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Making the invisible visible

The role of undergraduate textbooks in the teaching and learning of physics and chemistry

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Overview

The wider study

Development of specialized semiotic resources

Disciplinary and pedagogical affordance

Unpacking

Semiotic audit

An example

Future directions

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The study

Four-year Swedish Research Council project.

Interested in the ways undergraduate students come to understand invisible phenomena through the specialized resources used in their disciplines.

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Two areas of interest:

- Electromagnetic fields
- Chemical bonding

Research questions

In these two areas:

1. *What discipline-specific semiotic resources are made available to students?*

2. *How might these be unpacked for students?*

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Professional vision

Goodwin (1994) explains the development of professional vision—coming to see things in a particular, disciplinary way

We frame the development of professional vision in terms of coming to understand how to interpret and use disciplinary-specific resources

Airey (2006, 2009)

Tracking the development

An example of the development of specialized disciplinary meaning-making:

Building on O´Halloran (2007)

- Slide 9: Drawing Newton's discovery of colour refraction (newton and assistant present)
- Slide 10: 3D sketch by newton (no people much less detail)
- Slide 11: 2D presentation to royal society (standardized left to right, but many more rays than we would draw today
- Slide 12: 2D presentation today (single rays, but addition of colour)

The curse of knowledge

- There are a number of reasons why students don't understand disciplinary-specific resources

- Omission
  Experts leave things out
- Overloading
  Experts give too much information
- History
  Disciplinary resources are idiosyncratic
- Expectations
  Students' everyday misconceptions

Airey & Eriksson (2019)

Affordance

What has happened?

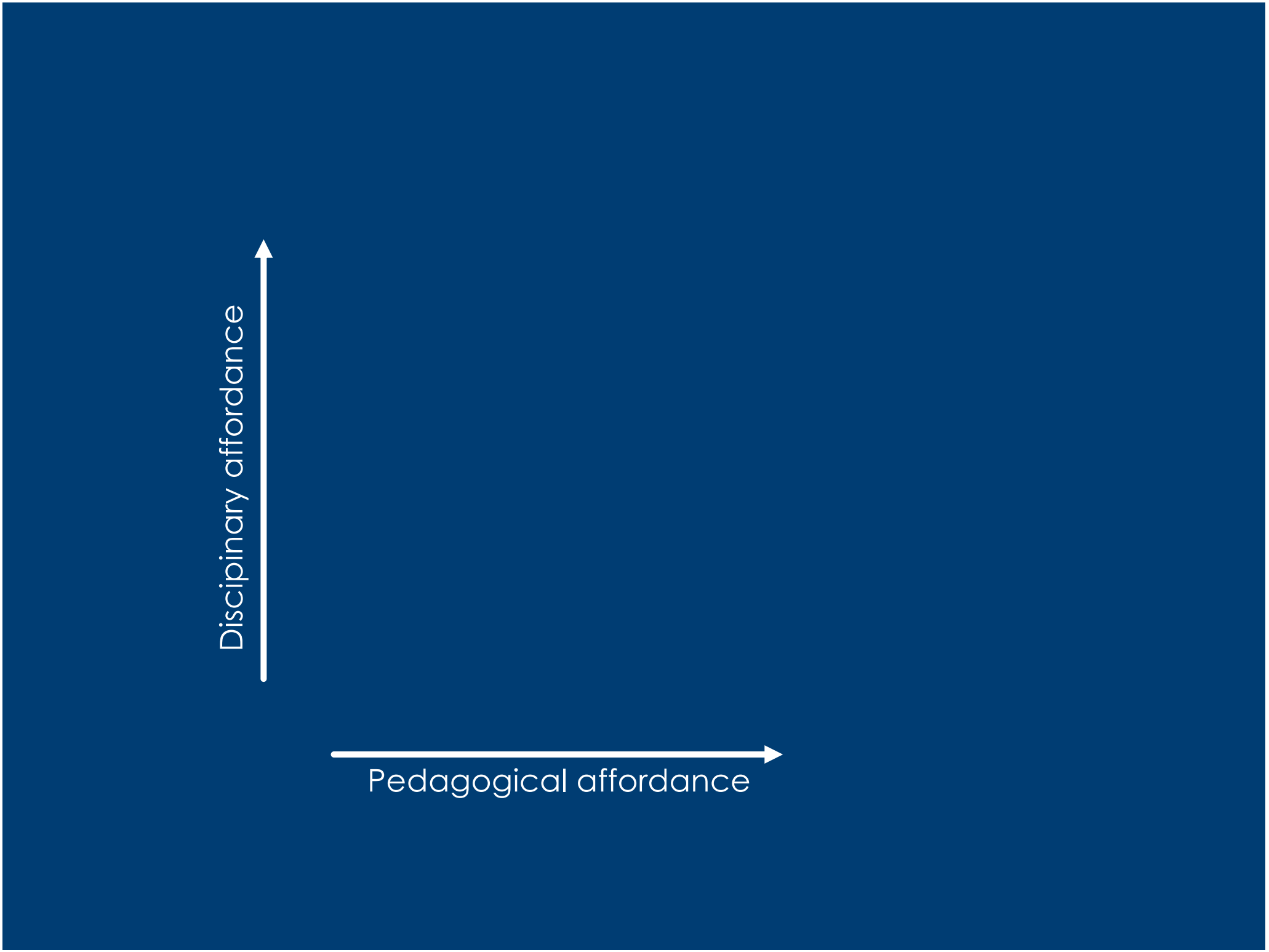
Removed information that is ”irrelevant” for the discipline.

