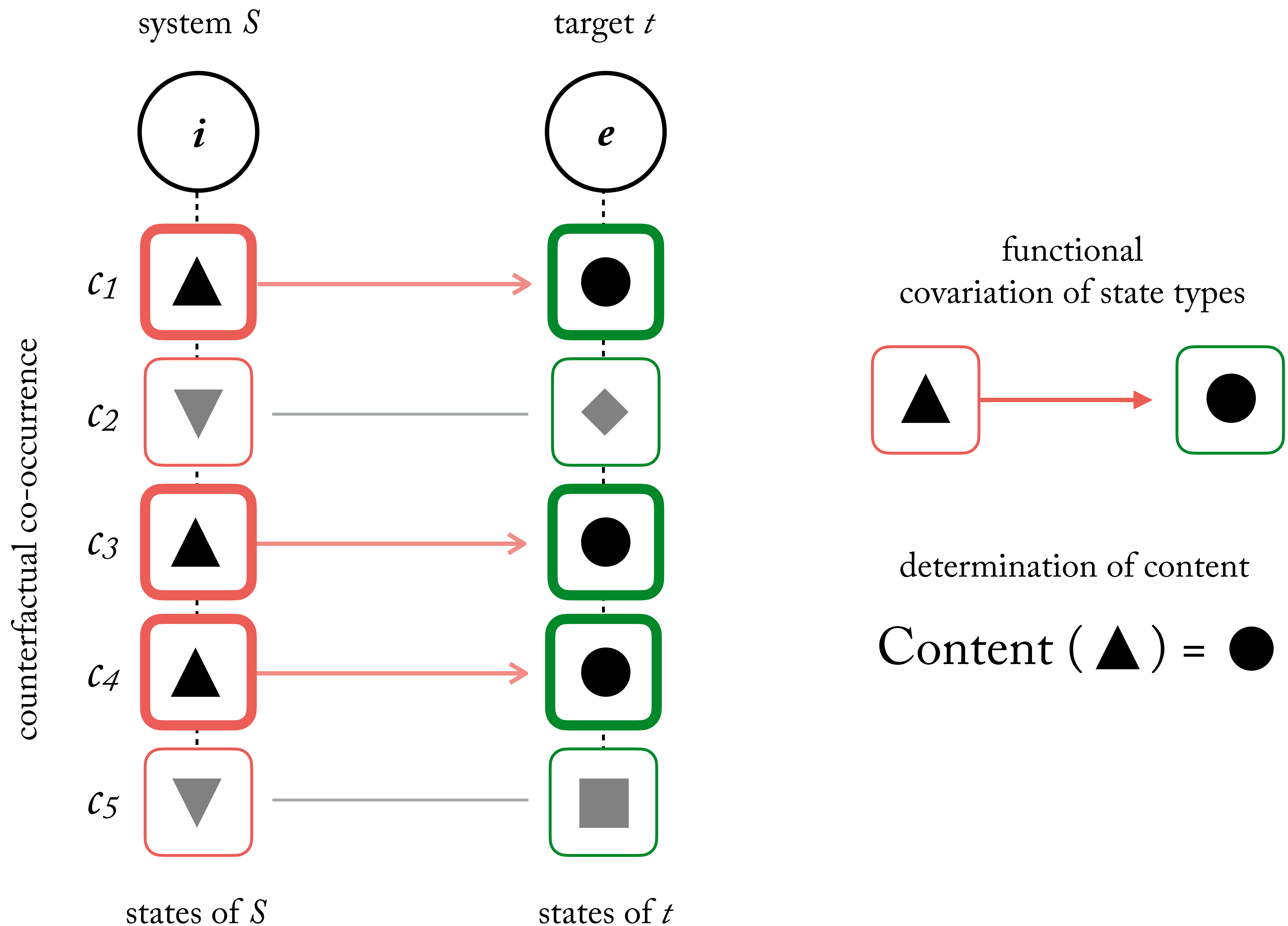
- Iconic and symbolic functions mark **two ways** a system can function to carry information about the environment.
- **Symbolic functions** are functions to token representations in covariation with states of the target.
- **Iconic functions** are functions to token representations whose form bears a natural dependence on states of the target.
  - Both entail functional covariation between representation types and external state types, so both give rise to content.

- **Compare:** Shea (2018) on functions for *correlation* vs. *structural correspondence*; Neander (2017) on *causally driven analogs*; Burge (2021, 305) on *iconic information registration*.

