How Material Models Represent

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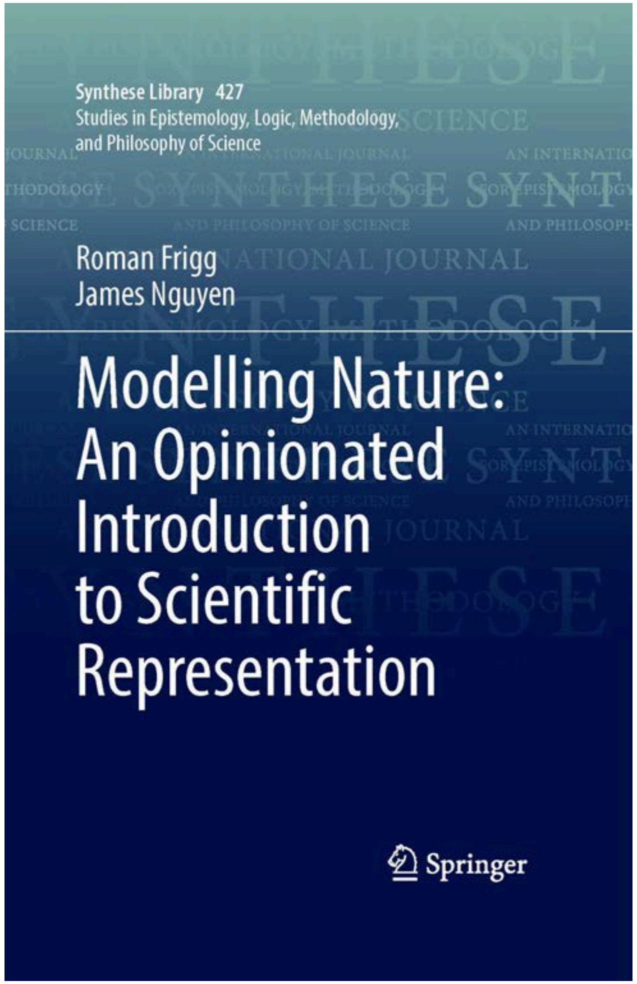
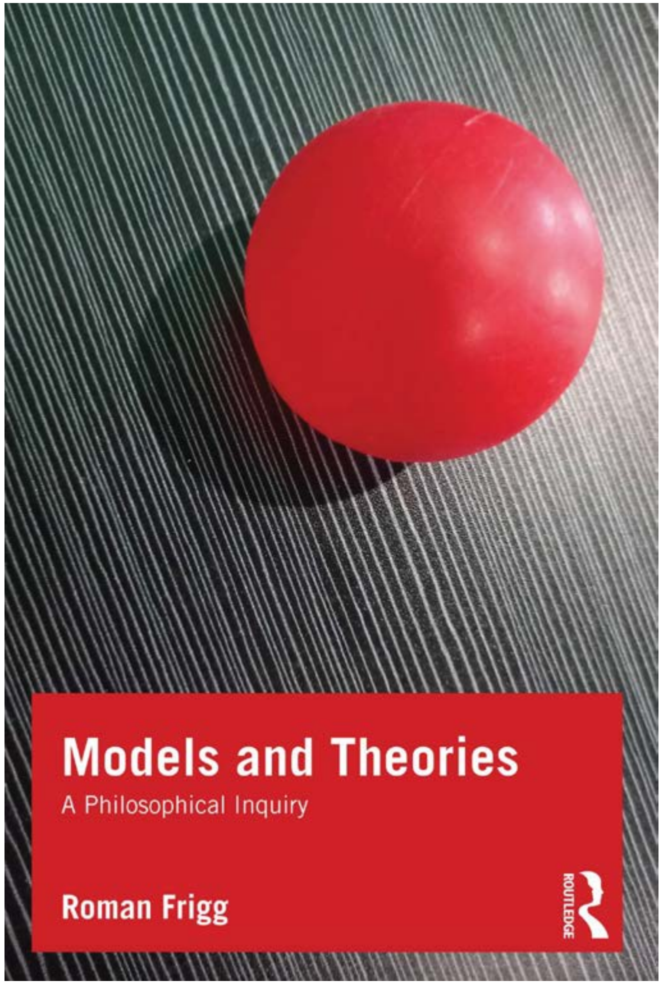


Chs. 8 and 9



Chs. 9 and 14

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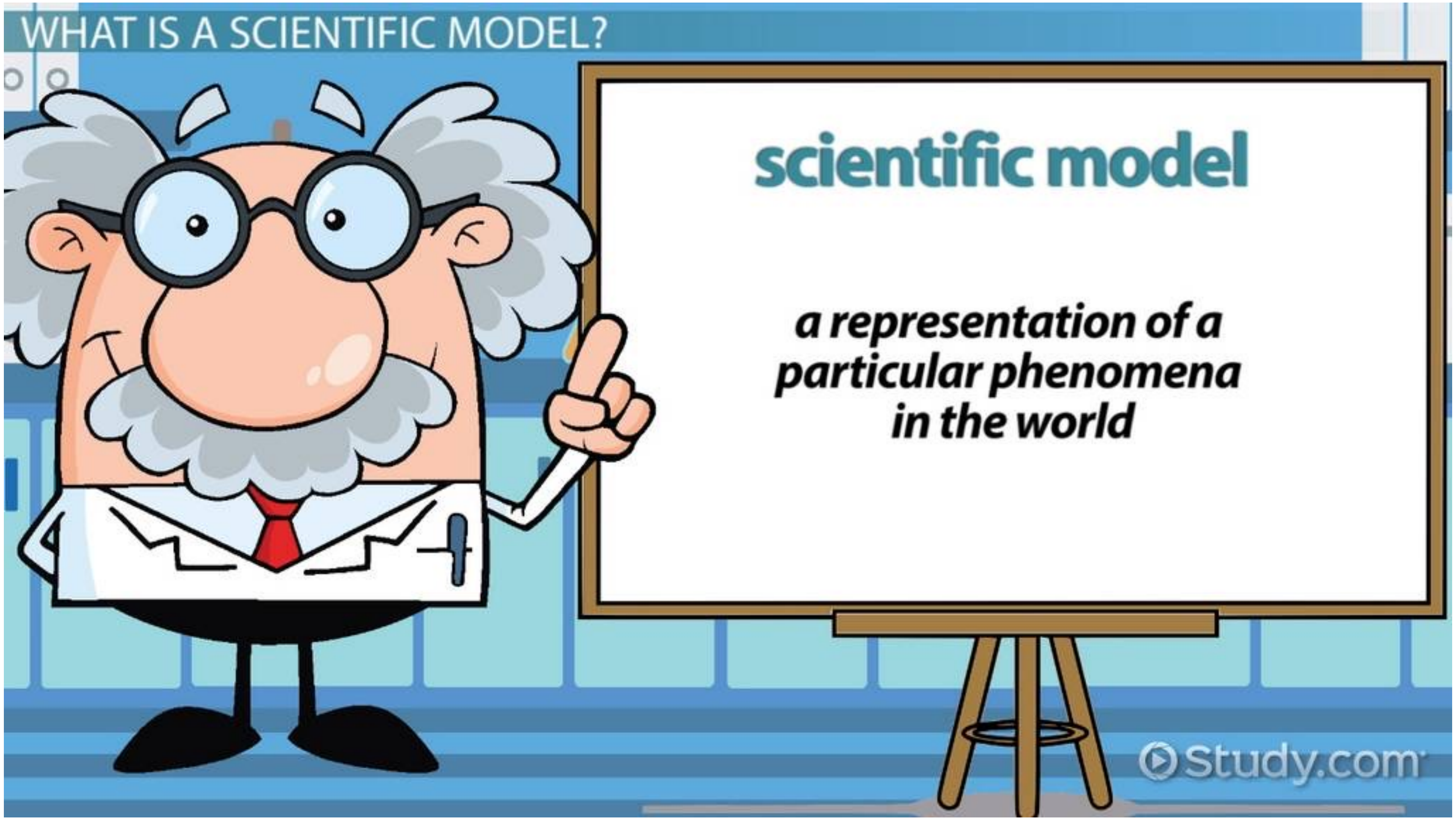
Models Matter

Models are ubiquitous in science (and engineering)

There is hardly a scientific achievement that did not involve a model:

- Planetary motion
- Theory of heat and SM of gases
- Nuclear and atomic structure
- DNA structure
- Higgs boson
- …

But what is a model?


WHAT IS A SCIENTIFIC MODEL?
scientific model
a representation of a particular phenomena in the world
Study.com

What is representation?

Available Accounts

Available Options:

- Conventionalism
- Similarity
- Isomorphism
- Inferentialism
- Direct Fictionalism
- DEKI

→ Book

Available Accounts

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Available Accounts

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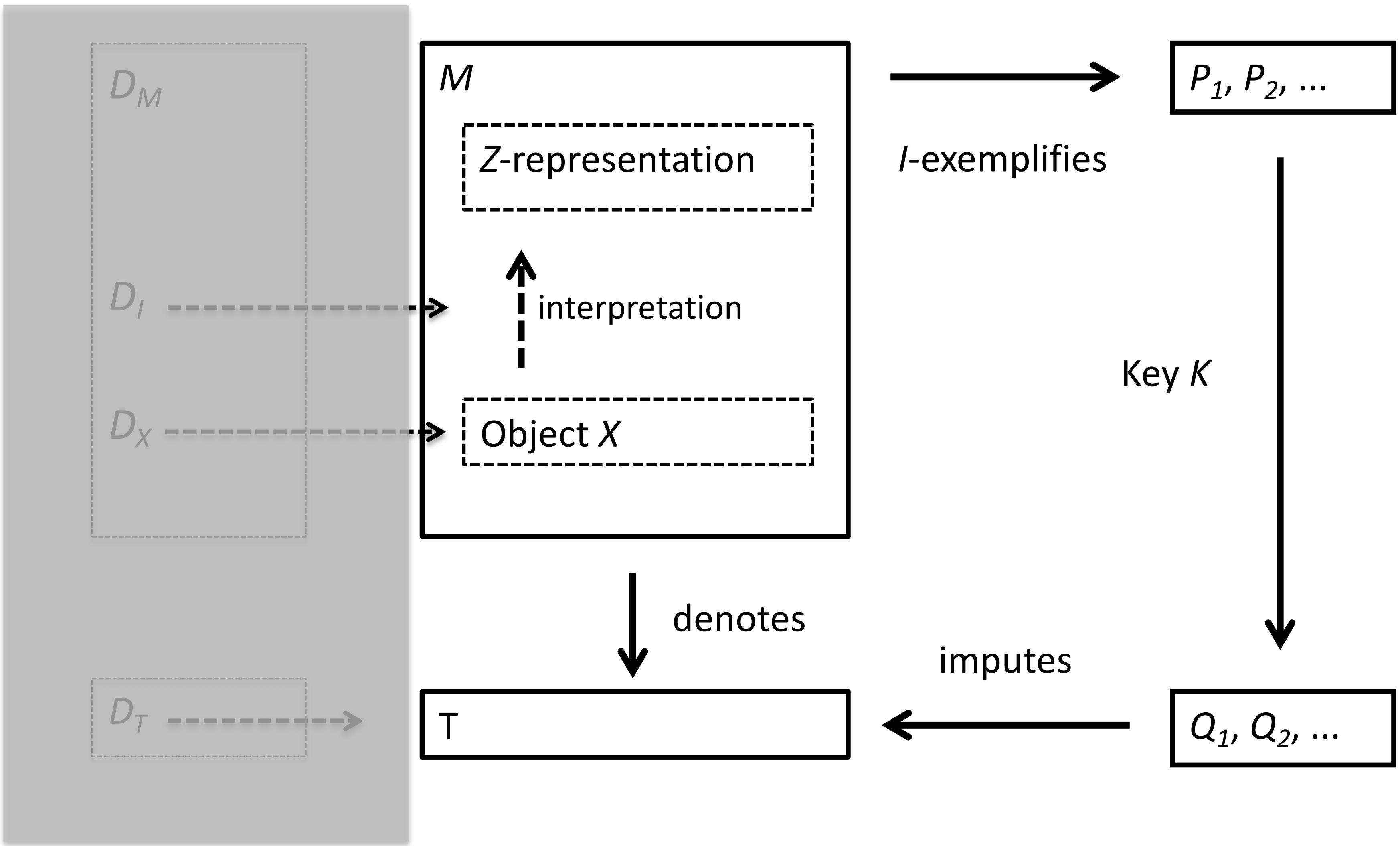
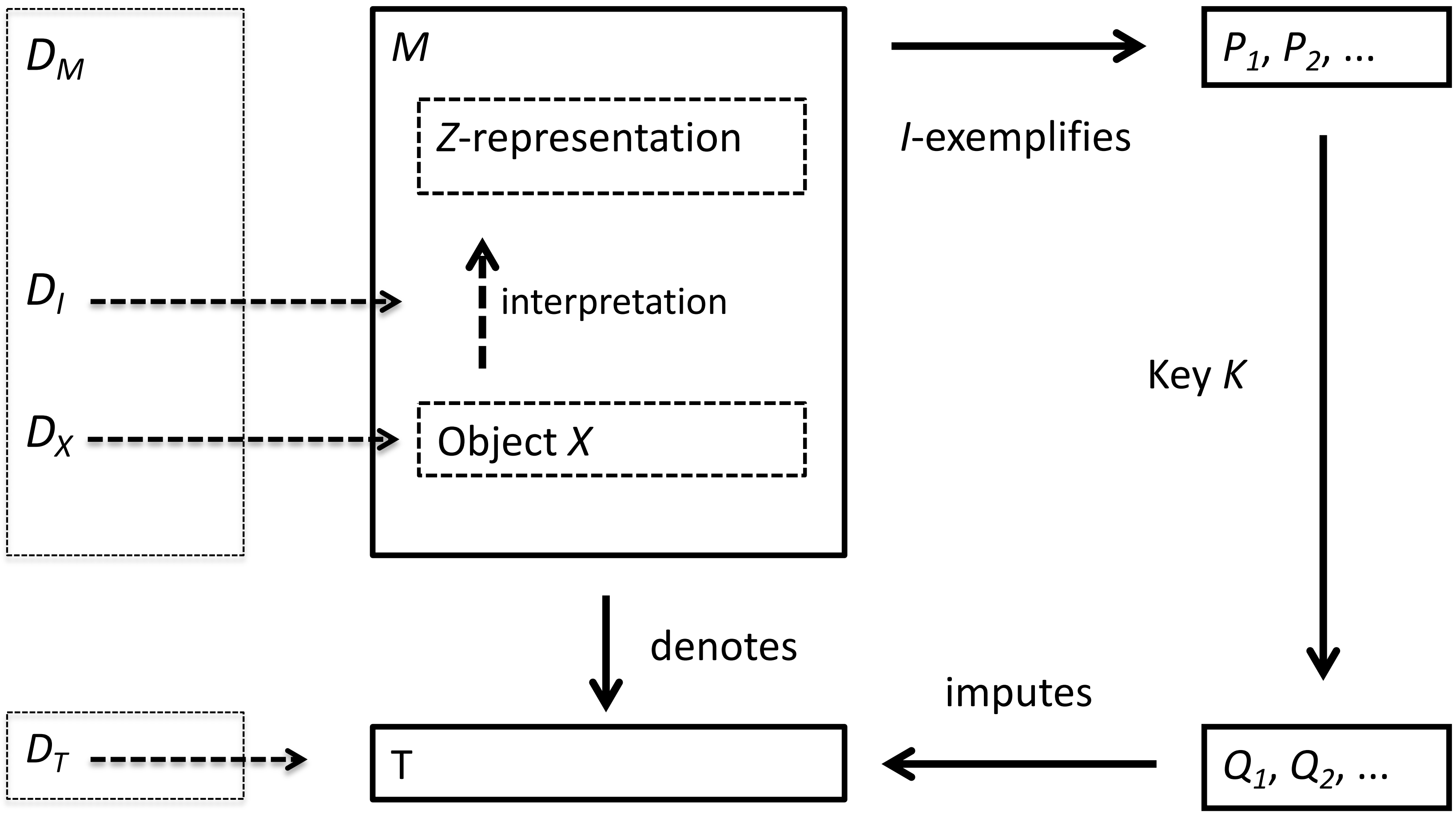
→ Today