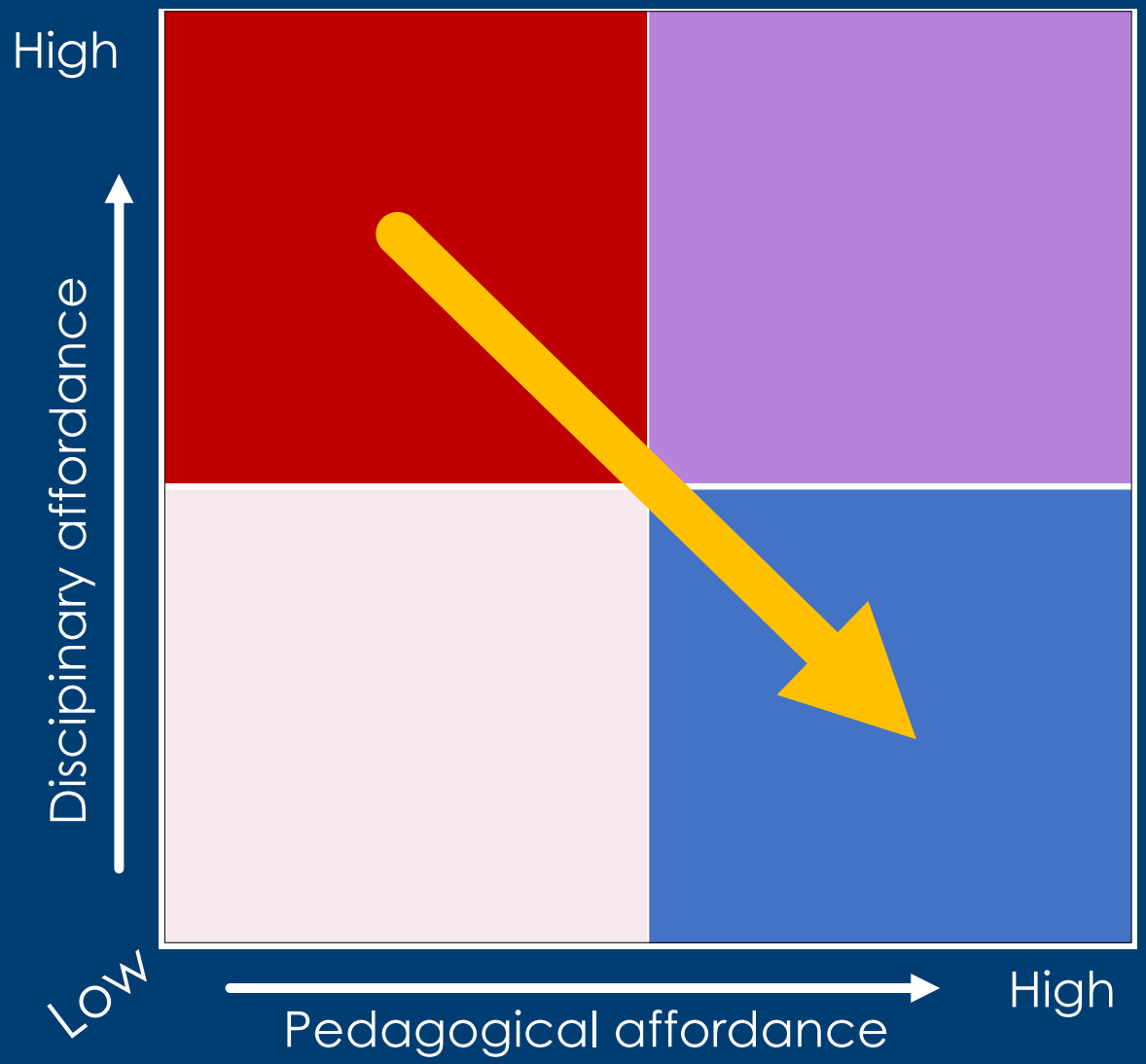
Higher Disciplinary Affordance

BUT:

Lower Pedagogical Affordance

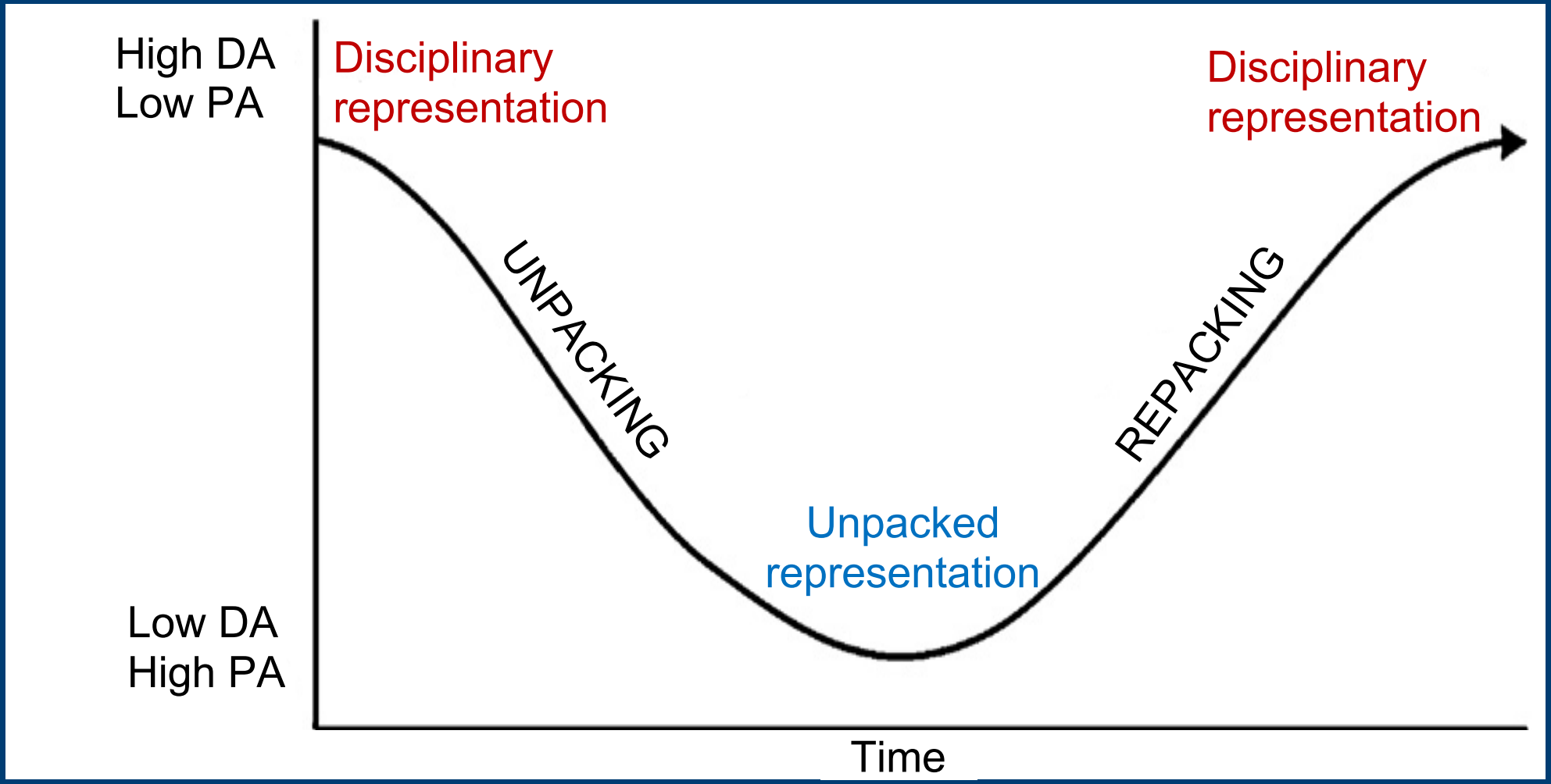
Airey (2015)


Discipinary affordance
Pedagogical affordance



Airey & Eriksson (2019)

Waves of affordance



Patron (2022)

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Semiotic audit

Semiotic audit—what is it?

Audit of semiotic resources made available to students and their affordances

Airey & Eriksson (2019)