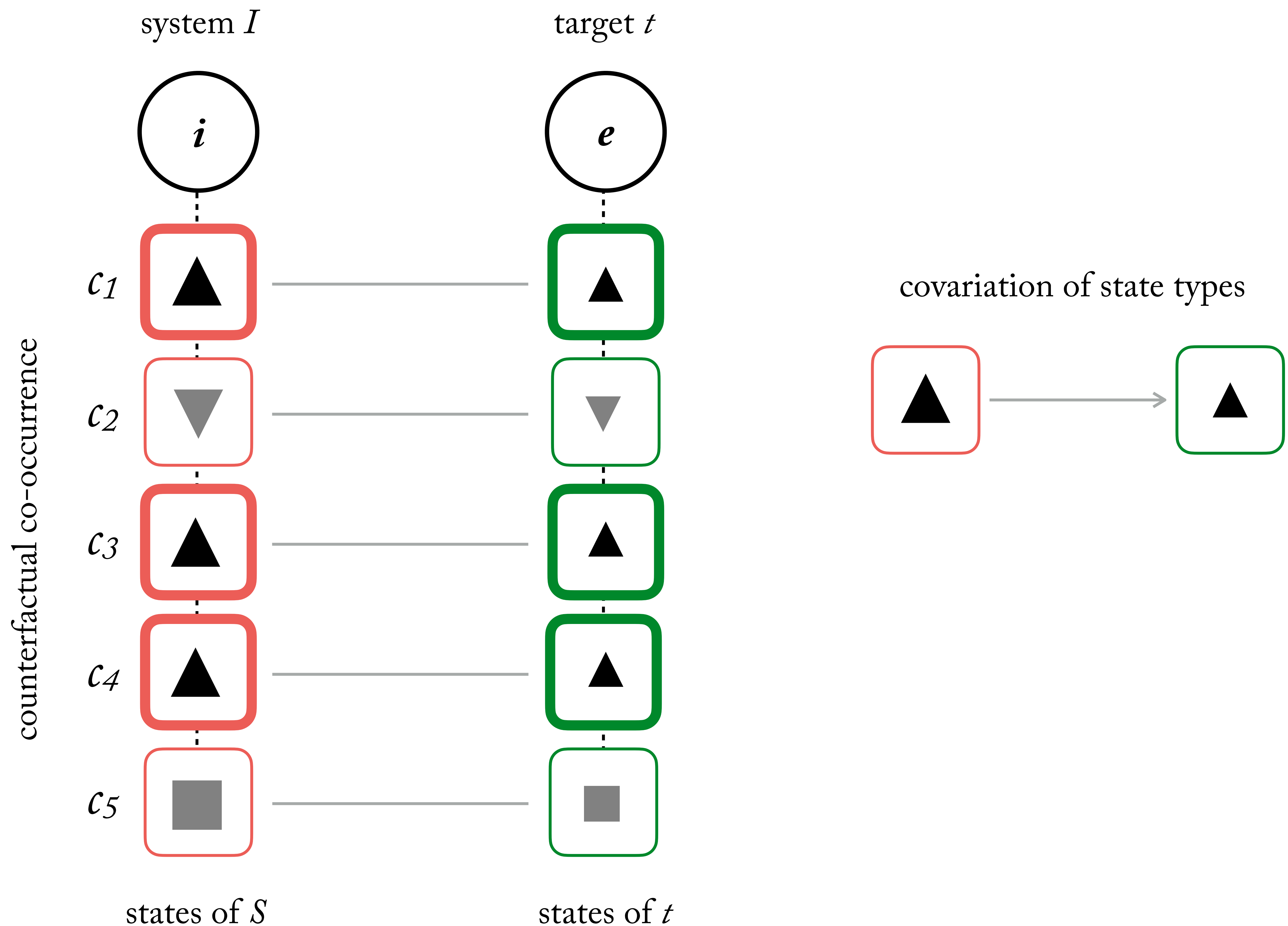
Symbolic informational function

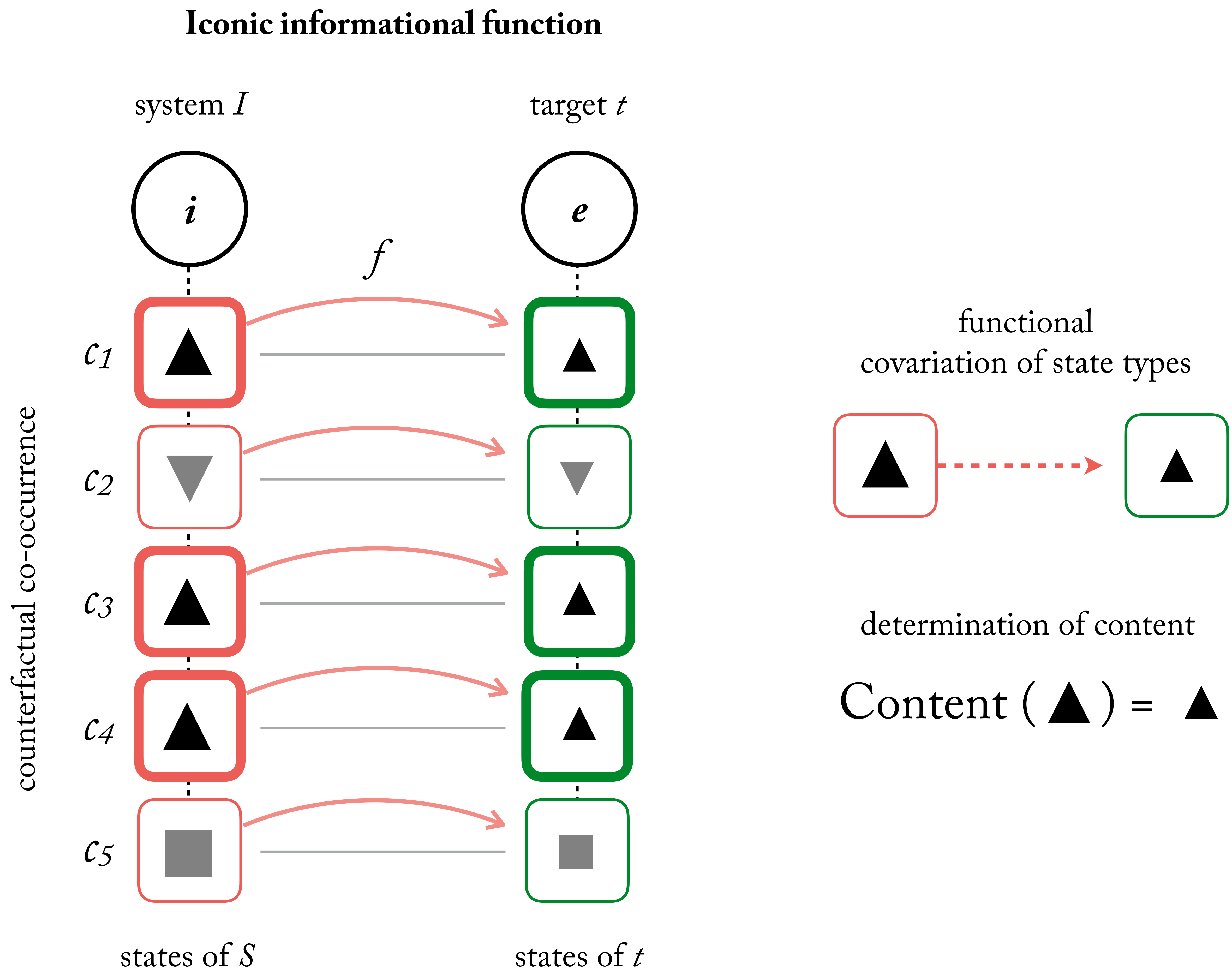


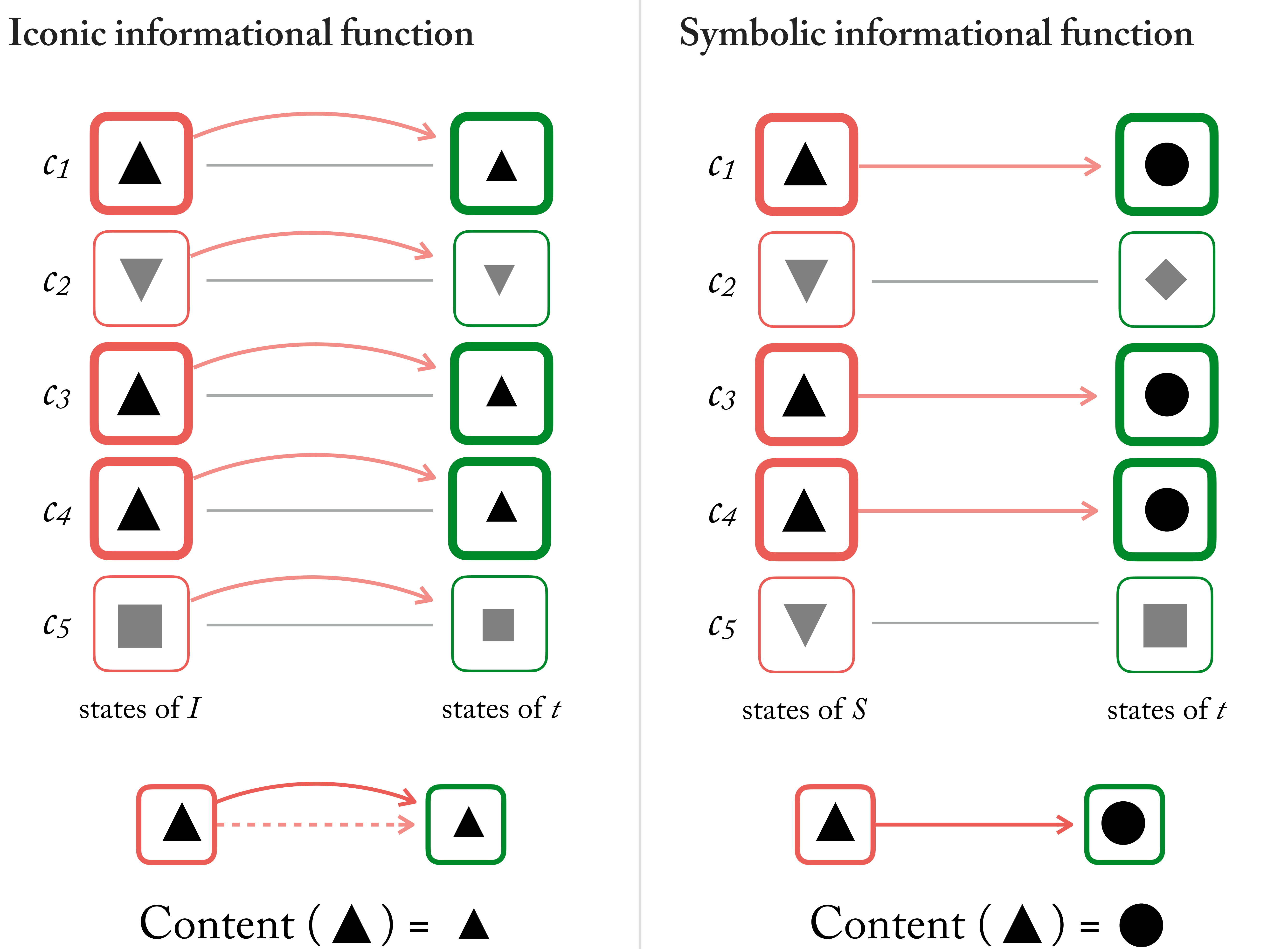
Symbolic informational function



Iconic informational function




Iconic informational function
system I
target t
i
e
f
c1
c2
c3
c4
c5
counterfactual co-occurrence
states of S
states of t
functional
covariation of state types
determination of content
Content (▲) = ▲


Iconic informational function
Symbolic informational function
c_1
c_2
c_3
c_4
c_5
states of *I*
states of *t*
states of *S*
states of *t*
Content (▲) = ▲
Content (▲) = ●

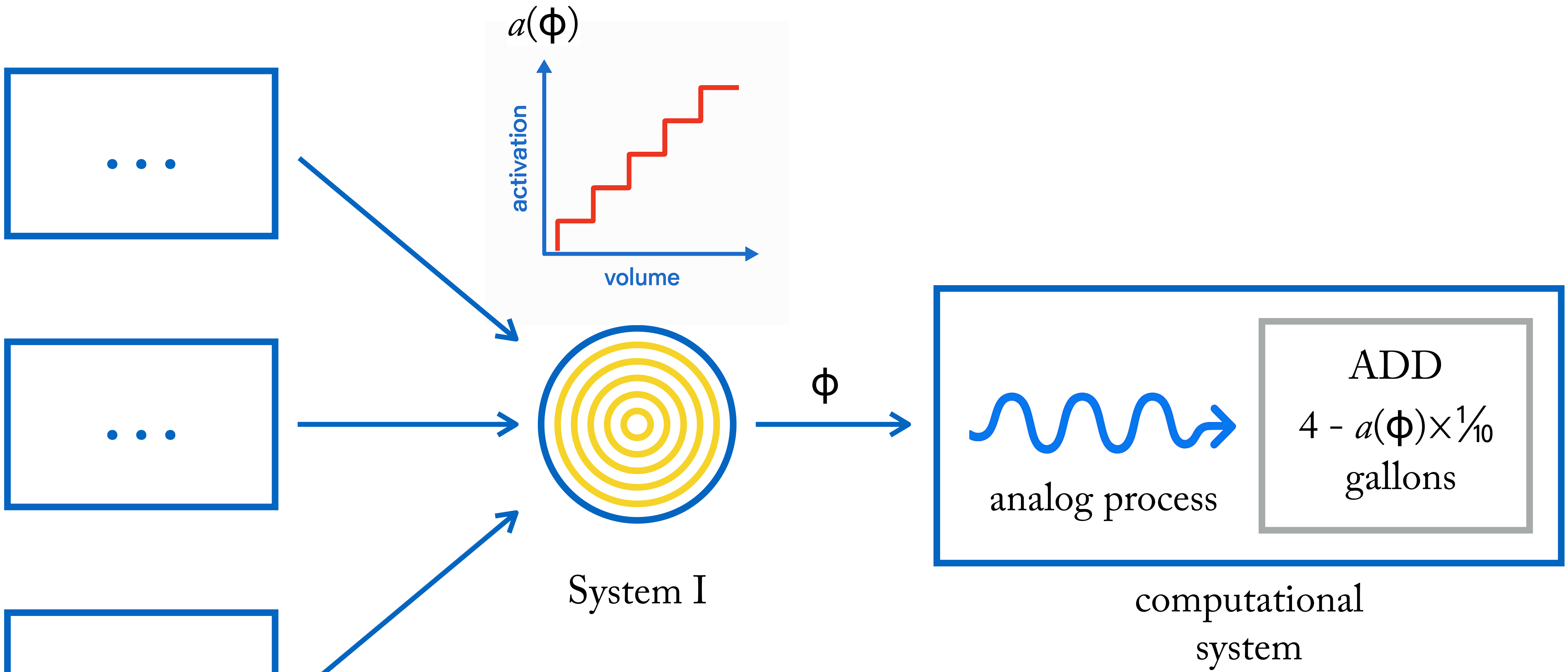
System I

- Organism O must periodically **refill a fluid reserve U** in order to survive and reproduce.