Preview: DEKI Account



Preview: DEKI Account



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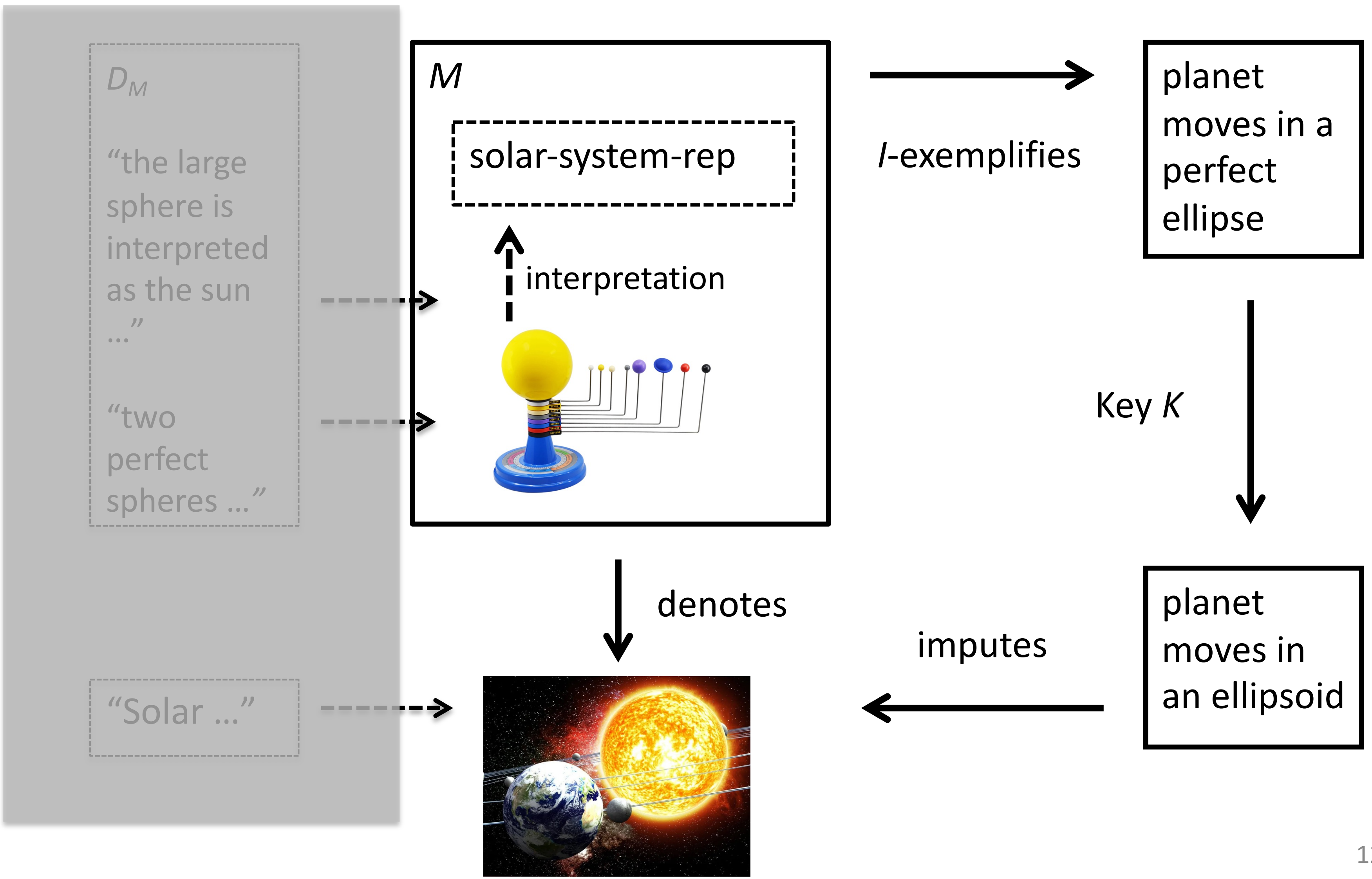

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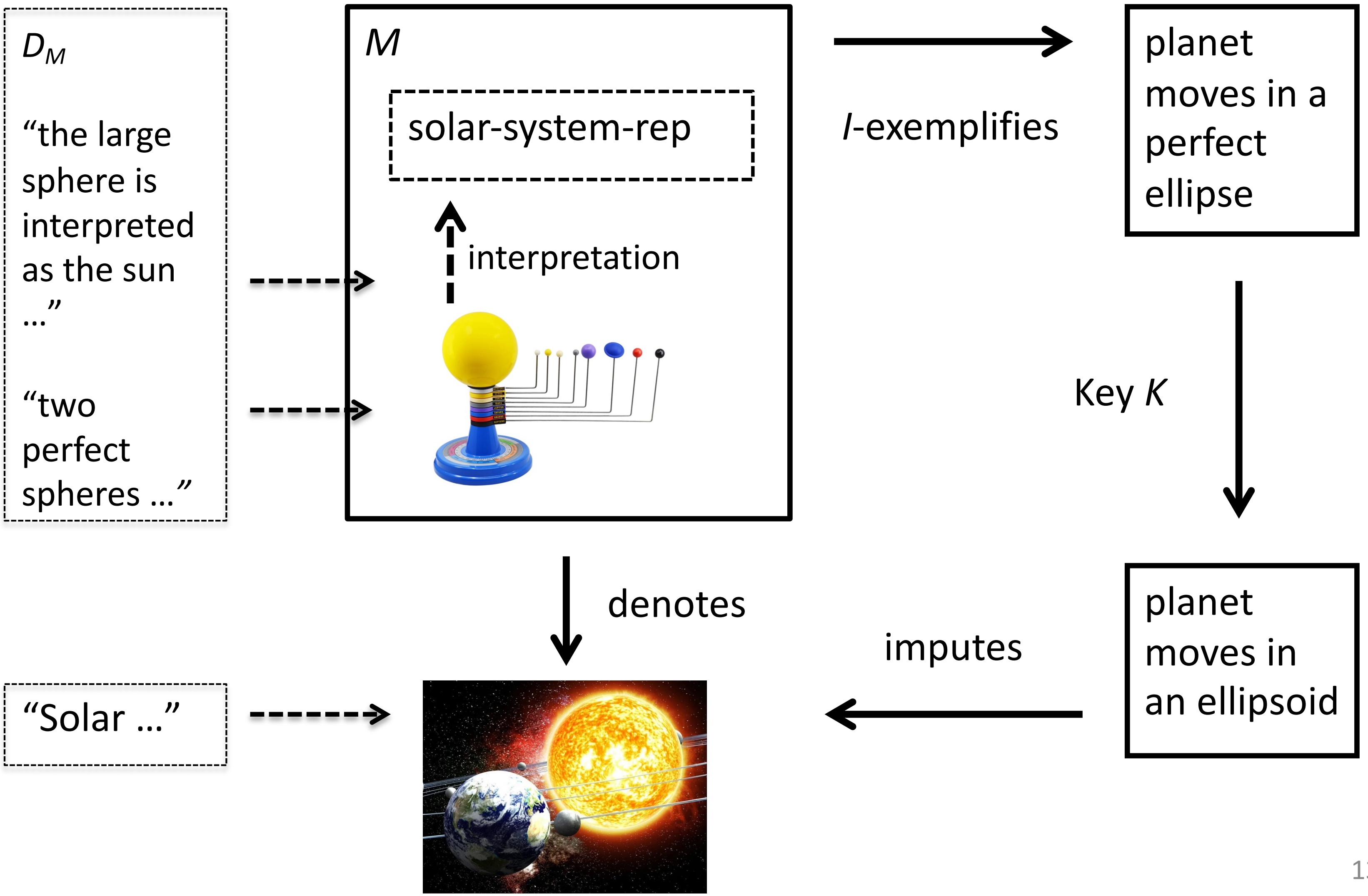
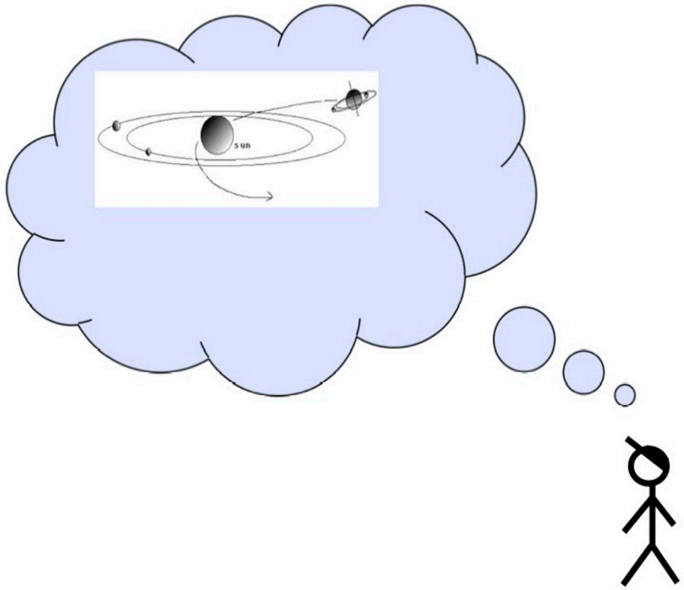