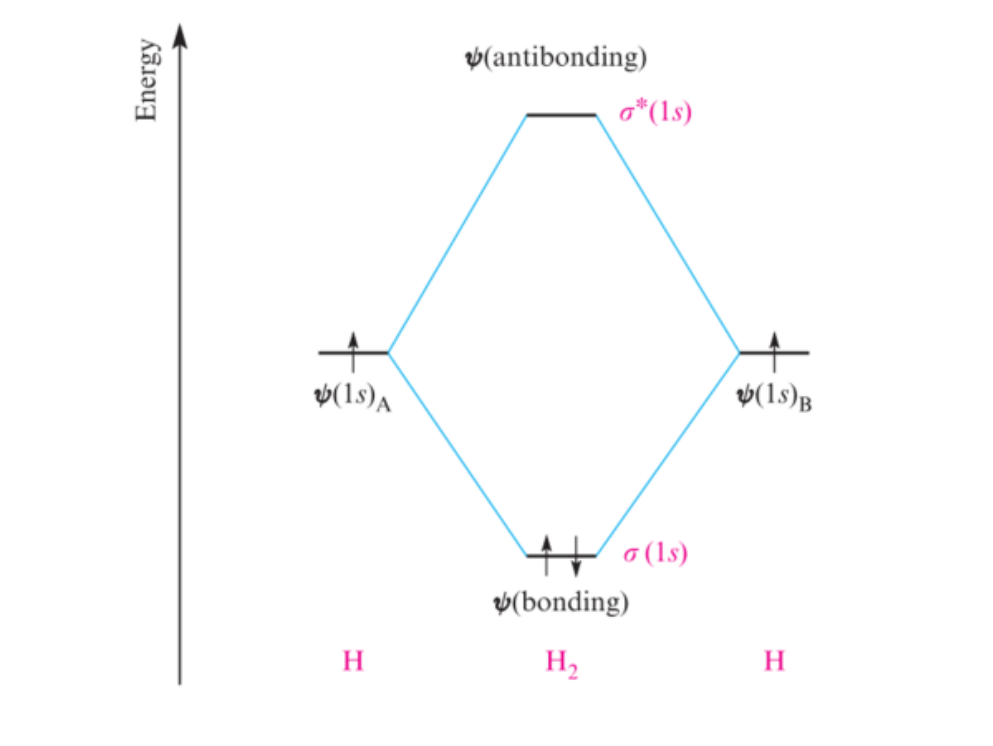
Visual resources in chemistry

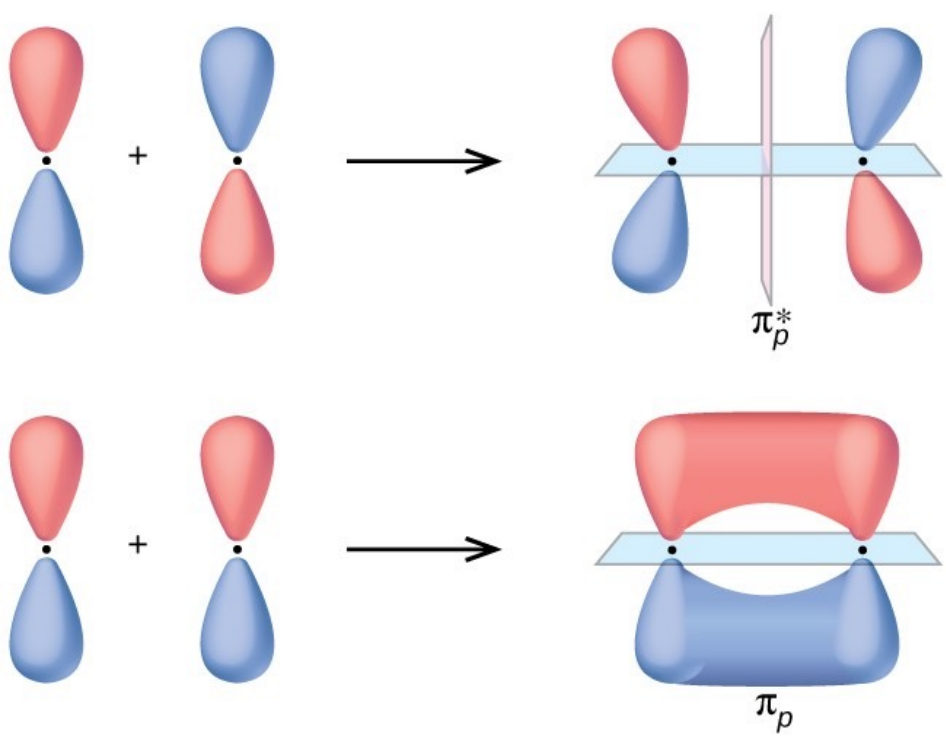
- *Mathematical formulas*
- *Chemical formulas*
- *Tables*
- *Diagrams*
- *Photos*
- *Graphs*
- *Physical objects*
- *Animations*
- *Simulations*

Frequency – chapter in chemistry book

1. Diagrams – 64%
2. Chemical formulas – 20%
3. Mathematical formulas – 6%
4. Photos – 5%
5. Tables – 3%

Examples of diagrams





Conclusion - Frequency

Large number of diagrams

High disciplinary affordance

Low pedagogical affordance

Need to be unpacked for students

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Why chemical bonding?

Only 94 naturally occurring elements

How do these 94 elements combine to make everything around us ?

Chemical bonding

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Why chemical bonding?

Simplest chemical bonding

Two hydrogen atoms join to form a hydrogen molecule

Important model (Molecular Orbital Diagram)

Models nature, but it is only a model

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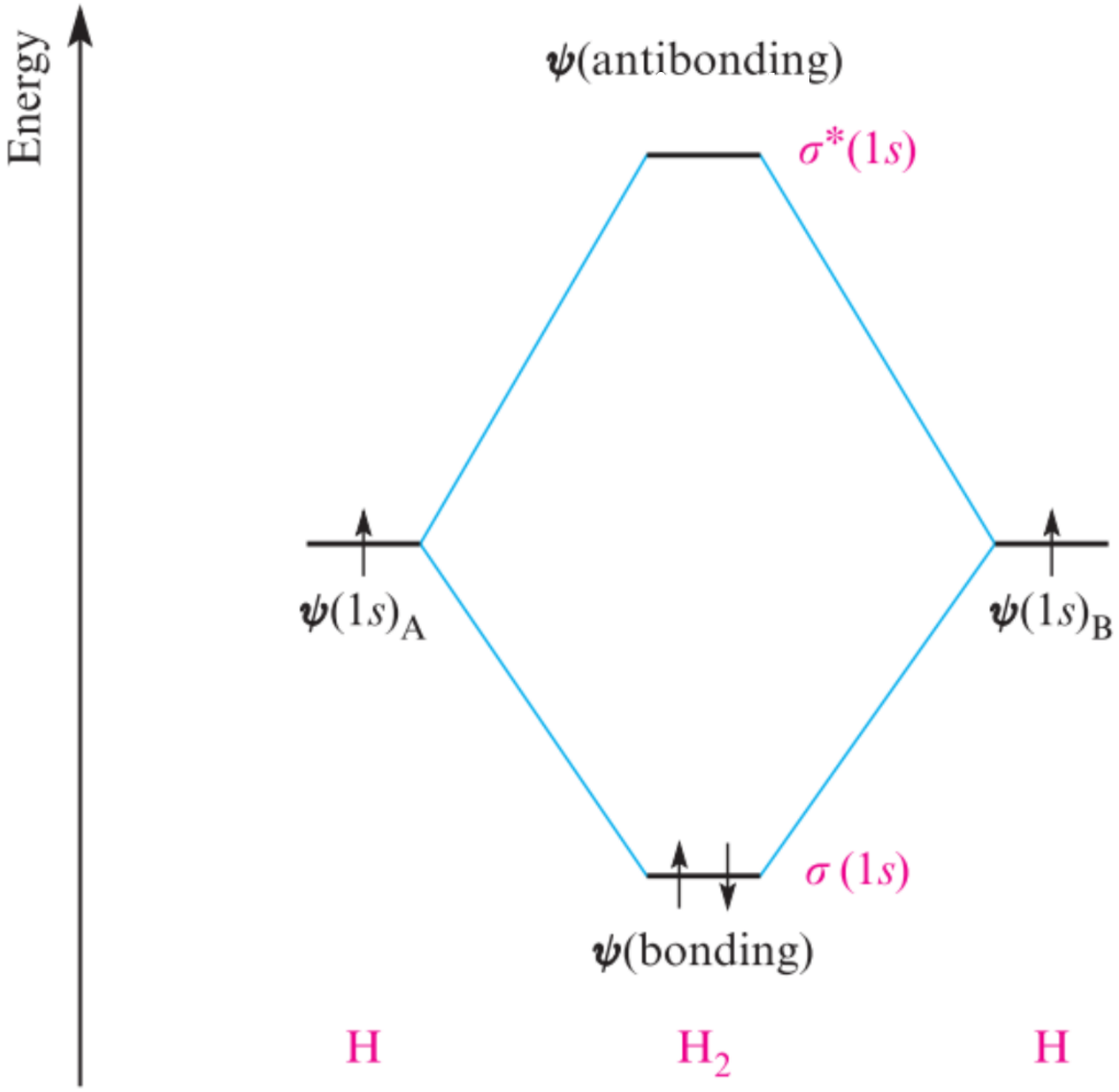
Molecular Orbital Diagram

$$H + H \rightarrow H_2$$

How is the diagram introduced in the textbook?