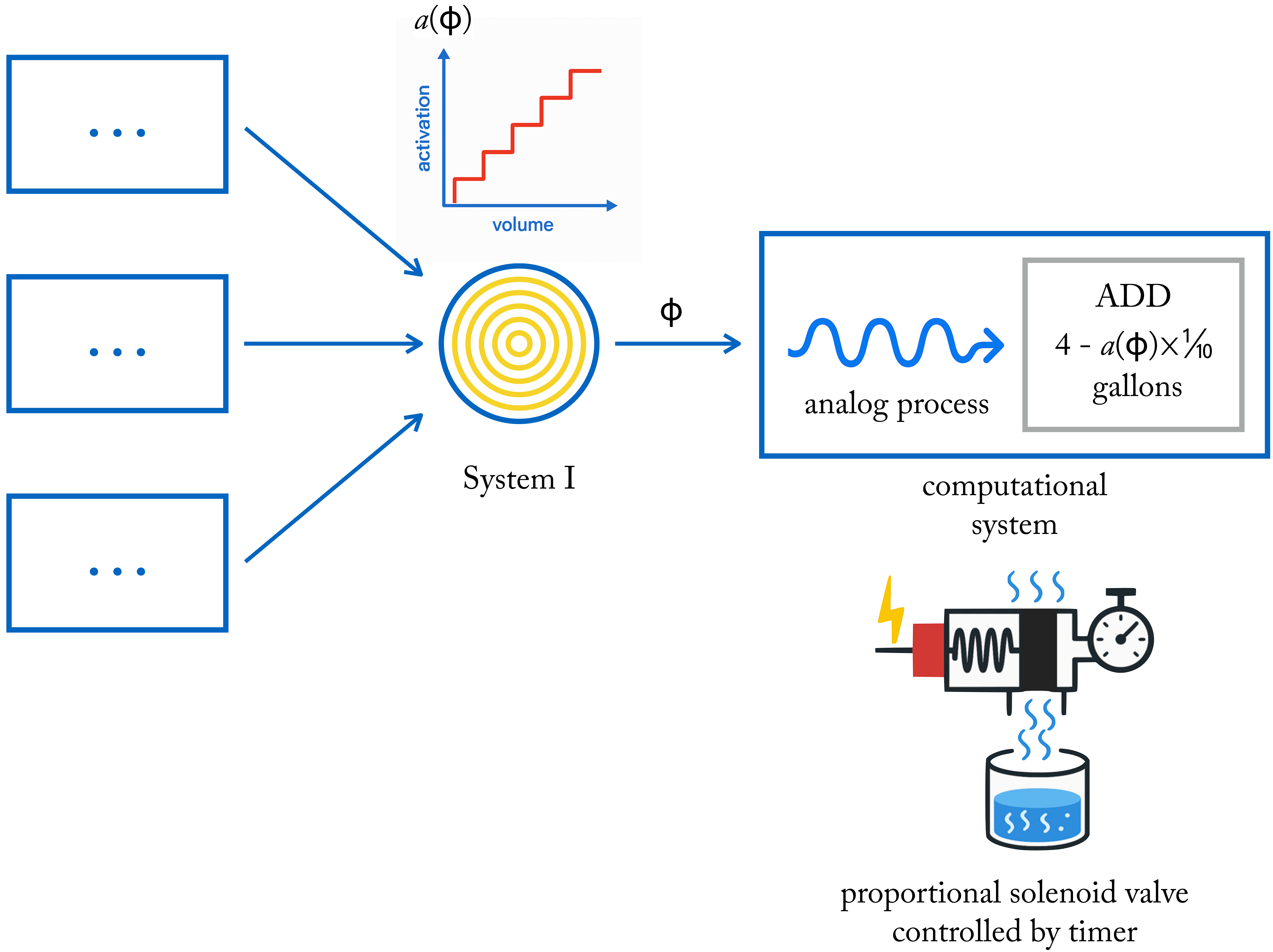
- U may contain five different volumes of liquid:
  0 gallons, 1 gallon, … 4 gallons.

- **System I** enters into one of five states of activity, measured as levels of activity **0 u, 10 u, … 40 u.**

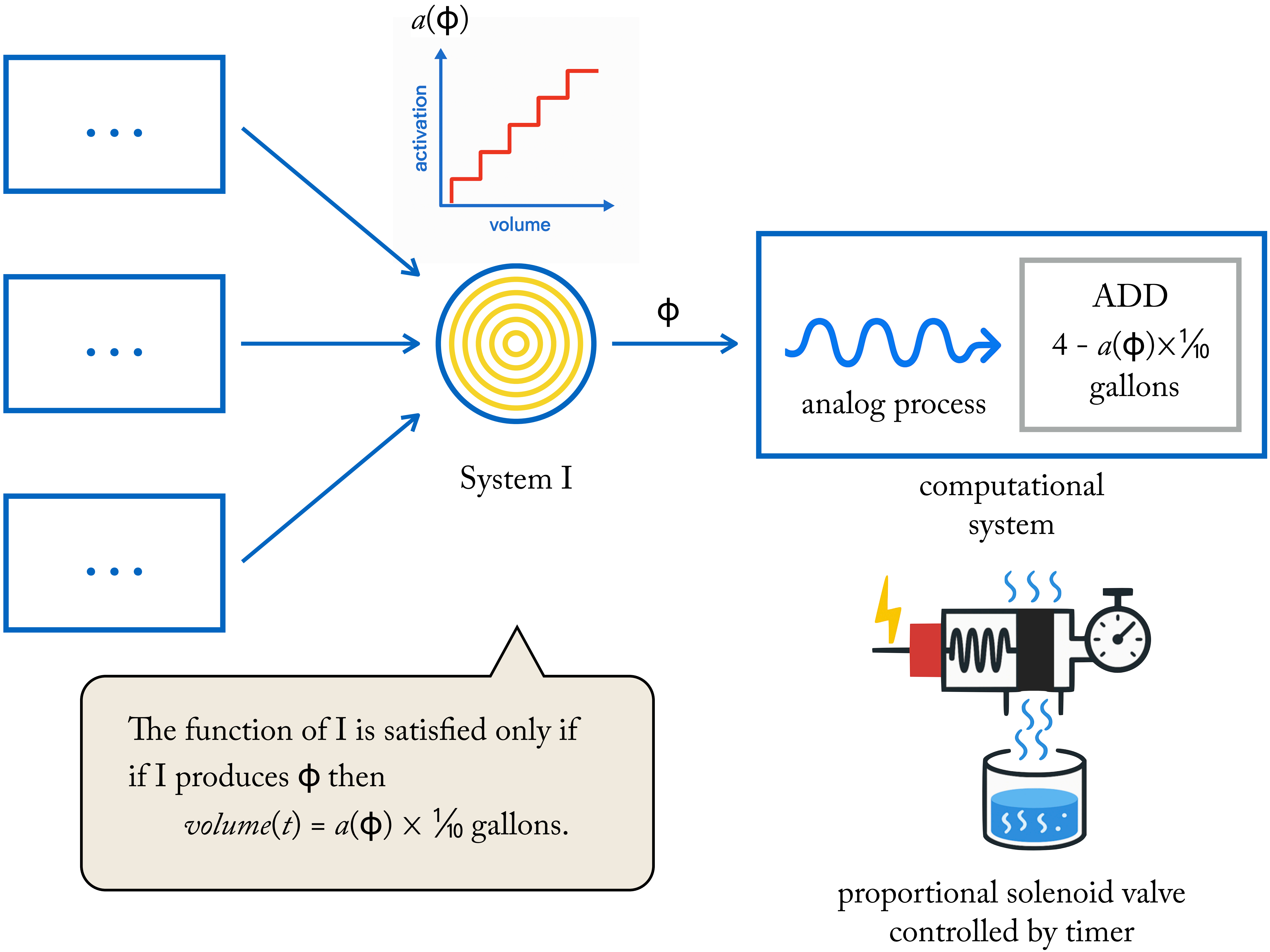
- Computational module M takes inputs from I:0-40u and outputs actions:
  add 0 gal., add 1 gal., … add 4 gal.