Plan

- Explain what motivates this picture
- Explain how we get there
- Flesh out details

Two Kinds of Models



Concrete model

Material Object

Non-concrete Model

'Something things that one holds in one's head rather than one's hands' (Hacking)

Two Kinds of Models

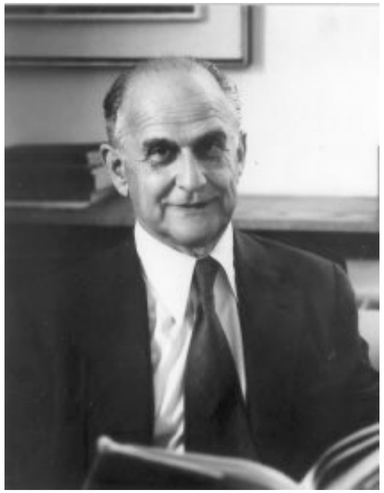
<u>Concrete model</u>

Material Object

<u>Non-concrete Model</u>

'Something things that one holds in one's head rather than one's hands' (Hacking)

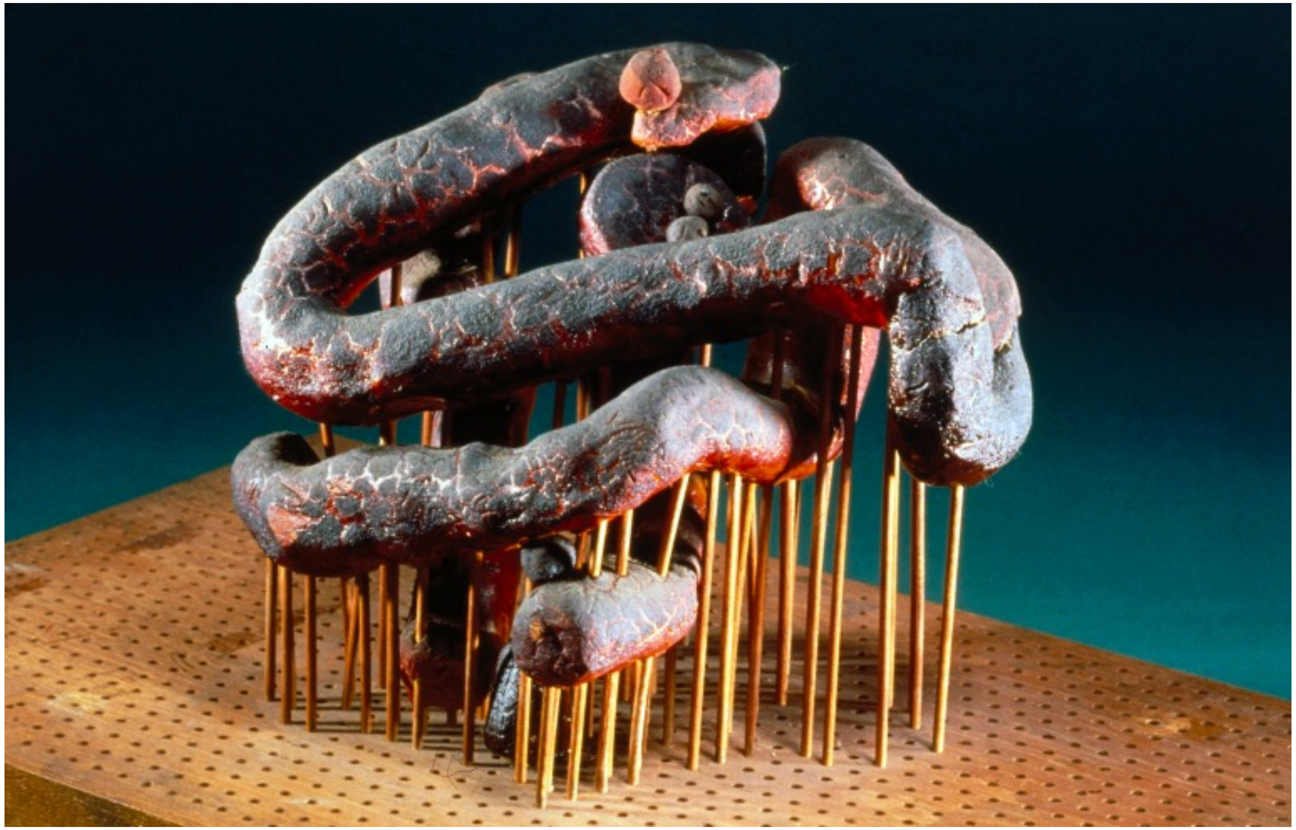
Background: Representation-As



Nelson Goodman and Catherine Elgin

Margaret Thatcher represented *as* a boxer

Liz Truss represented *as* a puppet on strings



Myoglobin represented *as* a plasticine sausage

The Guatemalan Economy represented
as system of pipes

Notation:

X -- the object that does the representing

In example: the drawing

T -- the real-world target of the representation

In example: Thatcher (the real person)

Z – kind of a representation

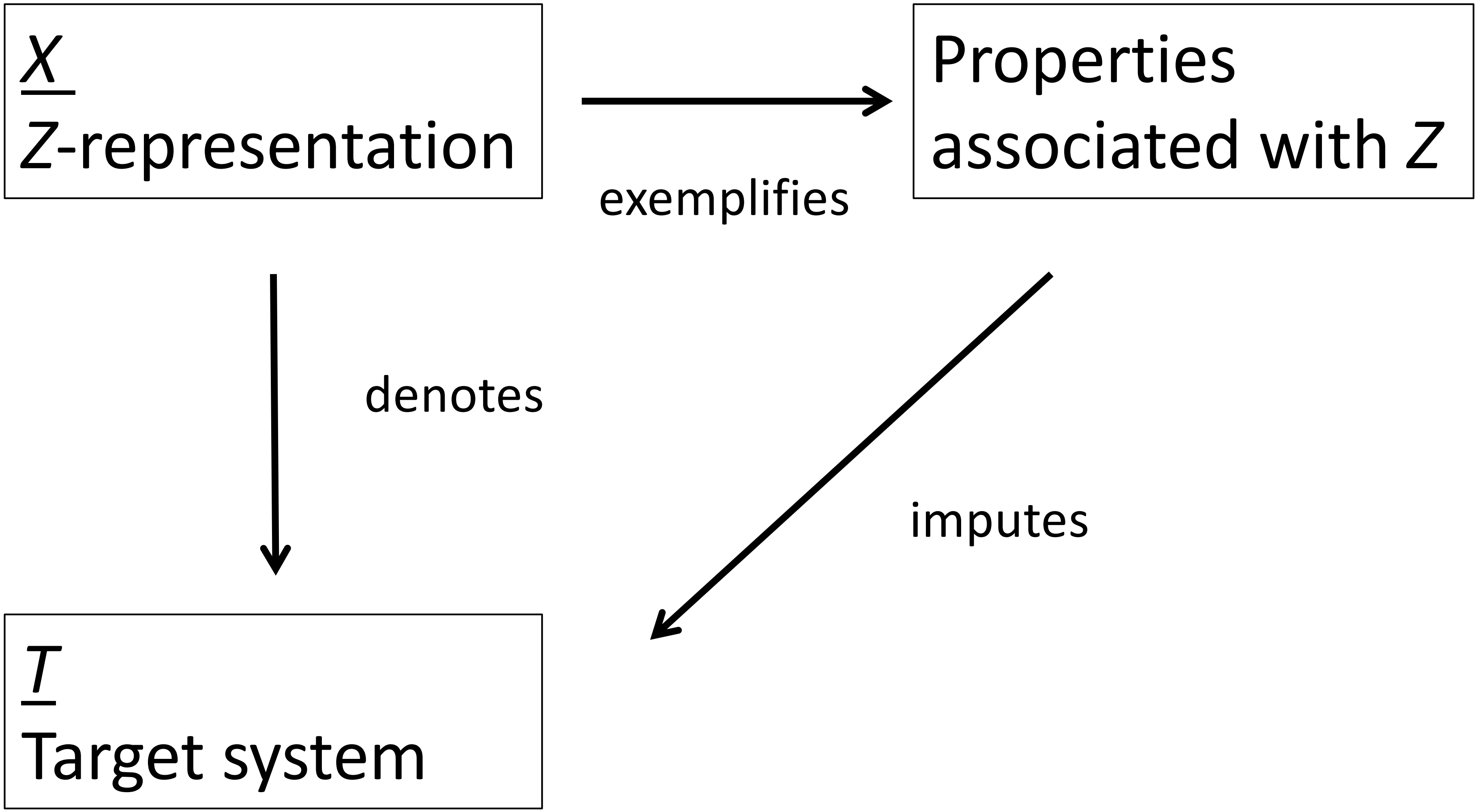
In examples: Boxer

Definition (Elgin)

‘when [X] represents [T] as [Z] … [it] is because [X] is a [Z]-representation that denotes [T] as it does. [X] does not merely denote [T] and happen to be a [Z]-representation. Rather in being a [Z]-representation, <u>[X] exemplifies certain properties and imputes those properties or related ones to</u> [T].’

(Telling Instances, p. 10)

Goodman and Elgin's Analysis:



Example: Thatcher as a boxer

Boxer-representation

exemplifies

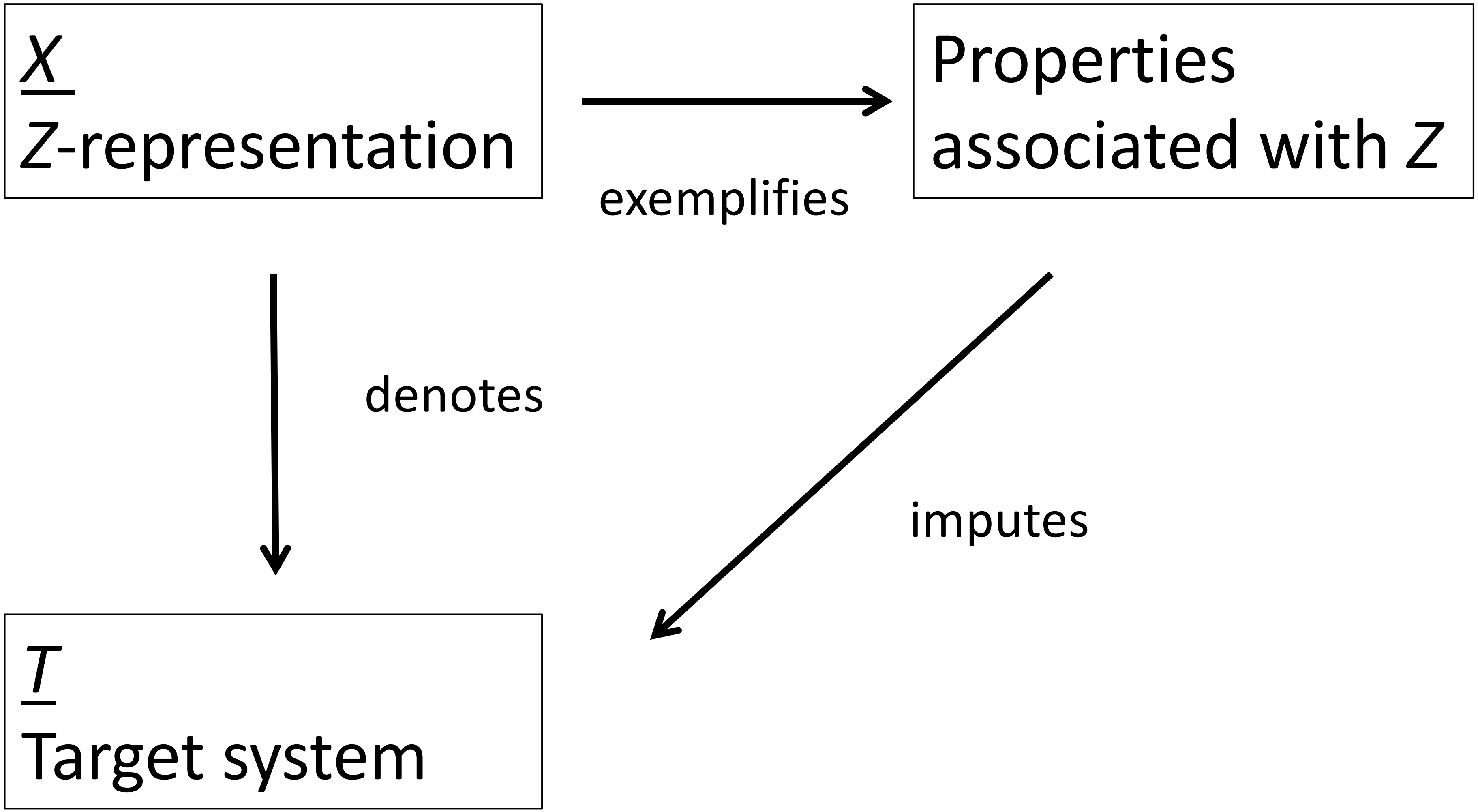
Boxer-properties:

- Brutality
- Ruthlessness
- Aggressiveness

denotes

imputes

Goodman and Elgin's Analysis:



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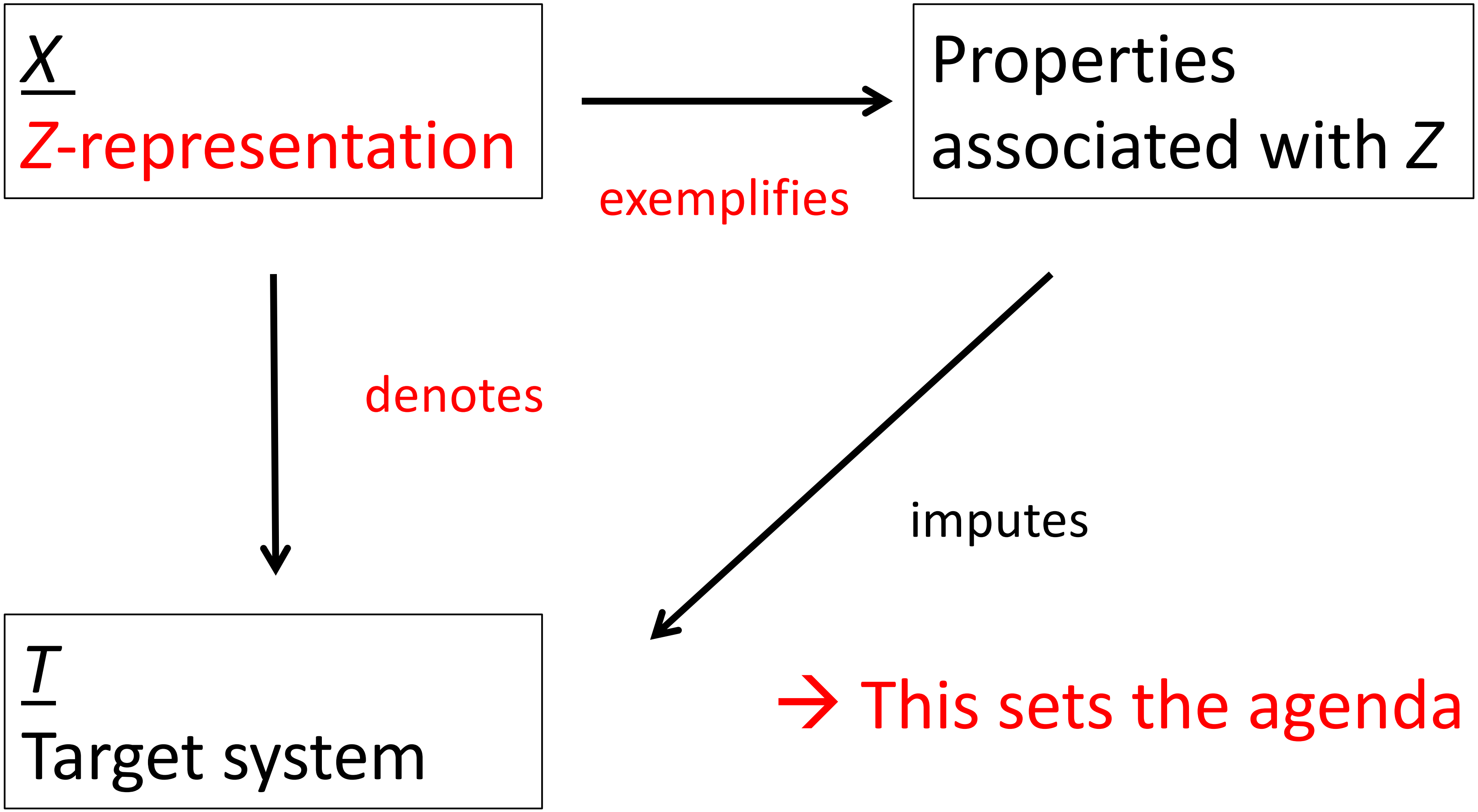

→ This sets the agenda

(a) Denotation

Denotation is the two-place relation between a symbol and the object to which it applies.

Example: proper names.

Denotation is the core of representation:

***X* is a representation of *T* iff *X* denotes *T*.**

(a) Denotation

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Denotation is the core of representation:

***X* is a representation <u>of</u> *T* iff *X* denotes *T*.**

Denotation presupposes existence: only something that exists can be denoted.

Consequence:

Pictures of unicorns do not *denote* anything because unicorns do not exist.

Such pictures therefore are not *representations* of anything.

Objection: This can't be …

Goodman's Diagnosis:

We are mislead into believing that something is a representation only if there is something in the world that it represents.

Distinguish between:

A picture of a unicorn

A unicorn-picture

More generally:

A representation of a *Z*

A *Z*-representation

One does not imply the other!

- Some *Z*-representations denote a *Z* and others don't.
- Some representations of a *Z* are *Z*-representations and others aren't.

Territory-representation and a representation of a territory (namely Japan)

Territory-representation but not a representation of a territory (not a representation of anything)

Japan

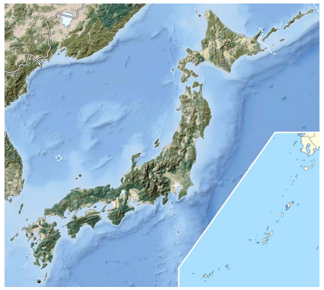
Japan

Not a territory-representation but
a representation of a territory

Summing up

Representation *of Z*

Z-Representation

	yes	No
yes		
no	“Japan”	[mere objects]

What makes something a *Z*-representation?

In the case of pictures:

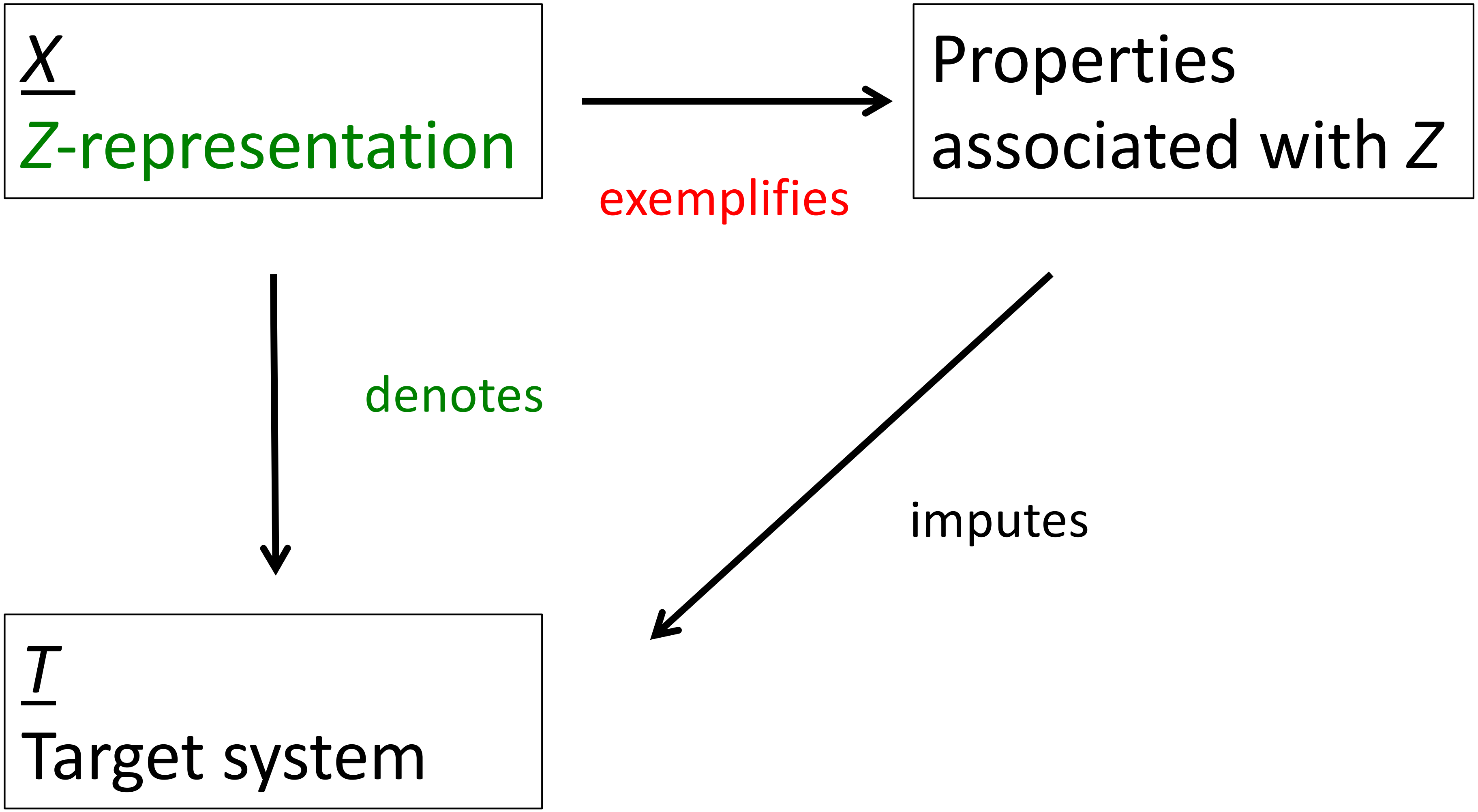
- Perceptual accounts: a picture *X* is *Z*-representation if, under normal conditions, an observer would see a *Z* in *X* (e.g. Lopes)
- Genre Account (G&E): Pictures belong to genres and are recognisable as such.

Neither of these works in the case of science.

Operate with an intuitive notion for now.

→ Come back to this later.

Taking stock:



(b) Exemplification

What we're getting at:

- Studying models requires "internal" structure.
- Theory of representation needs to take this into account.
- Denotation *by itself* is not enough.

Intuitively, an item <u>**exemplifies**</u> a property if it represents by instantiating a property.

Exemplification is possession *plus* reference.

Example: samples (chees on the market, …)

Notice: lexicographical signs don’t work this way.

Exemplification implies instantiation

Converse does not hold: not every property that is instantiated is also exemplified.

→ Exemplification is <u>selective</u>.