Energy
ψ(antibonding)
σ*(1s)
ψ(1s)A
ψ(1s)B
σ (1s)
ψ(bonding)
H
H2
H

Interpreting the diagram

Semiotic aspects students need to notice

- It's an energy diagram
- Energy increases "up the page"
- Diagram is read from the outside inwards

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Interpreting the diagram

Chemistry aspects students need to understand

- Bonding depends on sharing electrons
- Change in energy
- Lowest energy ”preferred”

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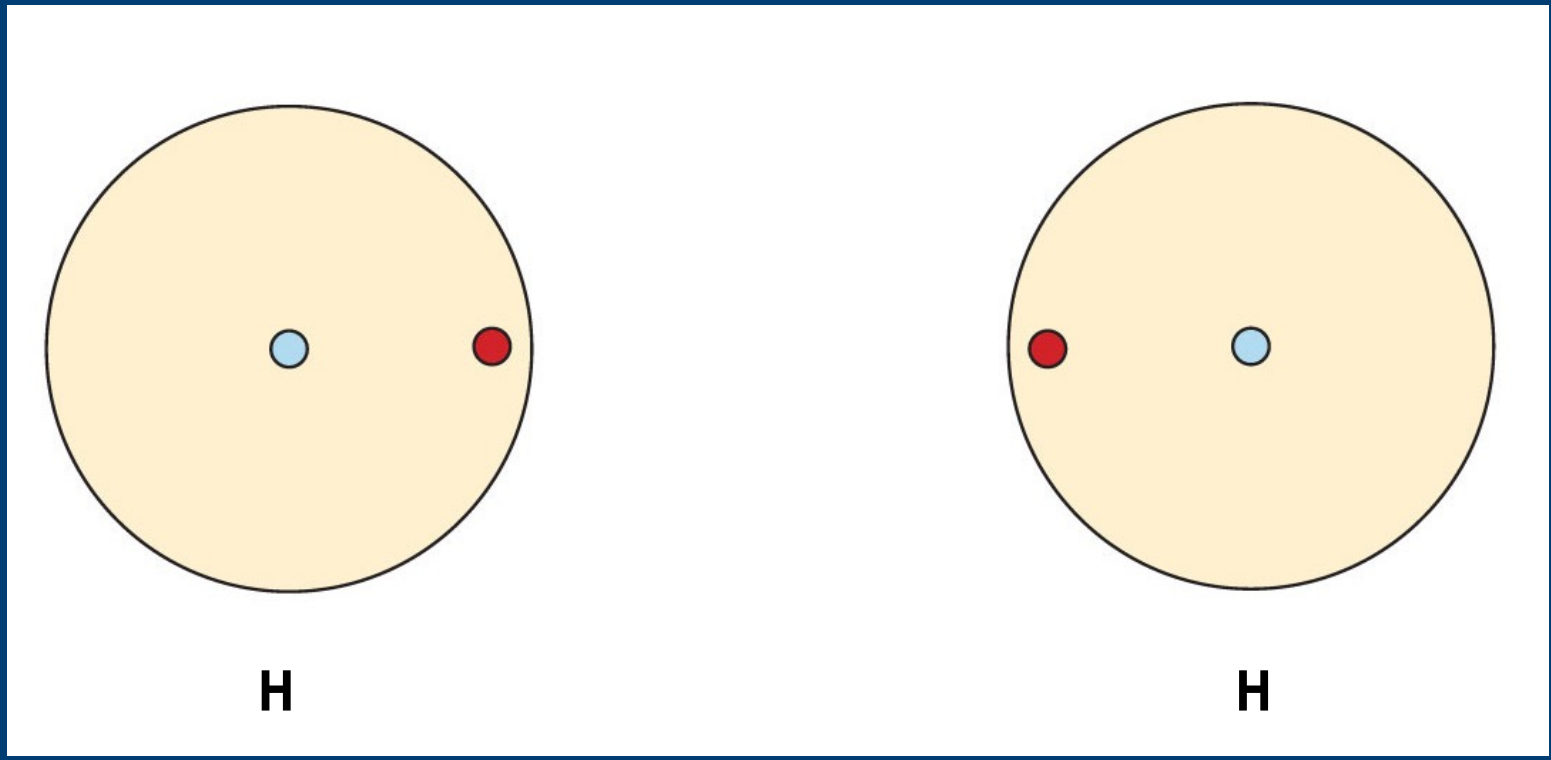
Bonding depends on sharing electrons