. . .
. . .
. . .
$a(\phi)$
activation
volume
ϕ
System I
ADD
$4 - a(\phi) \times 1/10$
gallons
analog process
computational system



a(ϕ)
activation
volume
ϕ
System I
analog process
ADD
4 - a(ϕ)×1⁄10
gallons
computational system
proportional solenoid valve controlled by timer



a(ϕ)
activation
volume
System I
ϕ
analog process
ADD
4 - a(ϕ)×1⁄10
gallons
computational system
The function of I is satisfied only if
if I produces ϕ then
volume(t) = a(ϕ) × 1⁄10 gallons.
proportional solenoid valve controlled by timer

System I's informational function

- The function of system I is satisfied in context c only if
  - for any state ϕ produced by I in c:
    - $volume(t_c) = activation(\phi) \times \frac{1}{10}$ gallons.

- **Uniform:** applies to all internal states in the same way.
- **Form-dependent:** imposes a dependence between the form of internal states and the features of an external state.

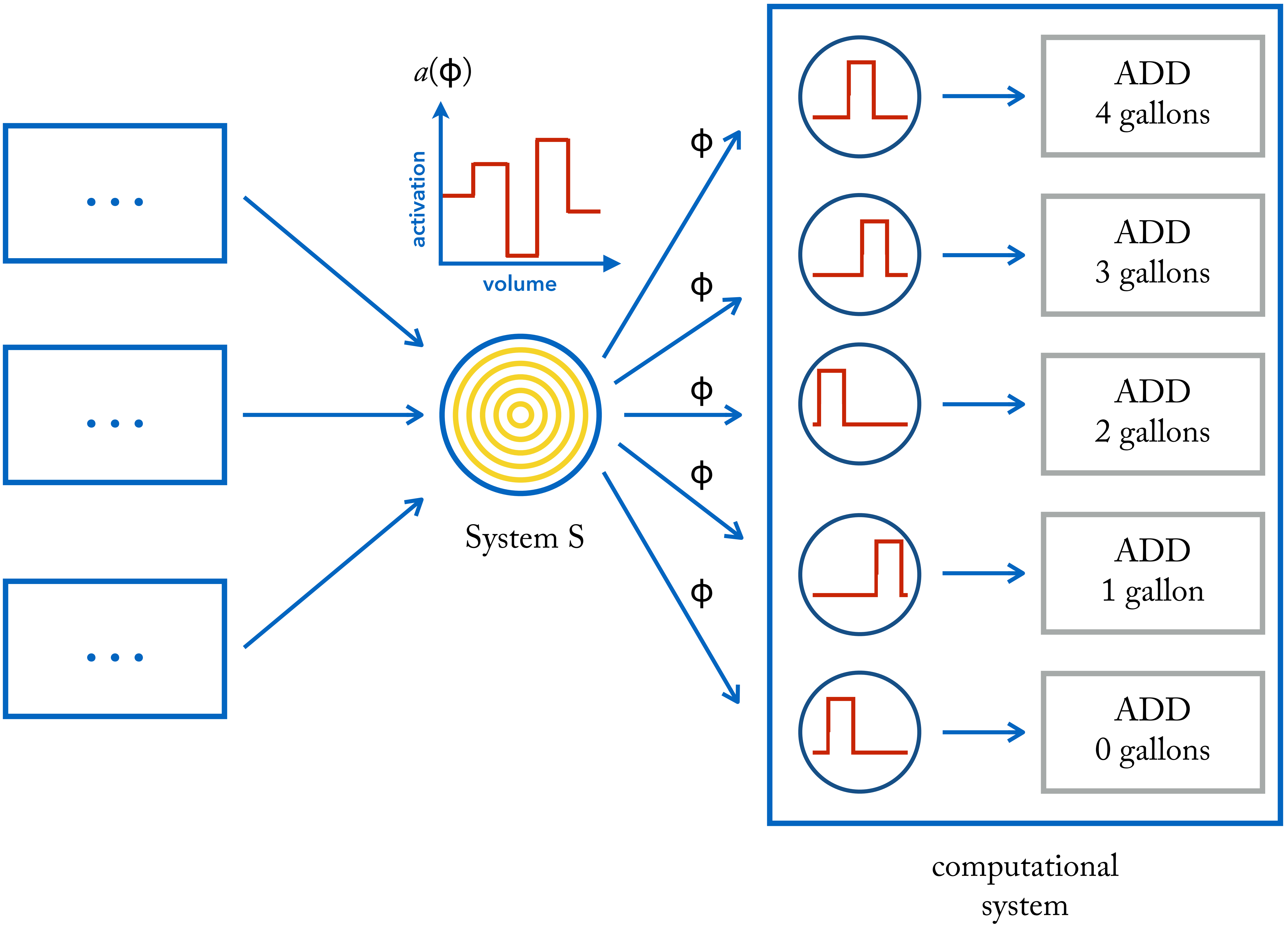
System S

- Organism O must periodically **refill a fluid reserve** U in order to survive and reproduce.

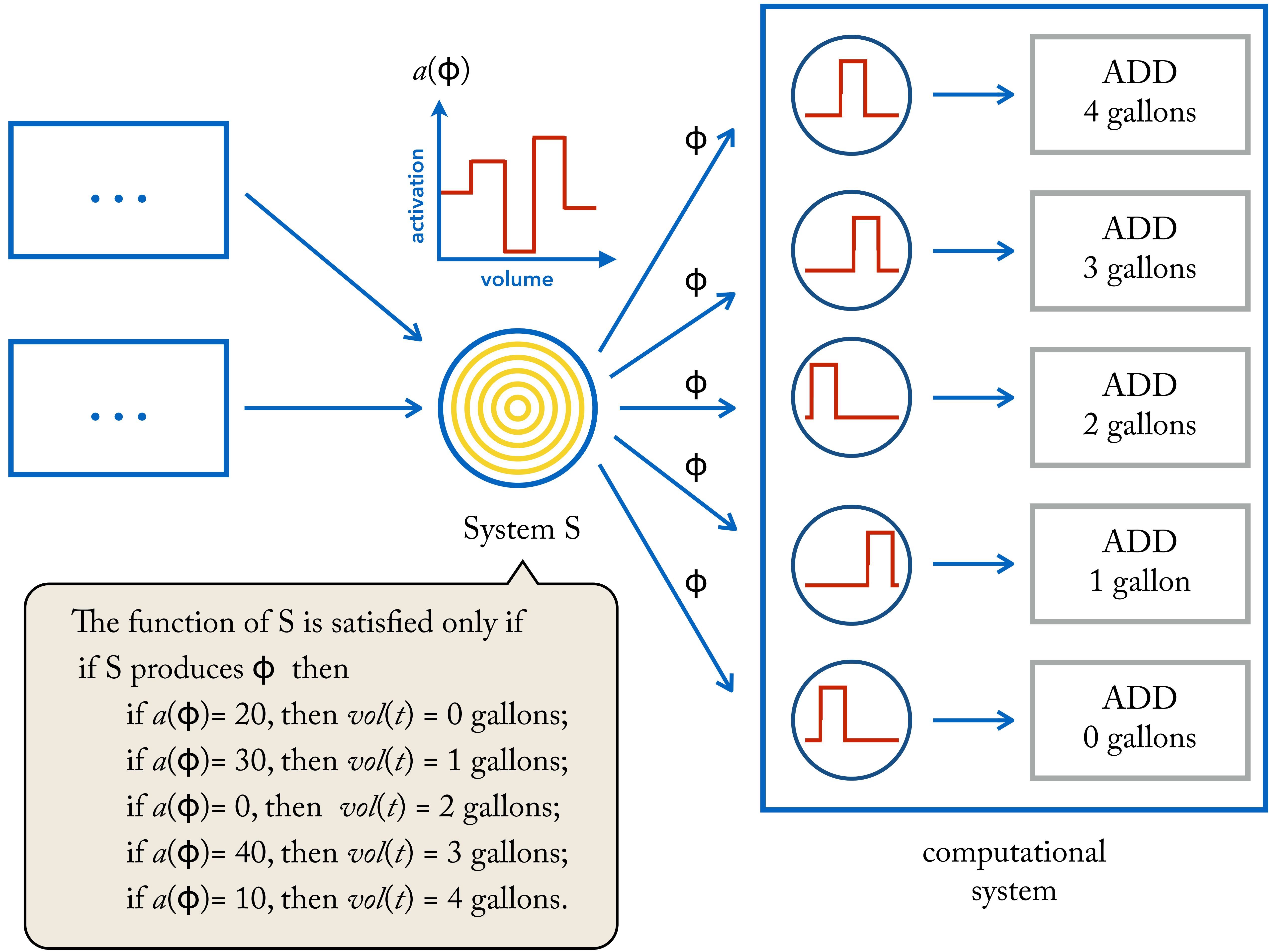
- U may contain five different volumes of liquid:
0 gallons, 1 gallon, … 4 gallons.