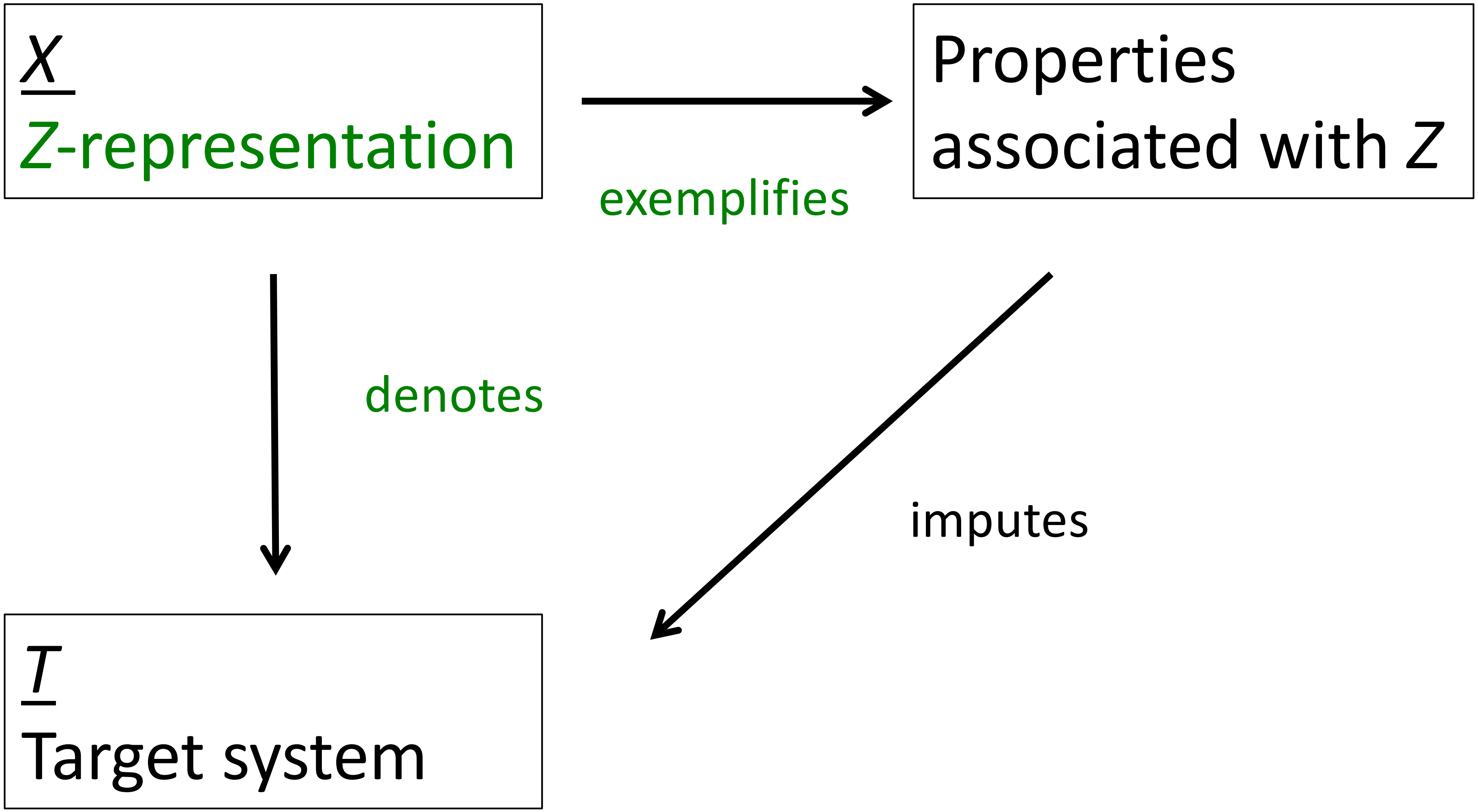
Selection depends on context.

Why exemplification?

1.) “Internal behaviour”

2.) **Epistemic access** to the properties they exemplify: from an exemplar we can learn about the properties that it exemplifies.

Taking Stock



Example: Thatcher as a boxer

Example: Thatcher as a boxer

Boxer-representation

Example: Thatcher as a boxer

Boxer-representation

denotes

Example: Thatcher as a boxer

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imputes

Entering the Arena of Science

Main idea:
Just replace the caricature with a scientific model.

4. Entering the Arena of Science

Economy-representation

exemplifies

Economy-properties:
- Anti-correlation of interest rates and inflation
- …

denotes

imputes

Economy of Guatemala

4. Entering the Arena of Science

Economy-representation

exemplifies

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- Anti-correlation of interest rates and inflation
- …

denotes

Economy of Guatemala

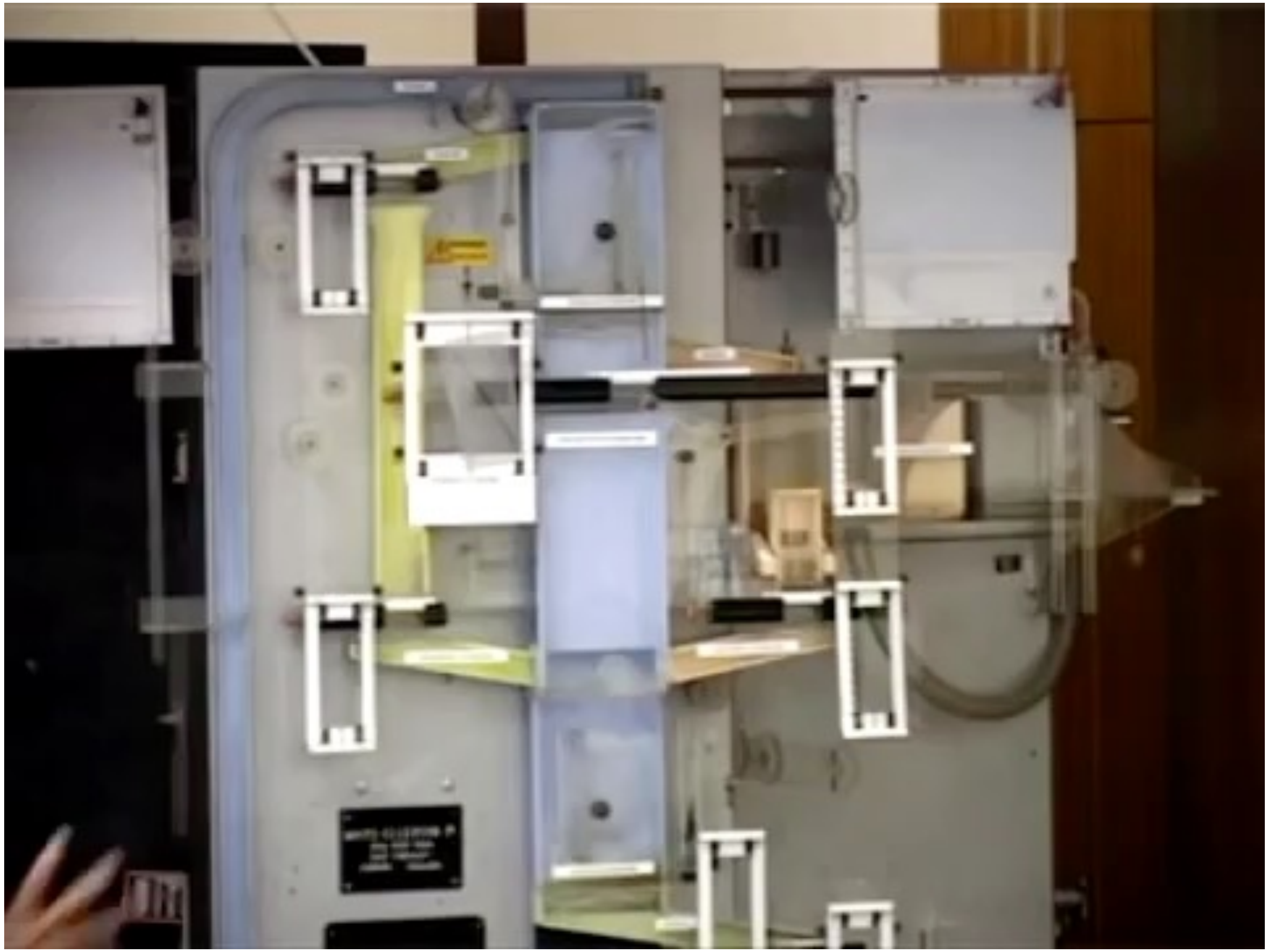
imputes

→ This sets the agenda

(a) *Z*-representation in Science

What turns a system of pipes into an economy-representation?

→ **<u>Interpretation</u>**: We interpret water-pipe-properties in terms of economy properties.



https://www.youtube.com/watch?v=k_-uGHWz_k0

Objects *X*

Objects have *X*-properties

Example: water properties

Z-Domain

Field/object of interest. *Z*-properties

Example: *Z* = Economy

(interest rate, capital holdings, …)

Interpretation *I*

Pairing up of *X* and *Z* properties:

- Sortal predicates are "paired up"

  (Having large reservoir → having a central bank)

- Mass terms also receive a mass-correlation function.

  (Amount of water → amount of money and

  1 liter of water = 1,000,000 in model-currency)

Now we can define:

Z-representation: <*X*, *I*> where:

- *X* is an object and
- *I* is an interpretation.

Model: *Z*-representation where *X* has been chosen by a scientist (or scientific community) to be a model.

Notice: models need not have a target!

The "Google definition" has to be qualified: a model is a *Z*-representation!

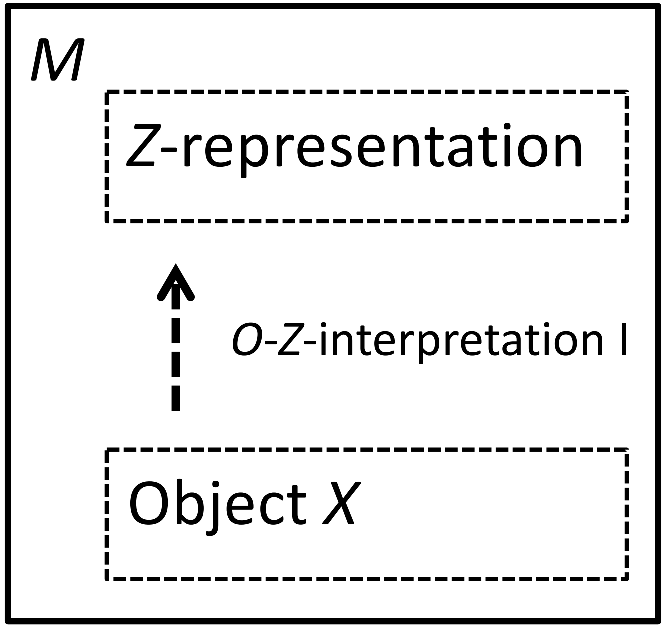
Example

The P-N Machine
X = water pipe system
Z = economy
I is an *O*-*Z*-Interpretation

The P-N Machine (*X*) becomes an economy representation if it is described as an *X*-object and endowed with interpretation.

Again: no target is needed for that.

Toward a General Account



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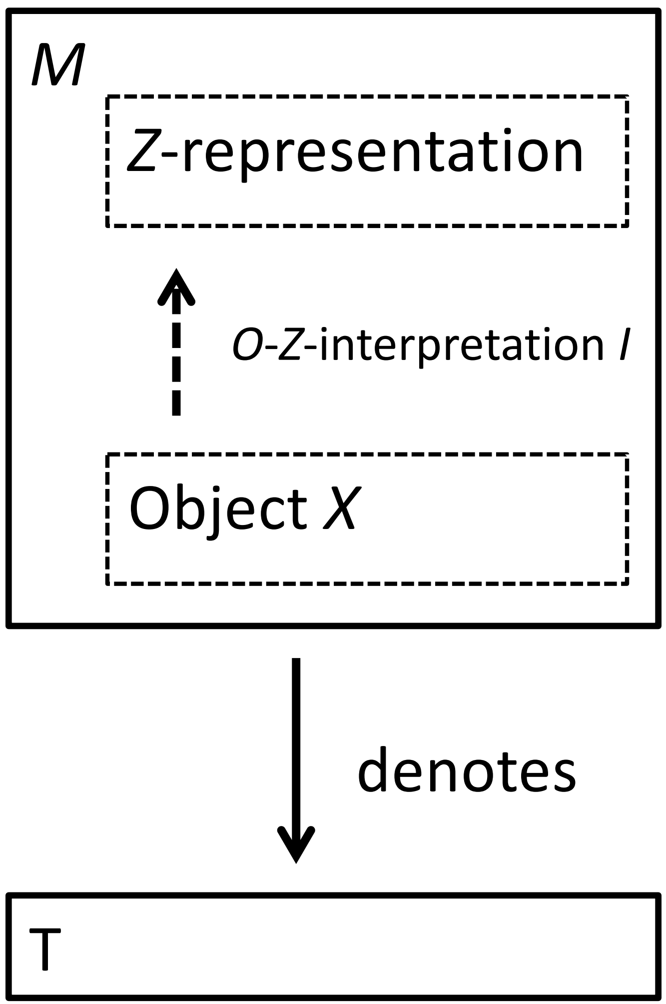