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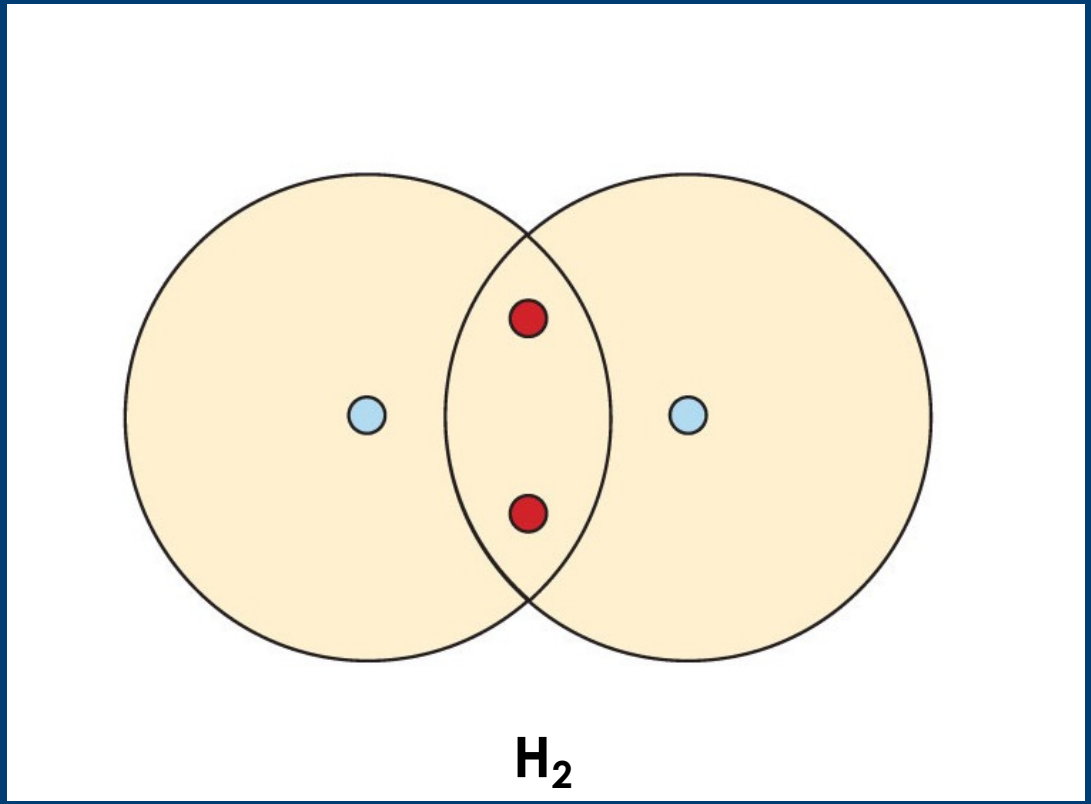
Bonding depends on sharing electrons



H_2