- **System S** enters into one of five states of activity, measured as levels of activity **0 u, 10 u, … 40 u.**

- Computational module M takes inputs from I:0-40 and outputs motor actions M: **add 0 gal., add 1 gal., … add 4 gal.**



. . .
. . .
. . .
a(ϕ)
activation
volume
System S
ϕ
ϕ
ϕ
ϕ
ϕ
ADD 4 gallons
ADD 3 gallons
ADD 2 gallons
ADD 1 gallon
ADD 0 gallons
computational system


. . .
. . .
a(ϕ)
activation
volume
ϕ
ϕ
ϕ
ϕ
ϕ
System S
The function of S is satisfied only if
if S produces ϕ then
if a(ϕ)= 20, then vol(t) = 0 gallons;
if a(ϕ)= 30, then vol(t) = 1 gallons;
if a(ϕ)= 0, then vol(t) = 2 gallons;
if a(ϕ)= 40, then vol(t) = 3 gallons;
if a(ϕ)= 10, then vol(t) = 4 gallons.
ADD 4 gallons
ADD 3 gallons
ADD 2 gallons
ADD 1 gallon
ADD 0 gallons
computational system

System S's informational function

- The function of system S is satisfied in context c iff
  - for any state ϕ: if S produces ϕ in c, then:
    - if *activation*(ϕ)= 20, then *volume*(t_c) = 0 gallons;
    - if *activation*(ϕ)= 30, then *volume*(t_c) = 1 gallon;
    - if *activation*(ϕ)= 0, then *volume*(t_c) = 2 gallons;
    - if *activation*(ϕ)= 40, then *volume*(t_c) = 3 gallons;
    - if *activation*(ϕ)= 10, then *volume*(t_c) = 4 gallons.

System S's informational function

- The function of system S is satisfied in context c iff
  - for any state ϕ: if S produces ϕ in c, then:
    - if *activation*(ϕ)= 20, then *volume*(t_c) = 0 gallons;
    - if *activation*(ϕ)= 30, then *volume*(t_c) = 1 gallon;
    - if *activation*(ϕ)= 0, then *volume*(t_c) = 2 gallons;

- **Itemized**: applies differently to each internal state type.
- **Form-independent:** imposes no dependence between internal states' forms and the external states' features.

Two paths to content…

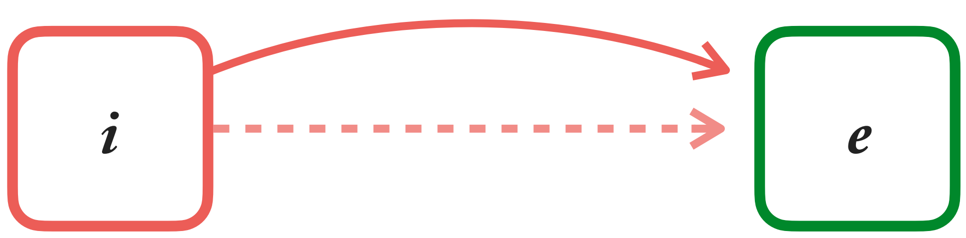
- **System S function:**
  - $\forall \phi$: if *activation*(ϕ)= 20, then *volume*(t_c) = 0 gallons;
  - $\forall \phi$: if *activation*(ϕ)= 40, then *volume*(t_c) = 1 gallon;

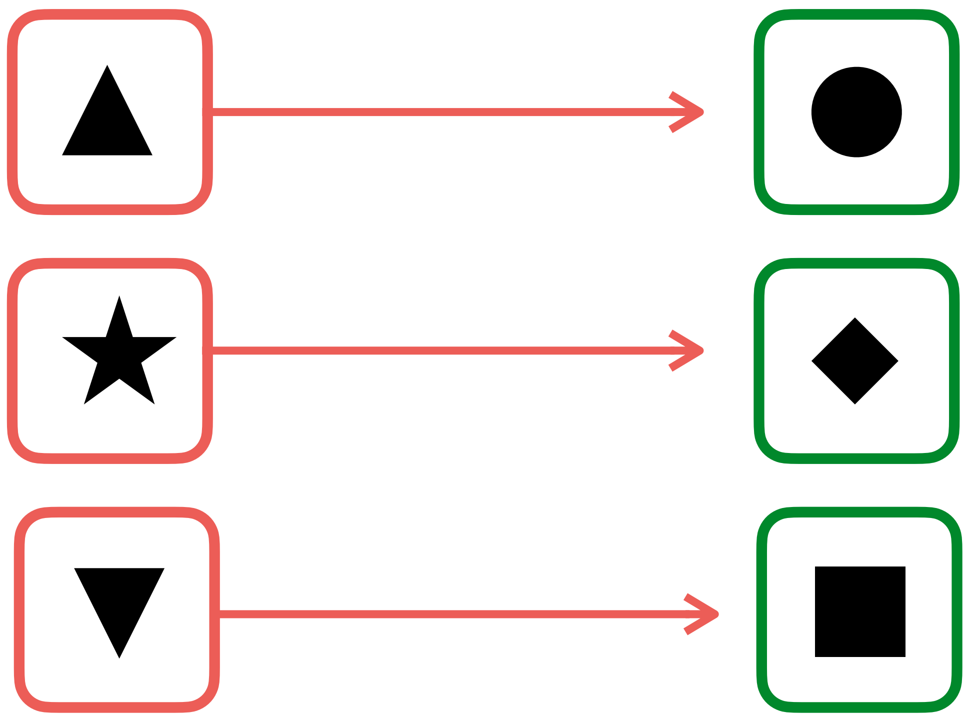
- **System I function:**
  - $\forall \phi$: *volume*(t_c) = *activation*(ϕ) × ⅒ gallons.

- **Content:**
  For a representation A, where *activation*(A)=20:
  - S: *Content*(A) = λ*x*. *volume*(*x*) = 0 gallons
  - I: *Content*(20) = λ*x*. *volume*(*x*) = *activation*(A) × ⅒ gallons
    = 20 × ⅒ gallons
    = 2 gallons

Iconic and symbolic functions, revisited

- **Iconic functions** are **uniform, form-dependent** functions to carry information.
- **Symbolic functions** are are **itemized, form-independent** functions to carry information.