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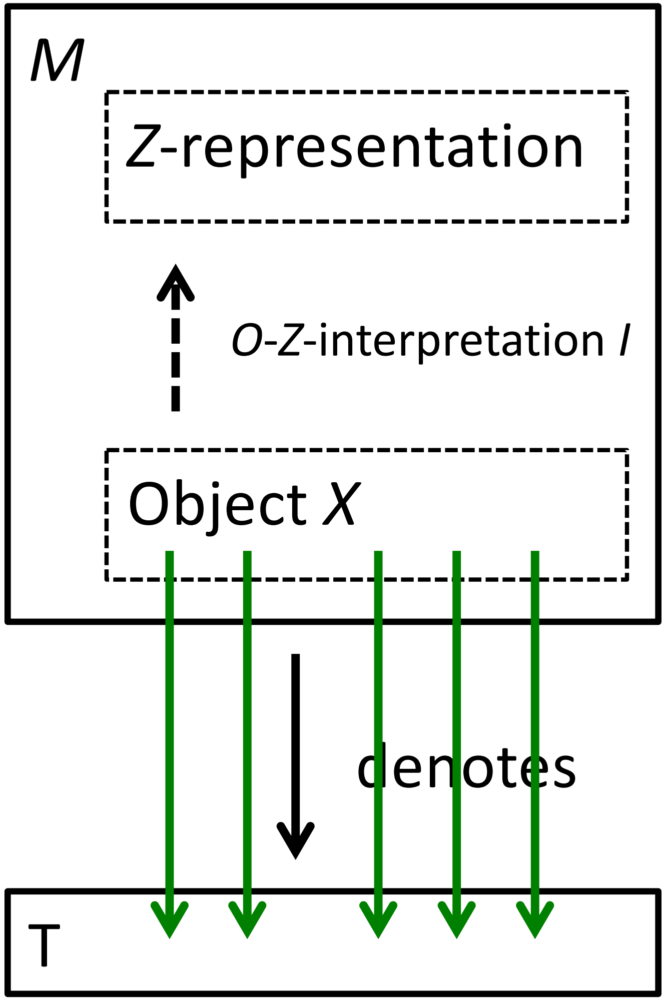


Notice:
This can also involve part-part denotation

(b) *I*-instantiation

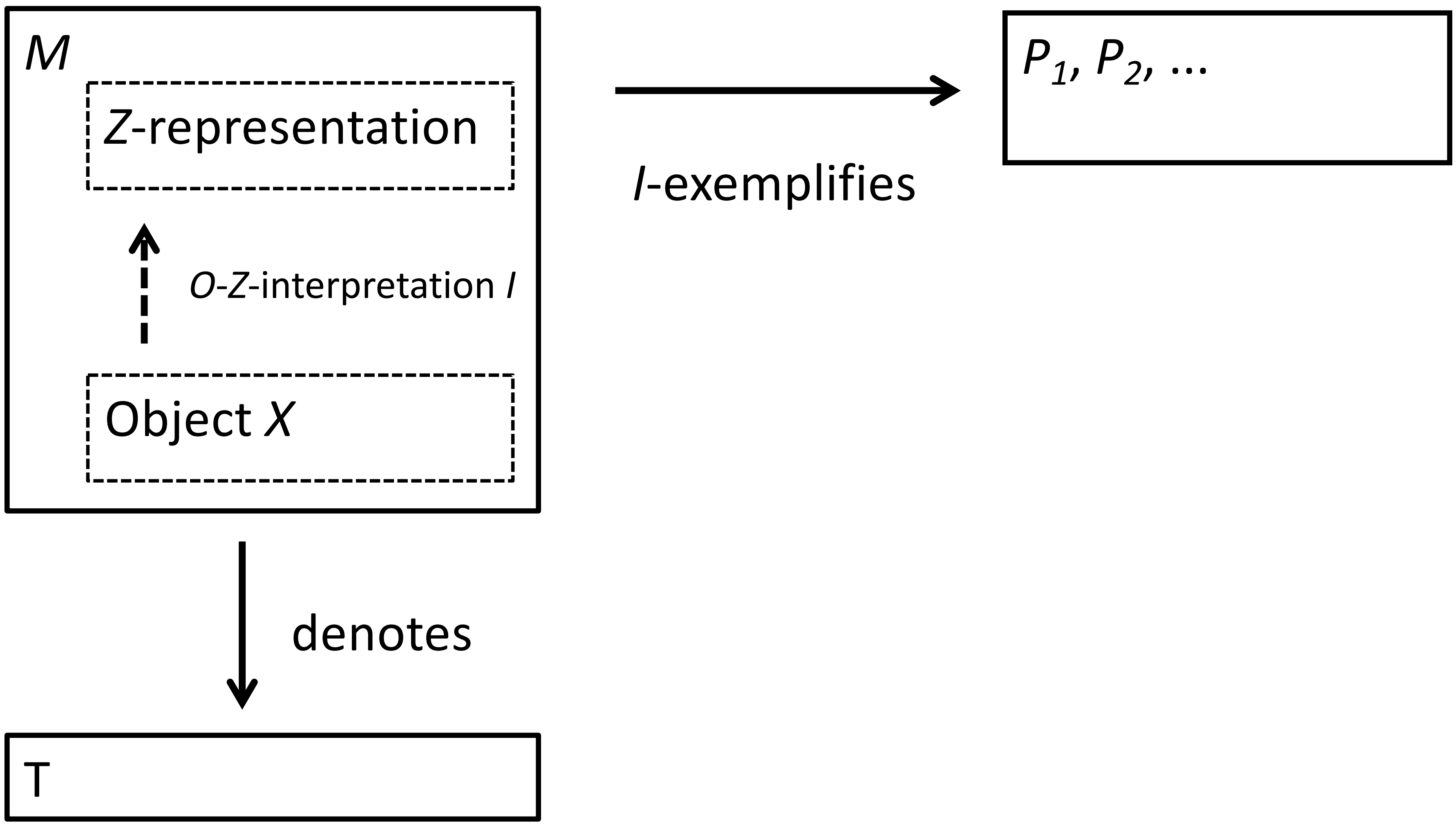
Recall: exemplification is instantiation plus reference.

But: pipes don't instantiate economy-properties.

Solution:

- instantiation under an interpretation *I*: "*I*-instantiation".
- *I*-Exemplification: *I*-instantiation plus reference.

Toward a General Account



(c) Imputation

Recall:

Boxer-representation

exemplifies →

Boxer-properties
- Brutality
- Ruthlessness
- Aggressiveness

↓ denotes

imputes

But: Scientific models don’t usually portray their targets as having <u>*exactly*</u> the same features as the model itself.

Hence, properties exemplified by the model are not the ones imputed to the target.

→ Translation key.


GERMANY
FRANCE
AUSTRIA
ITALY
SWITZERLAND
Jura Mountains
Swiss Plateau
Swiss Alps
Lake Constance
Lake Geneva
Schaffhausen
Konstanz
Basel
Rheinfelden
Winterthur
Zurich
Thur
Rhine
Aare
Reuss
Säntis 2503
Biel
La Chaux-de-Fonds
Luzern
Bern
Fribourg
Thun
Haldensteiner Calanda 2806
Chur
Tödi 3614
Inn
Dammastock 3630
Piz Kesch 3418
Finsteraarhorn 4274
Lausanne
Saane
Piz Bernina 4049
Rhone
Geneva
Dents Du Midi 3257
Grand Combin 4314
Matterhorn 4478
Dufourspitze 4634

Properties exemplified:

1. Distance between top and bottom end is 22cm.
2. The dot with “Chur” written next to it lies in a yellow area.

Properties exemplified:

1. Distance between top and bottom end is 22cm.
2. The dot with “Chur” written next to it lies in a yellow area.

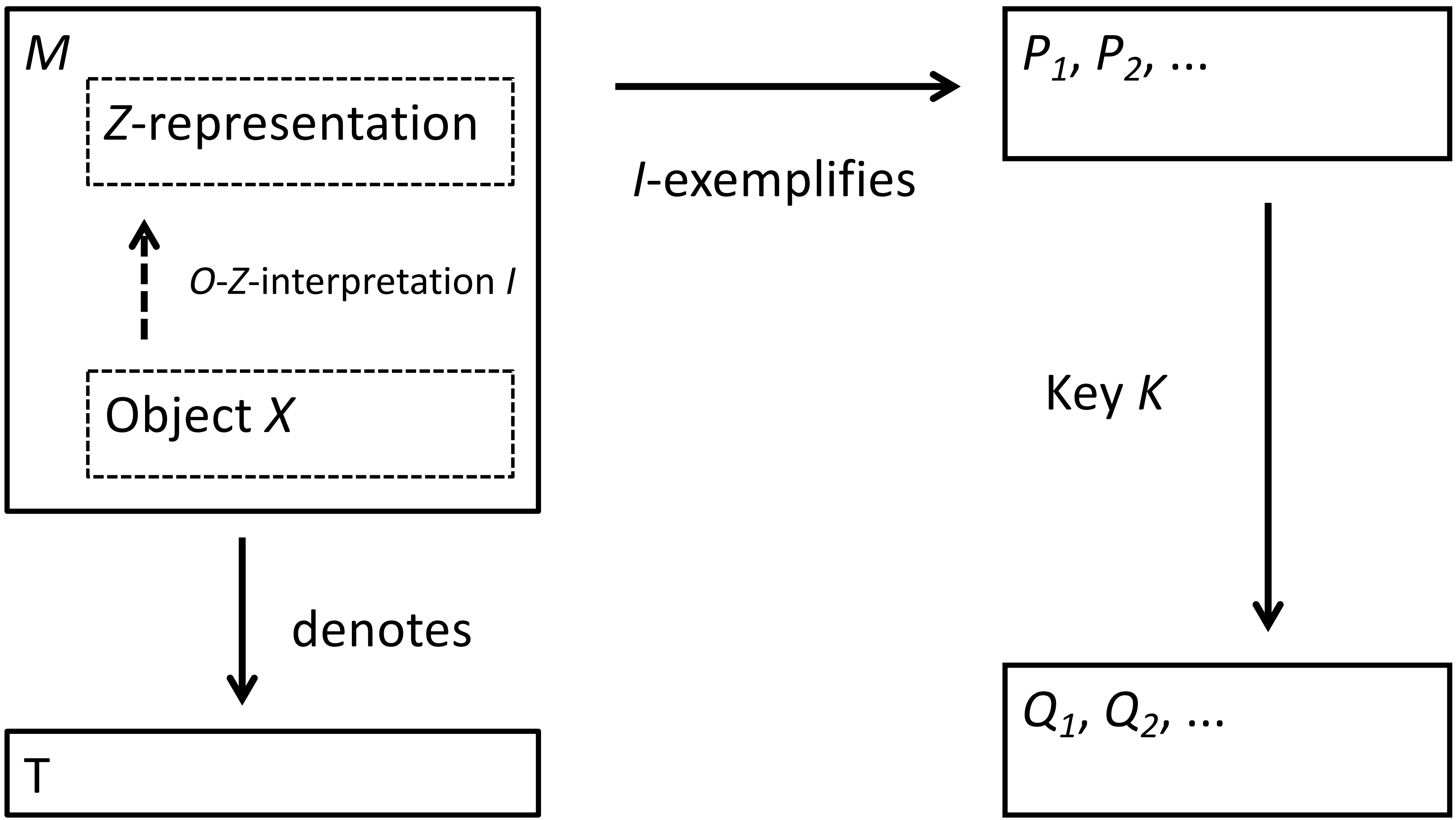
Properties imputed:

1. North south extension is 220km.
2. The city of Chur is 600m above sea level.

Other examples:

- When using litmus paper *P* is *red* and *Q* is *acidic*; red paper imputes acidity to the solution because the paper comes with key specifying *K*(red)=acidic.
- Tolerance thresholds: ± 5%
- Limit relations (Nguyen and Frigg 2020)
- Idealisations (Frigg 2022, Ch. 12)
- …