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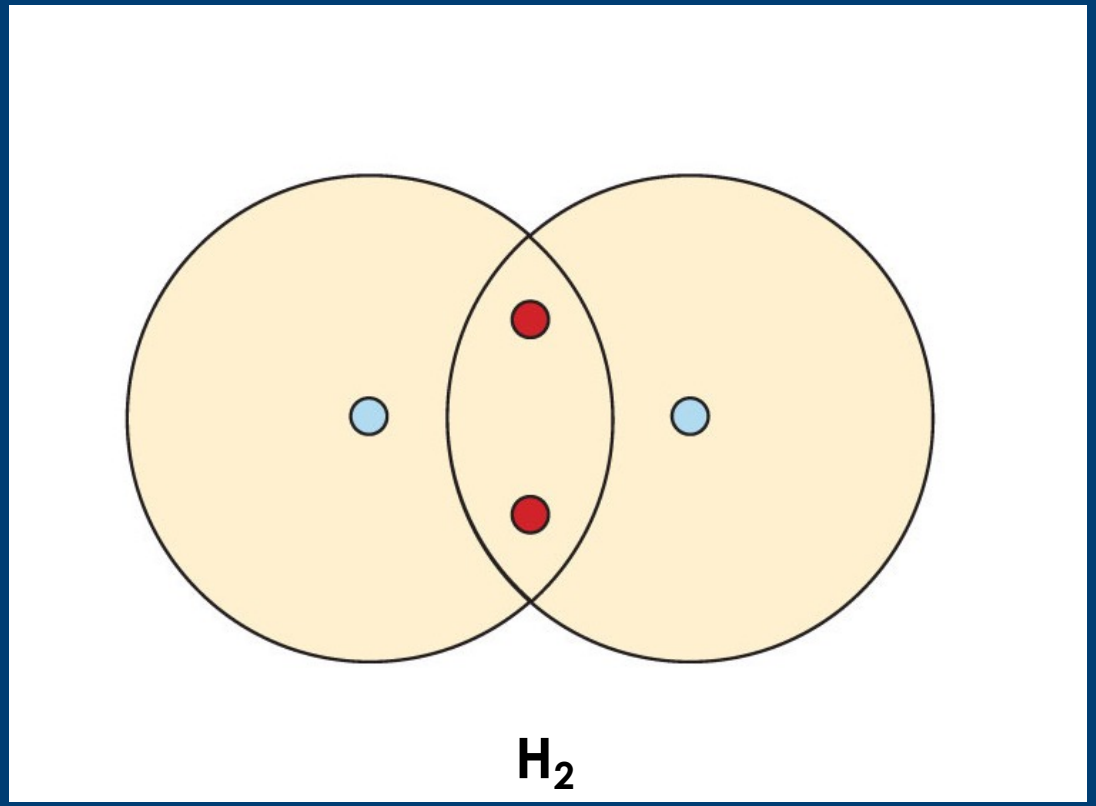
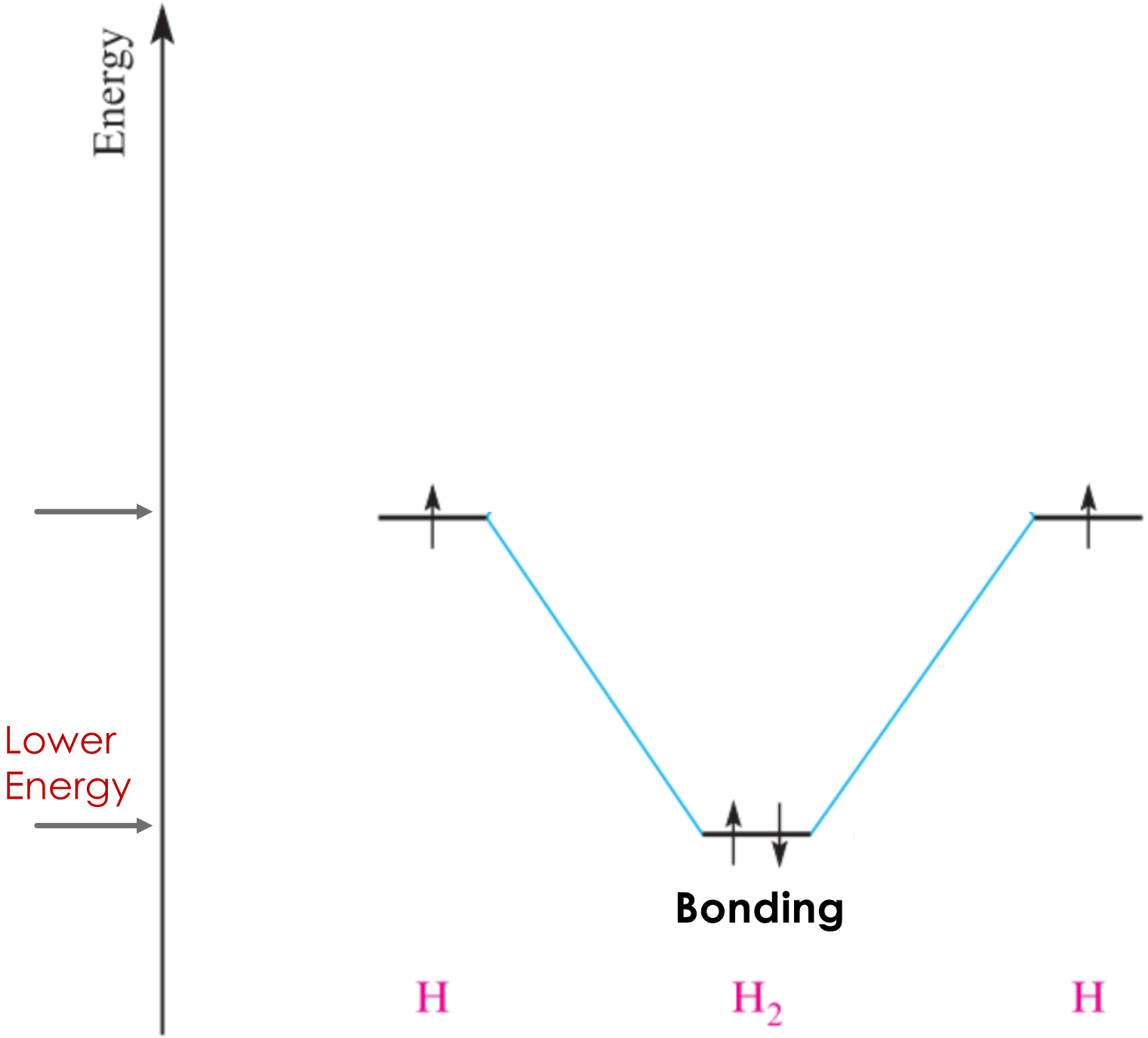
Bonding depends on sharing electrons