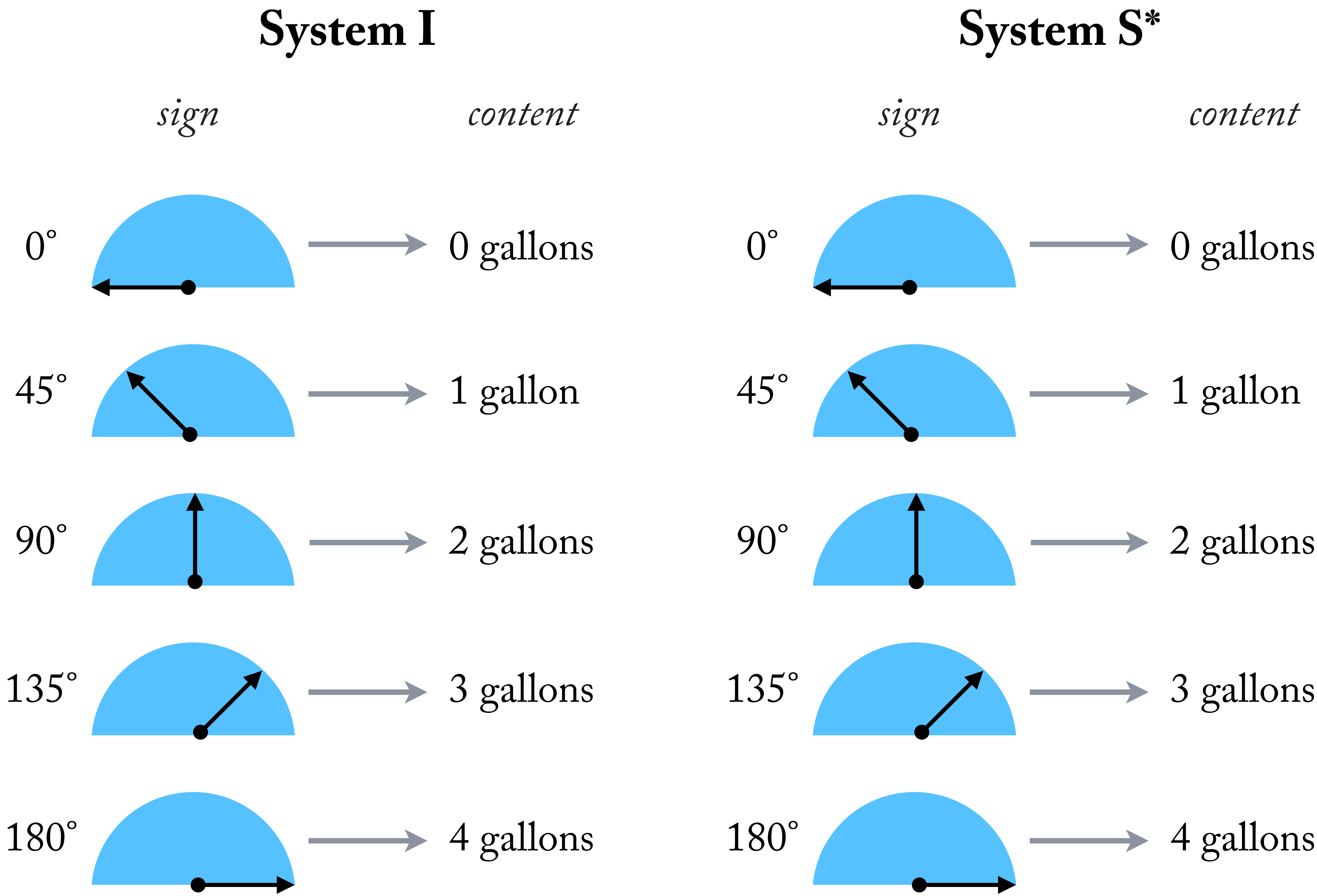




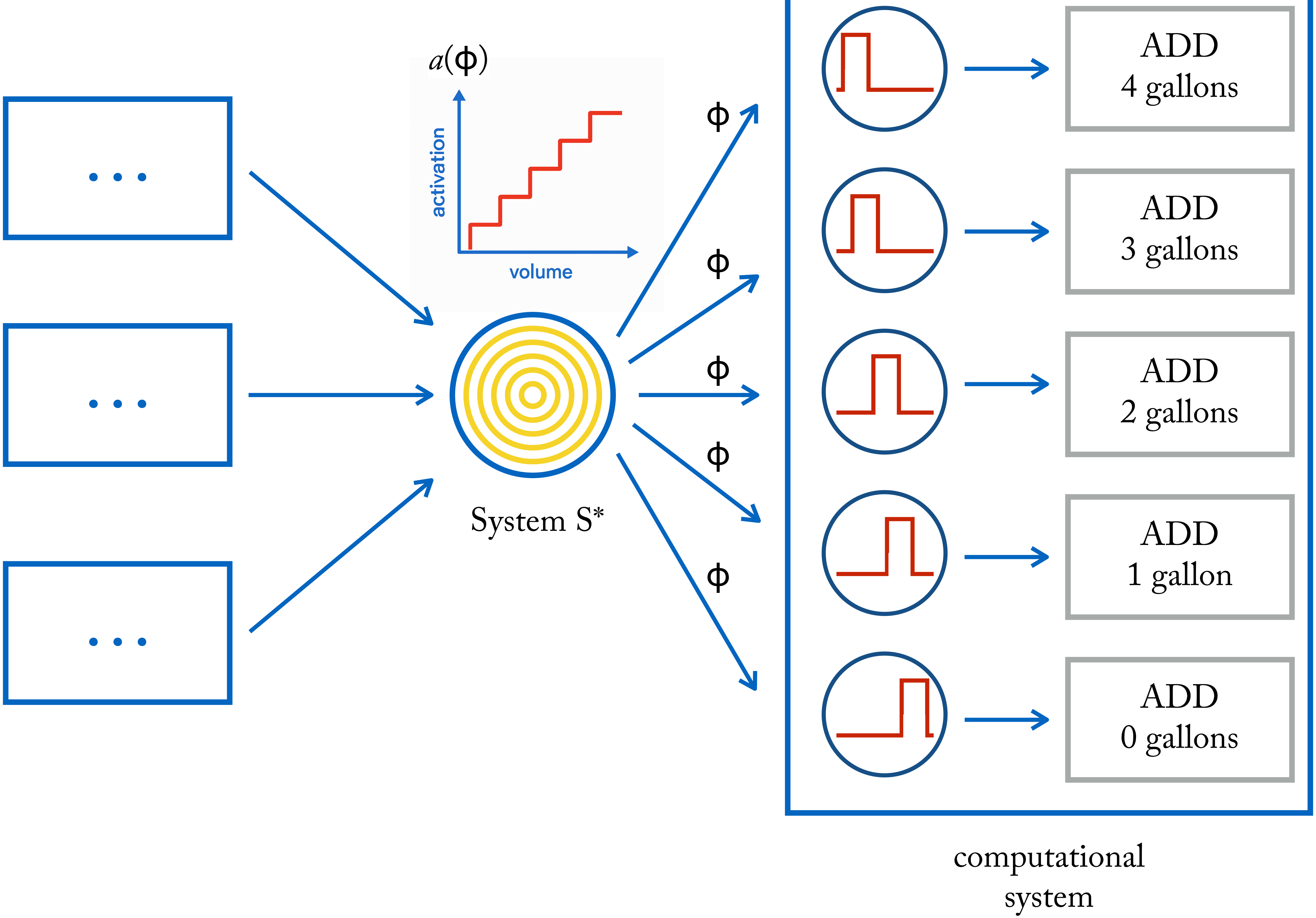
Structure in informational functions

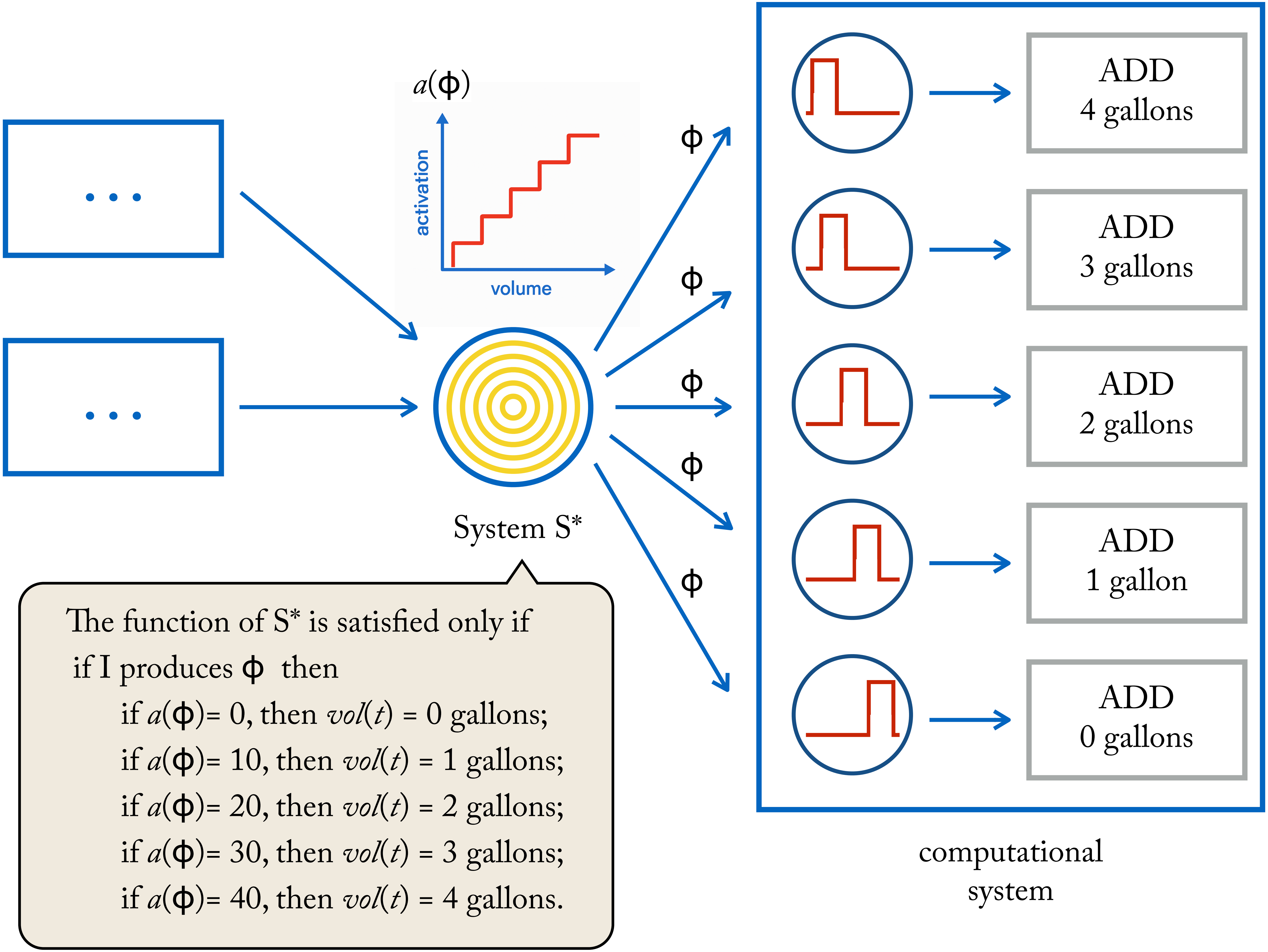
- Conditional and uniform functions
  - **Conditional**: sodium channels, blink reflex
  - **Uniform**: cell membrane, spine
- Form-dependent and form-independent functions
  - **Form-dependent:** adrenaline / heart-rate
  - **Form-independent:** reflex arcs (knee-jerk, eye-blink)

- Functions as structured and fine-grained abstracta.

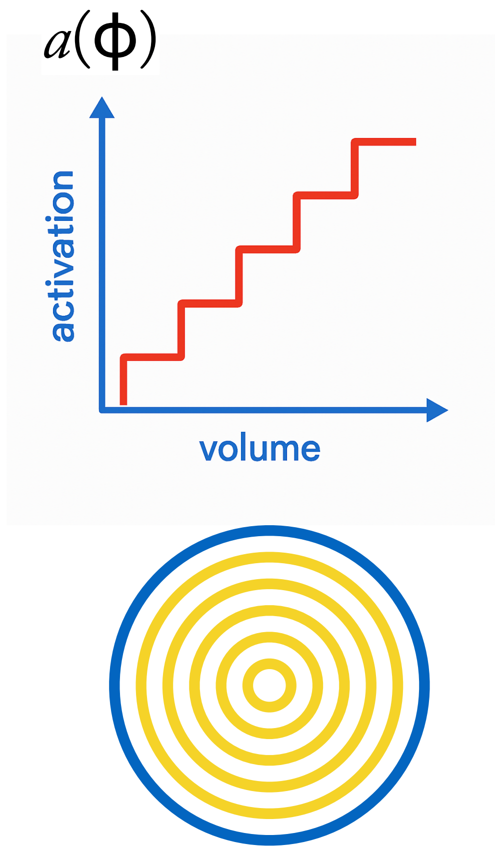

System I
sign
content
0°
0 gallons
45°
1 gallon
90°
2 gallons
135°
3 gallons
180°
4 gallons
System S*
sign
content
0°
0 gallons
45°
1 gallon
90°
2 gallons
135°
3 gallons
180°
4 gallons