Toward a General Account



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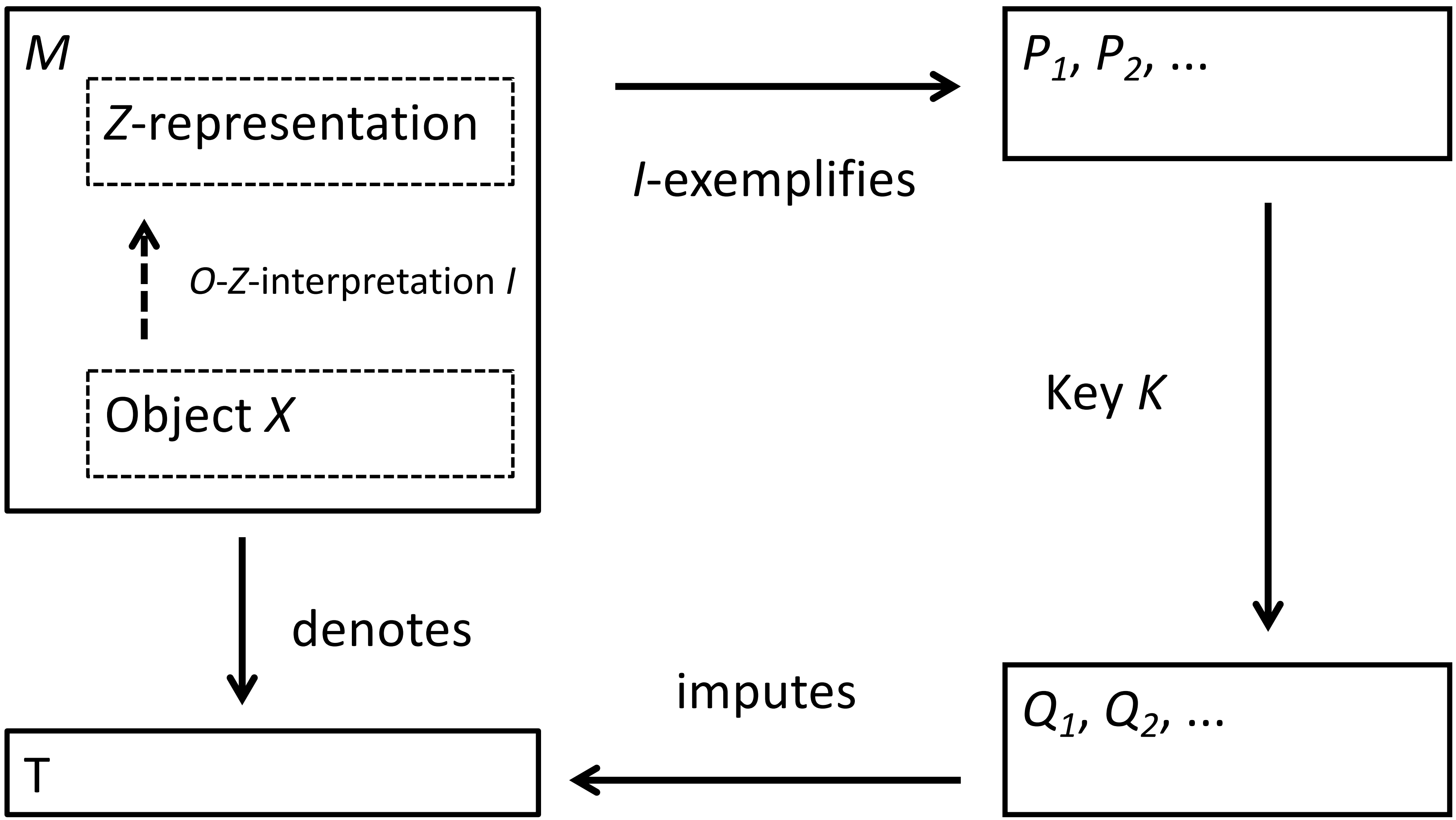

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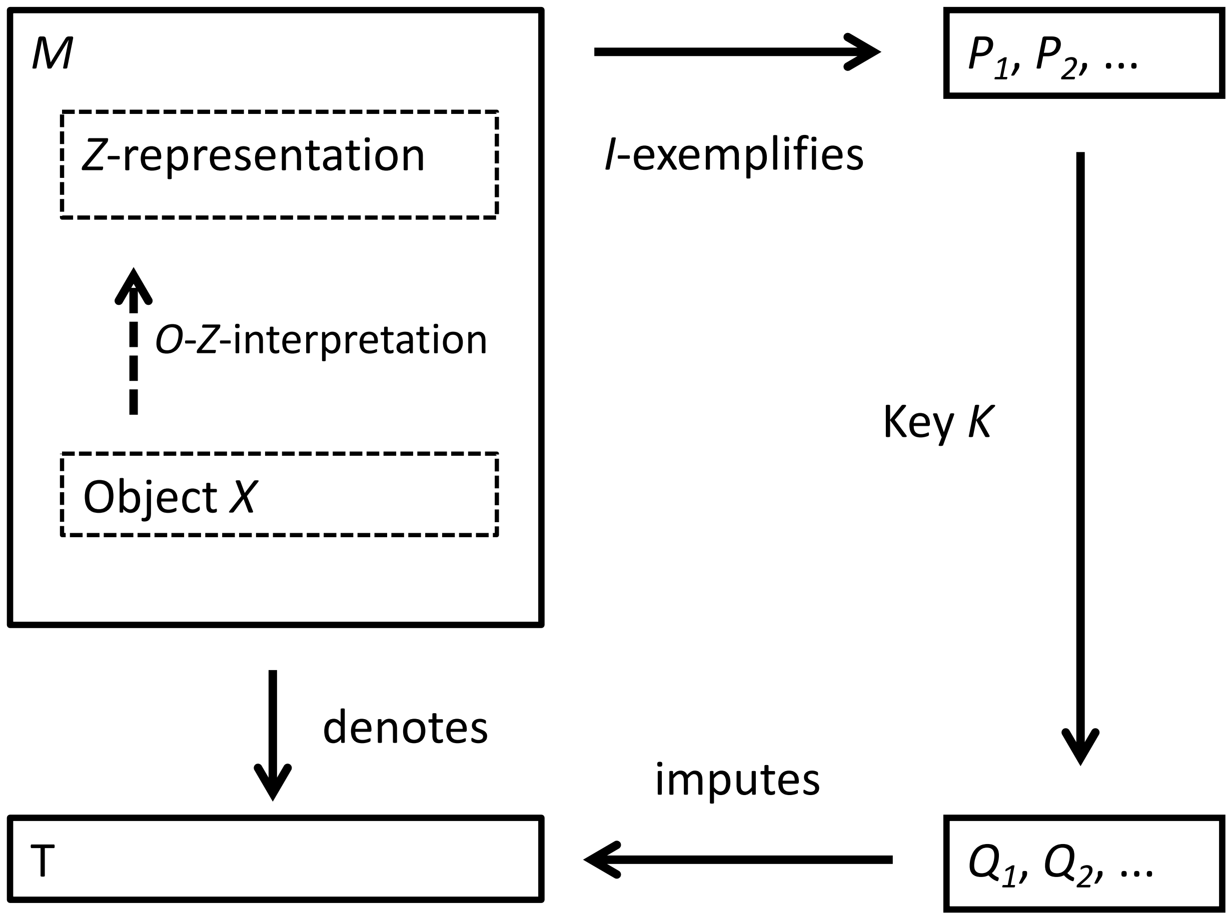

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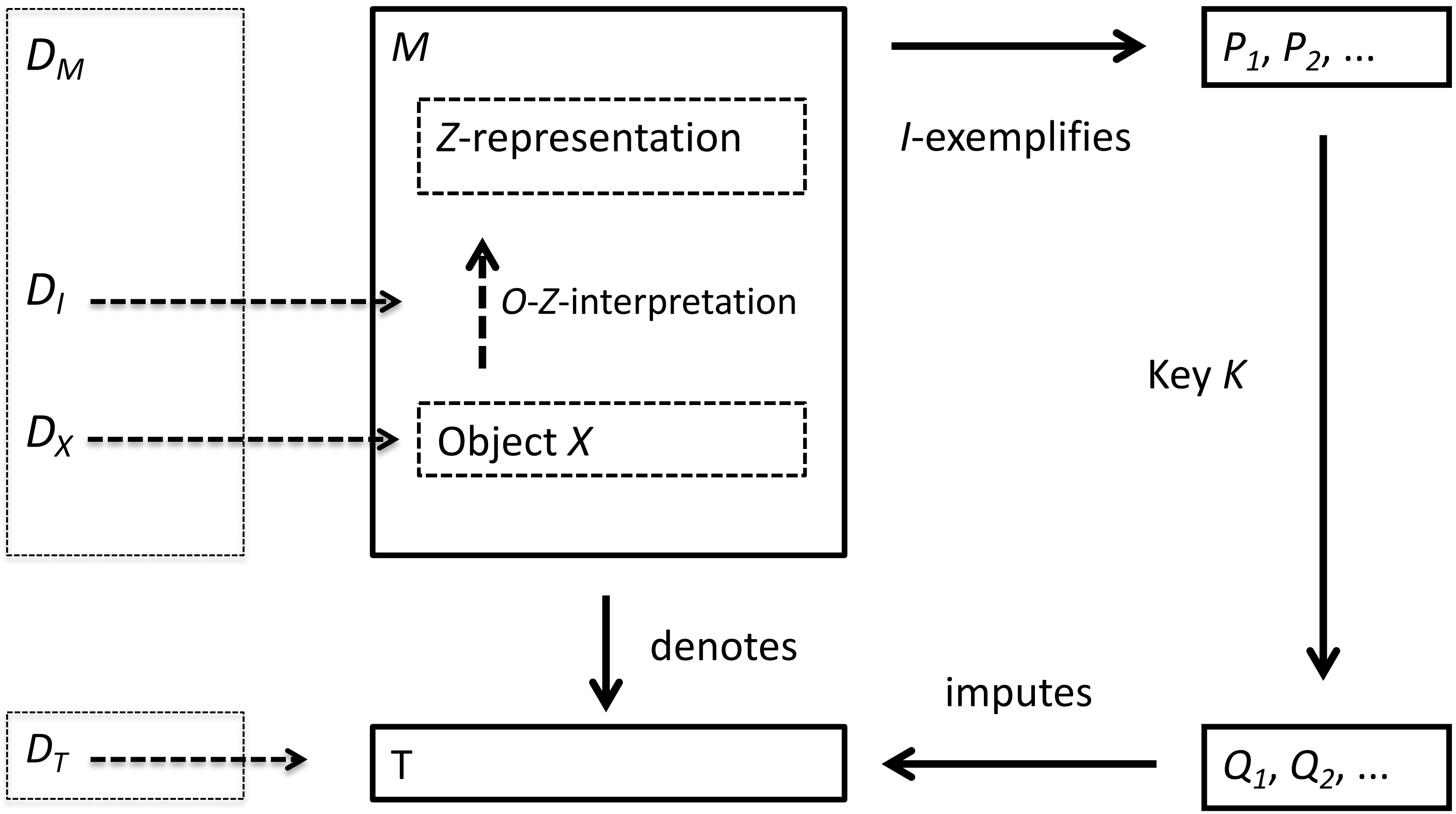


“DEKI” Account

Denotation

Exemplification

Keying-up

Imputation


free as a bird
DE KI 77


DE KI 77
free as a bird

Corollary 1:

A representation is *faithful* if T indeed posses the properties that the representation ascribes to it.

That this be the case is *not* built into the notion of representation-as.

X can represent T as possessing properties Q_1, …, Q_m and T can not instantiate a single of them.

Corollary 2:

‘scientific model’ is not a synonym for ‘scientific representation’:

- Not all models are reps-of something (multi-sex populations)
- Not all reps are models (graphs, diagrams)

Conditional claim: if a model represents a target, then it does so in the sense of the DEKI.

But note: the account has a nice story to tell about targetless models.

Corollary 3:

The DEKI account explains how learning from models takes place:

We look at the properties $P_1, \ldots, P_n$ exemplified by the model, along with the key, and infer that the target system has the properties $Q_1, \ldots, Q_m$ that result from the application of the key

Corollary 4:

This is the general form of an account of representation. The ‘blanks’ need to be filled on every occasion by specifying:

- how denotation is established;
- what properties the base object exemplifies;
- what translation key is used;
- how the imputation is taking place.