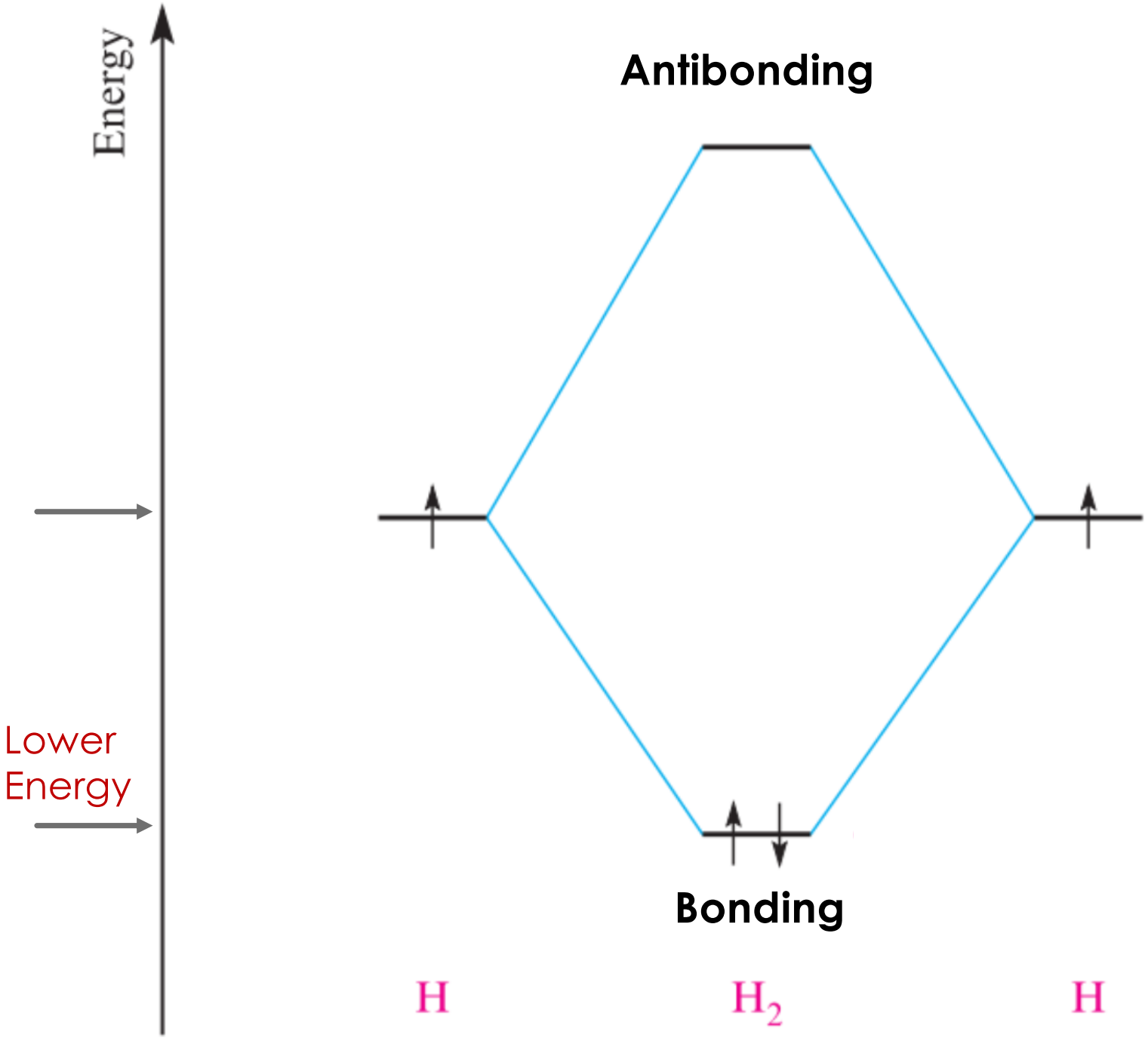


H_2

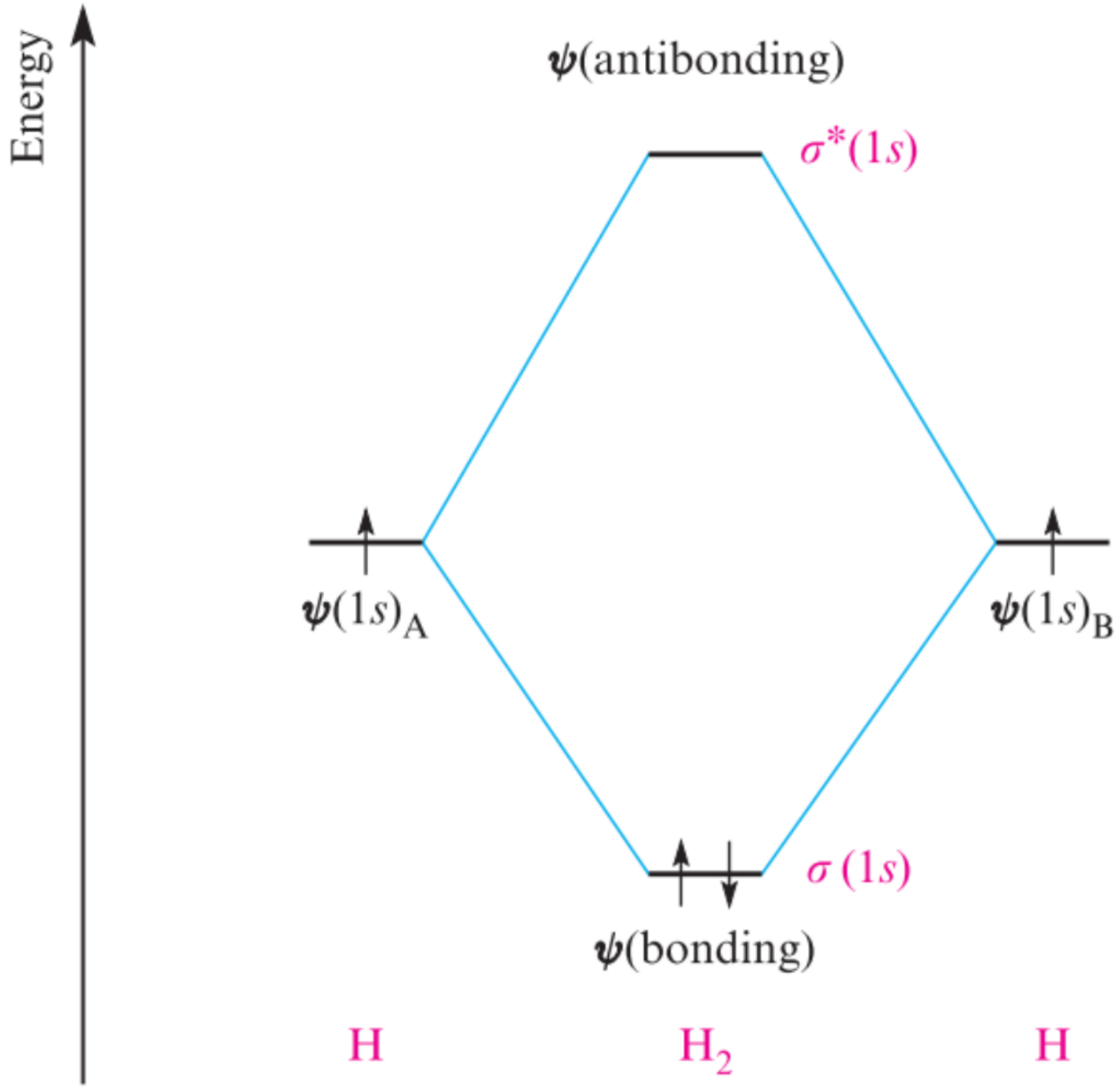
How is this shown in the diagram?

Bonding depends on change in energy


Energy
Lower
Energy
Bonding
H
H_2
H


Energy
Lower Energy
Antibonding
Bonding
H
H_2
H

What's wrong with this picture?



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Going forward

How do students experience disciplinary-specific resources across a range of settings

Analyse the disciplinary-specific resources presented in lectures

Multimodal orchestration

Interview lecturers and students about what they ”see”

Going forward

Unpacking and repacking strategies

Removing ”unnecessary” information

Possibility that transduction across resources is needed for disciplinary learning

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