By random mutation…





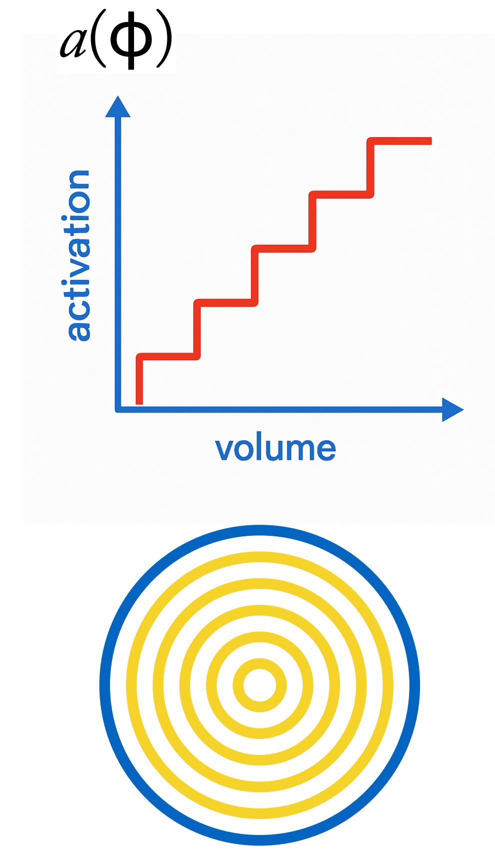
a(ϕ)
activation
volume
. . .
. . .
ϕ
ϕ
ϕ
ϕ
ϕ
System S*
The function of S* is satisfied only if
if I produces ϕ then
if a(ϕ)= 0, then vol(t) = 0 gallons;
if a(ϕ)= 10, then vol(t) = 1 gallons;
if a(ϕ)= 20, then vol(t) = 2 gallons;
if a(ϕ)= 30, then vol(t) = 3 gallons;
if a(ϕ)= 40, then vol(t) = 4 gallons.
ADD
4 gallons
ADD
3 gallons
ADD
2 gallons
ADD
1 gallon
ADD
0 gallons
computational
system



System I

The function of I is satisfied only if
if I produces ϕ then

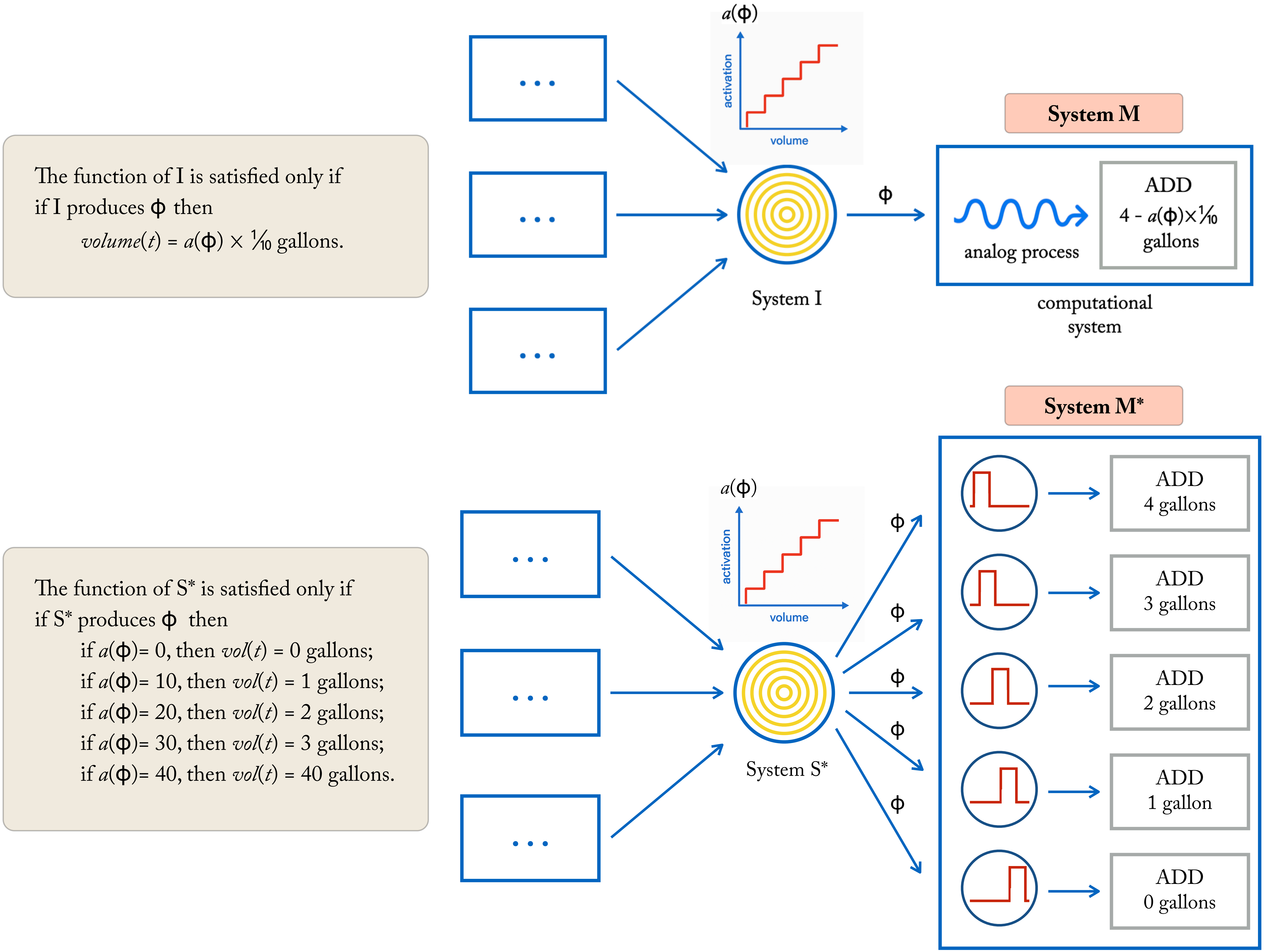
$$volume(t) = a(\phi) \times \tfrac{1}{10} \text{ gallons.}$$



System S^*

The function of S^* is satisfied only if
if S^* produces ϕ then

if $a(\phi) = 0$, then $vol(t) = 0$ gallons;
if $a(\phi) = 10$, then $vol(t) = 1$ gallons;
if $a(\phi) = 20$, then $vol(t) = 2$ gallons;
if $a(\phi) = 30$, then $vol(t) = 3$ gallons;
if $a(\phi) = 40$, then $vol(t) = 4$ gallons.


The function of I is satisfied only if
if I produces ϕ then
volume(t) = a(ϕ) × 1⁄10 gallons.
a(ϕ)
activation
volume
System I
ϕ
System M
analog process
ADD
4 - a(ϕ)×1⁄10
gallons
computational
system
The function of S* is satisfied only if
if S* produces ϕ then
if a(ϕ)= 0, then vol(t) = 0 gallons;
if a(ϕ)= 10, then vol(t) = 1 gallons;
if a(ϕ)= 20, then vol(t) = 2 gallons;
if a(ϕ)= 30, then vol(t) = 3 gallons;
if a(ϕ)= 40, then vol(t) = 40 gallons.
a(ϕ)
activation
volume
System S*
System M*
ADD
4 gallons
ADD
3 gallons
ADD
2 gallons
ADD
1 gallon
ADD
0 gallons

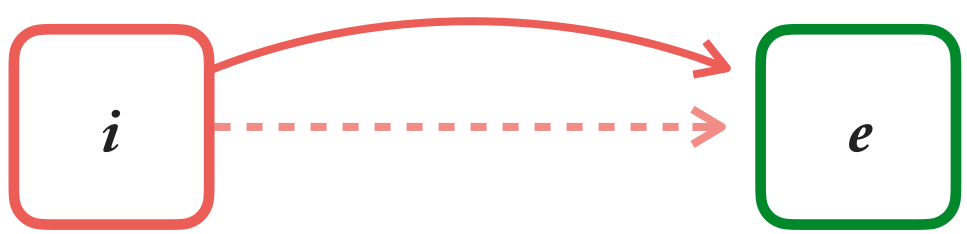
What is the difference between I and S*?