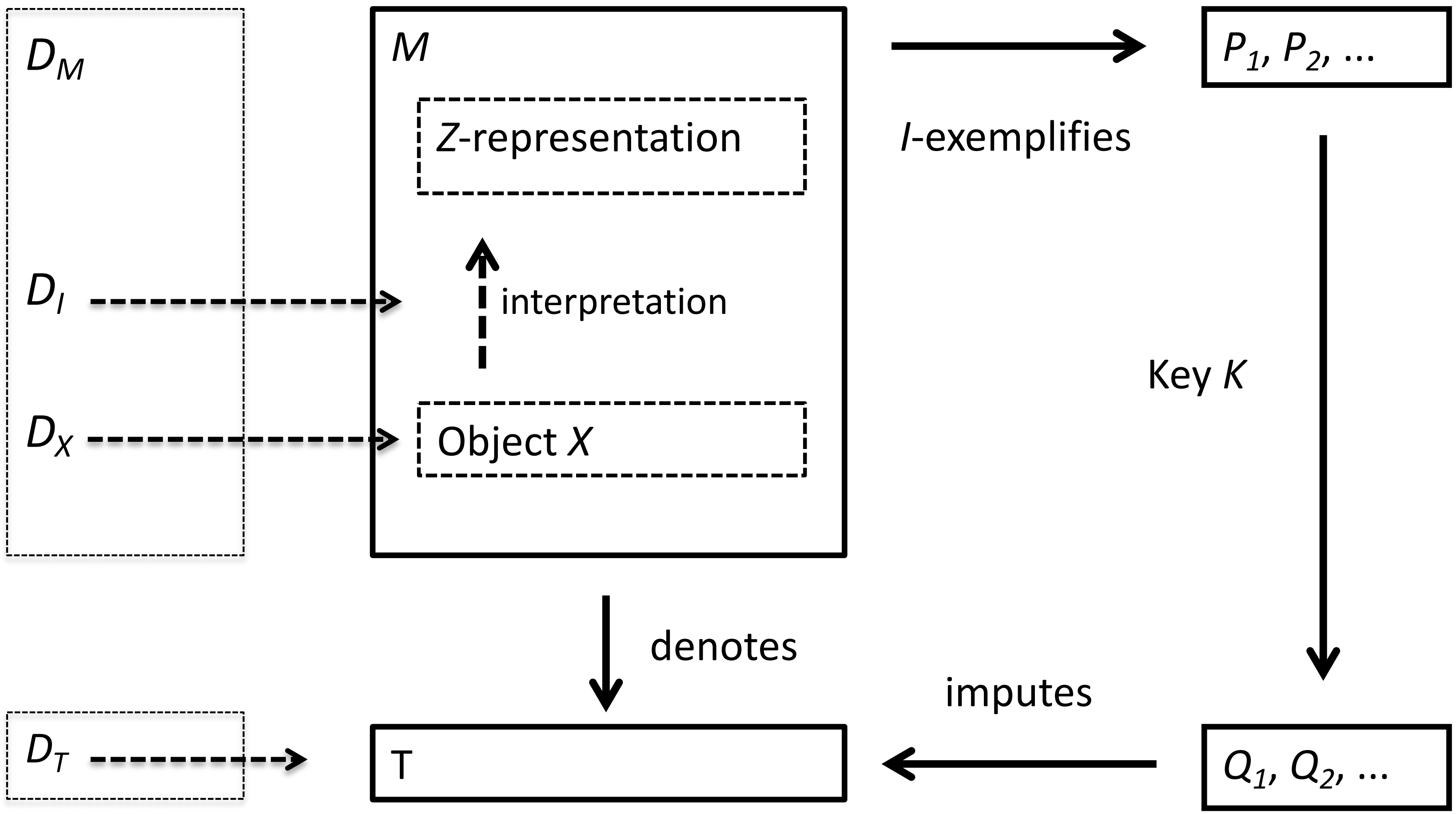
This completes my discussion of material models represent …

… but what about non-material models?

Material models are nice, but …

- The Newtonian Model of the Solar system
- The Bohr model of the atom
- The Schelling model of social segregation
- The Fibonacci model of population growth
- The billiard ball model of a gas
- The Lorenz model of the atmosphere
- The Lotka-Volterra model of predator and prey
- …

DEKI Account



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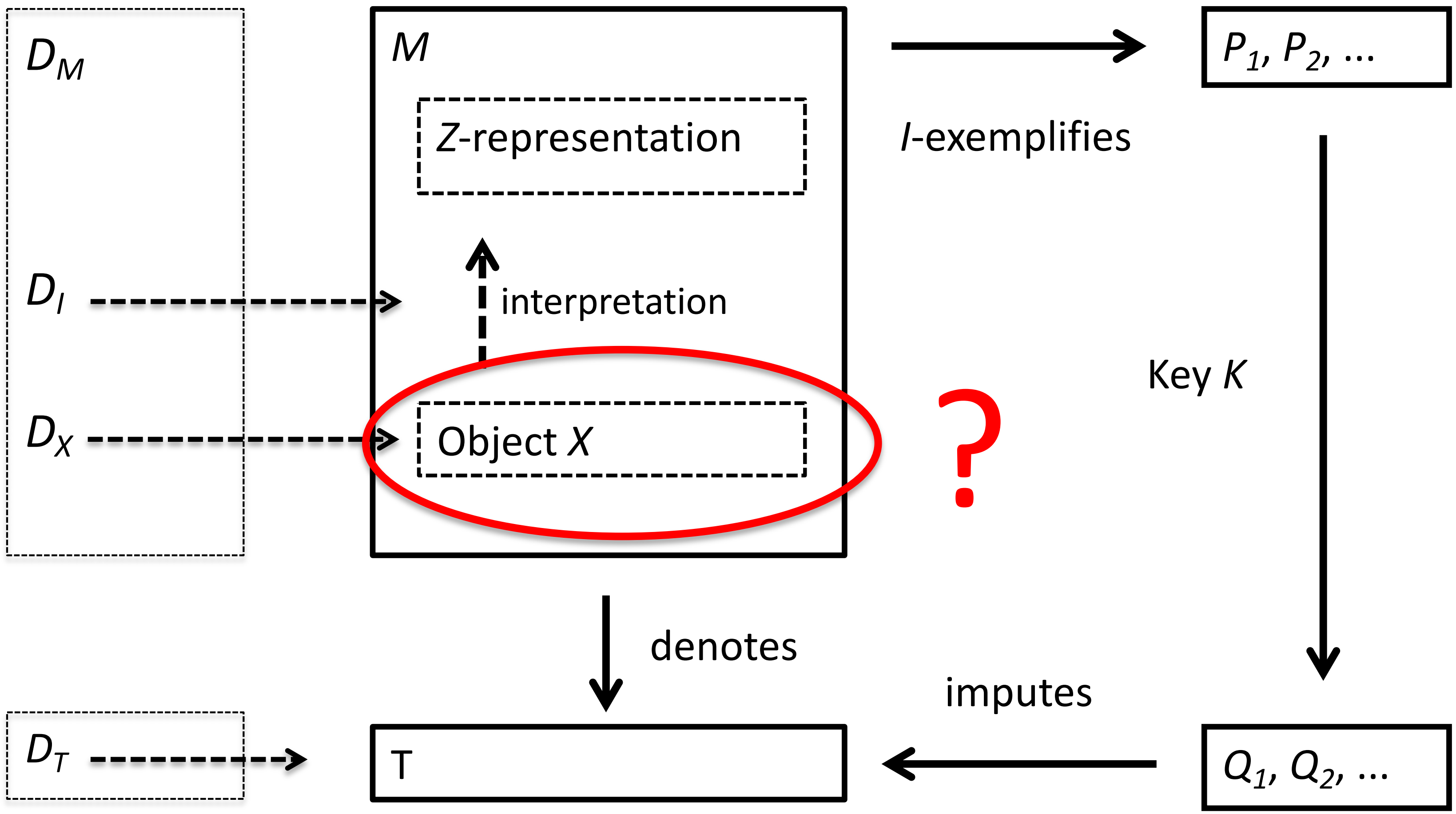


Two ways of thinking about this:

1. Models as fictional (entities)

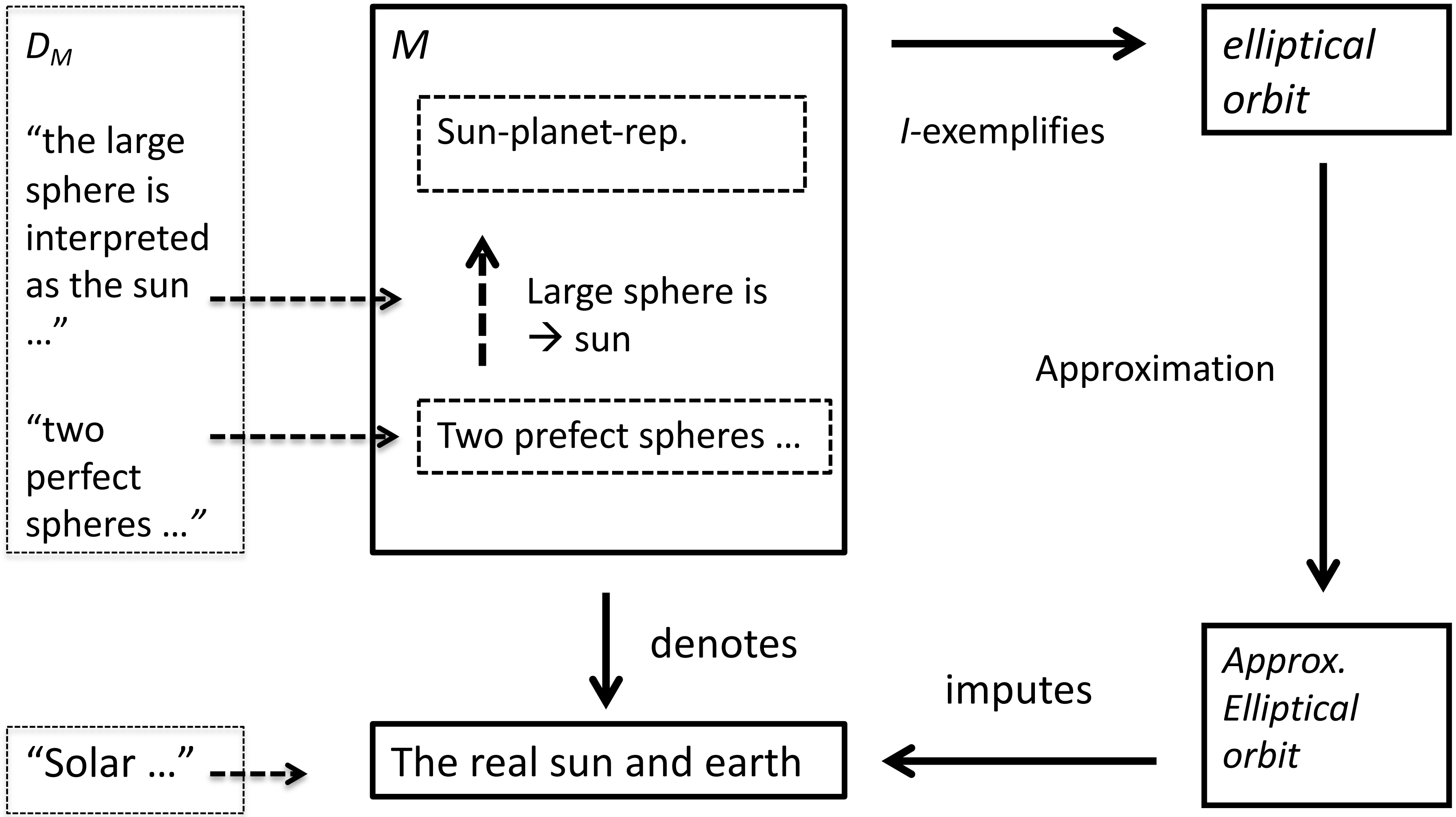
First postulate a fictional entity, then mathematise.

2. Models as mathematical

$$
\begin{aligned}
\nabla^2 c &= \kappa^2 c, \\
\partial c_{\mathrm{a}}/\partial t &= [J_{\mathrm{a}}^1 \alpha(c, c_{\mathrm{a}}) + J_{\mathrm{a}}(c_{\mathrm{a}})\beta(c, c_{\mathrm{a}})]R \\
&\quad + D_{\mathrm{a}}\nabla^2 c_{\mathrm{a}} - k c_{\mathrm{i}} c_{\mathrm{a}} \\
\partial c_i/\partial t &= D_{\mathrm{i}}\nabla^2 c_{\mathrm{i}} - k_{\mathrm{a}} c_{\mathrm{i}} c_{\mathrm{a}} + J_{\mathrm{i}}(c, c_{\mathrm{a}})\beta(c, c_{\mathrm{a}})R \\
\partial R/\partial t &= [D_{\mathrm{cell}} - (\lambda + \lambda_2\gamma(c, c_{\mathrm{a}}))R]\nabla^2 R \\
&\quad - \lambda_2 \partial\gamma/\partial c_{\mathrm{a}} R^2 \nabla^2 c_{\mathrm{a}} - \lambda_2 \partial\gamma/\partial c R^2 \nabla^2 c \\
&\quad + rR(R_{\mathrm{eq}} - R) - k_{23}\gamma(c, c_{\mathrm{a}})R.
\end{aligned}
$$

Begin with math. structure, then interpret

Example: Newton's model of solar system



The Good Modeler’s Checklist

1. Be clear on what your model entity *X* is and on what properties it has.
2. Make sure your interpretation is unambiguous and explicit.
3. Make sure it clear what the target is and denotation of the target is established.

If there is no target make that clear too.

Regarding 2 and 3: Never confuse a *Z*-representation with representation of a *Z*.

4. Be explicit about the properties you take to be exemplified.
5. Spell out the key
6. Say which properties are imputed.
7. Check accuracy of your representation: are the imputed properties really instantiated in the model?

ありがとうございます