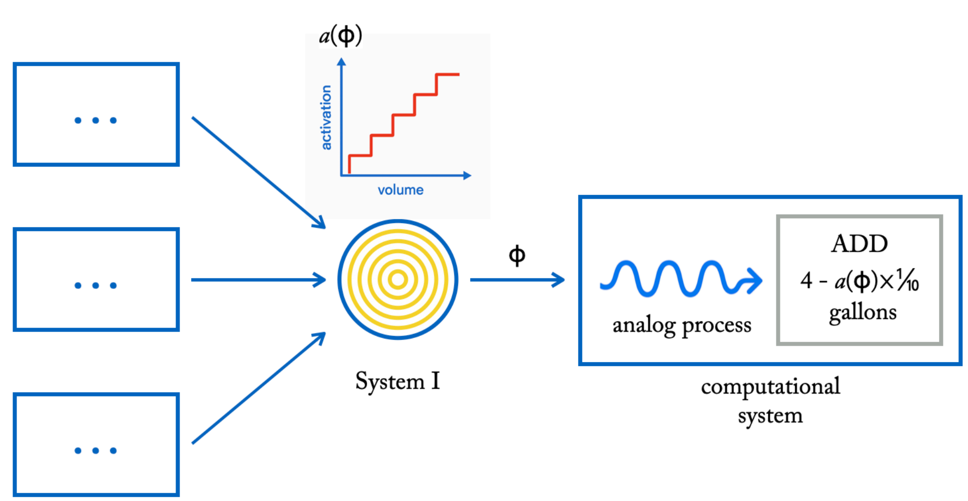
- I and S* use the same signs to carry the same information.
- But this information is **used** in different ways by different **consumer systems**.
- **Recall:** for information to be functional it must have a **selected effect** on the organism.
  - The effects of representational systems are felt by downstream consumer computations.
- A computational system **exploits** a relation to the environment iff it requires that relation to hold in order to fulfill (one of) its function(s).
- M and M* exploit different (but co-extensive) relations between the representational system and the environment.
  - The relation $\lambda t \lambda \phi.[\mathit{volume(t) = a(\phi)} \times \frac{1}{10}\ \mathit{gallons}]$ plays an essential role in causally explaining the function of M, but not M*.

Iconic Semantics

Content(s) = (*angle(s)* × $\frac{1}{45}$) *gallons of water in the tank*

Iconic Functions

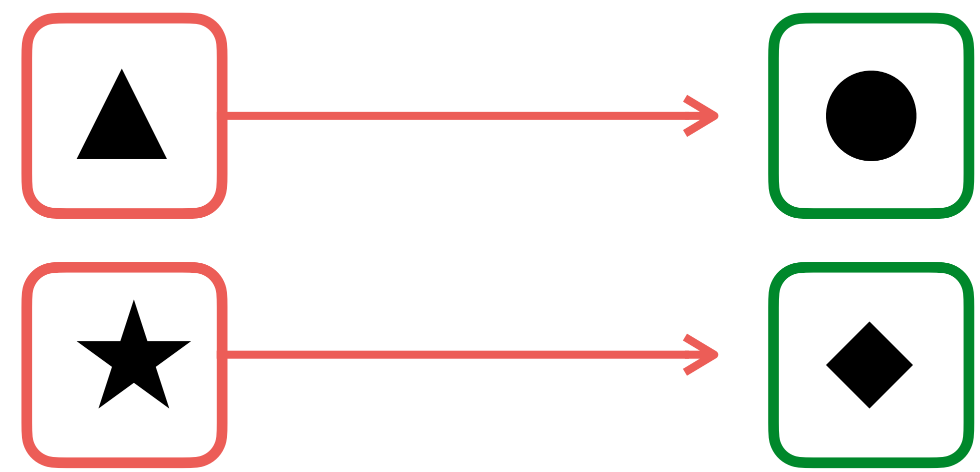


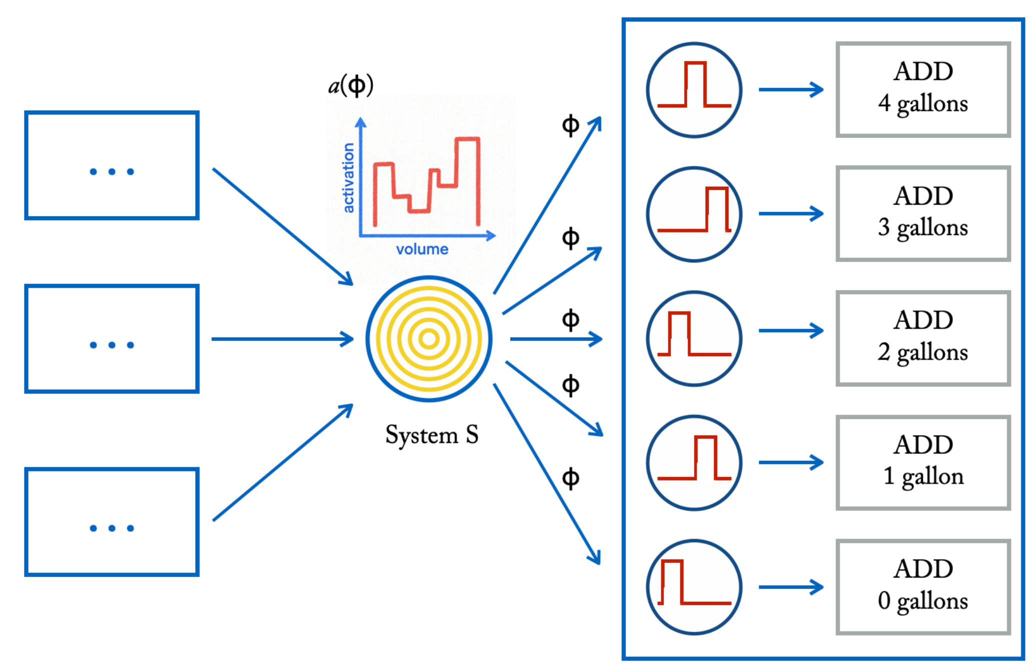


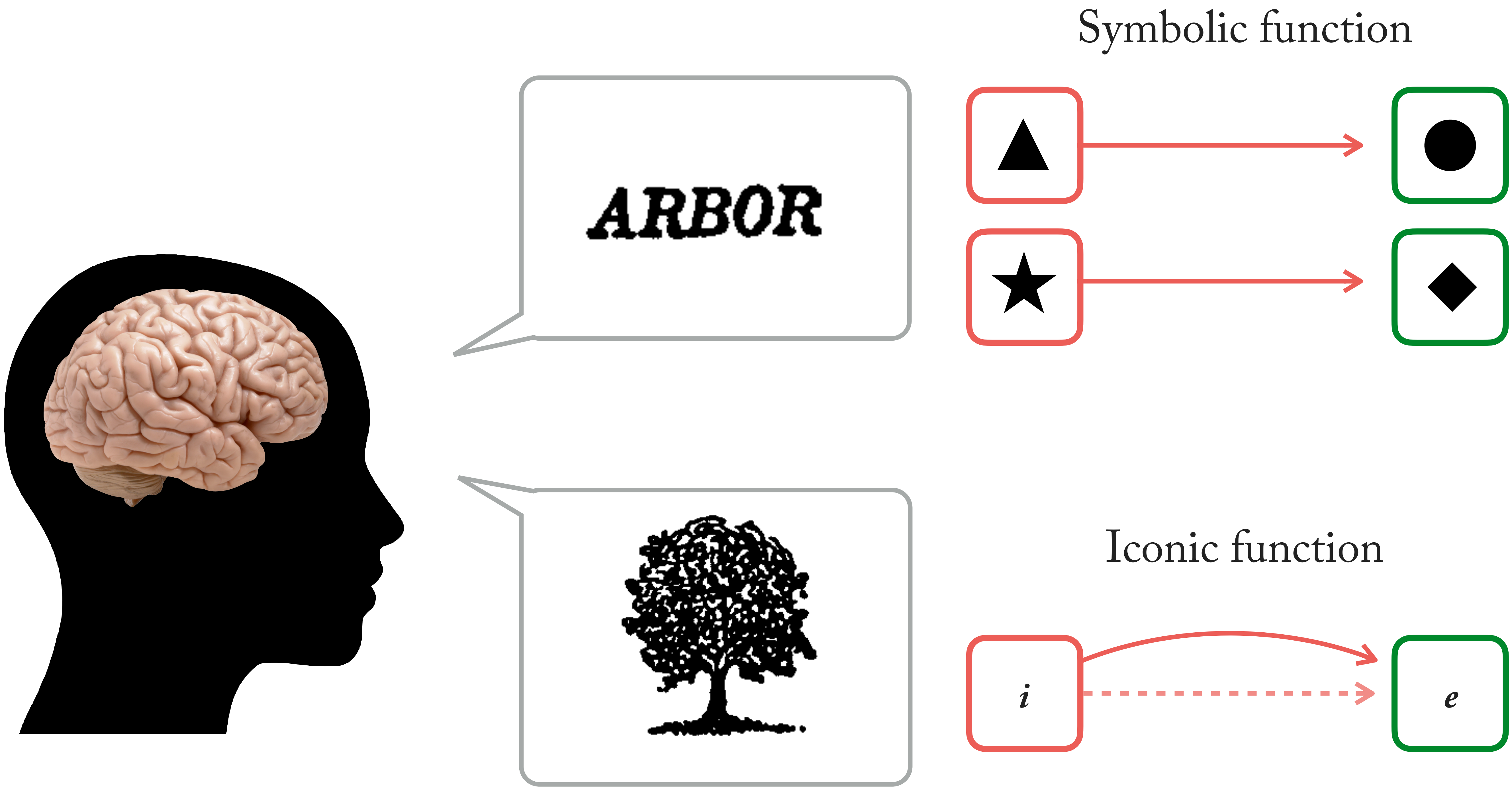
Symbolic Semantics

- if *angle(s)* = 90, *Content(s) = 0 gallons of water in the tank;*
- if *angle(s)* = 180, *Content(s) = 1 gallon of water in the tank;*
- if *angle(s)* = 45, *Content(s) = 2 gallons of water in the tank;*
- if *angle(s)* = 135, *Content(s) = 3 gallons of water in the tank;*
- if *angle(s)* = 0, *Content(s) = 4 gallons of water in the tank.*

Symbolic Functions







Two ways of leveraging brain-world relations to encode content.