Aalto University
School of Science

center for biomedical technology

POLITÉCNICA
"Engineering the future"

INTERNATIONAL CAMPUS OF EXCELLENCE

SUOMEN AKATEMIA
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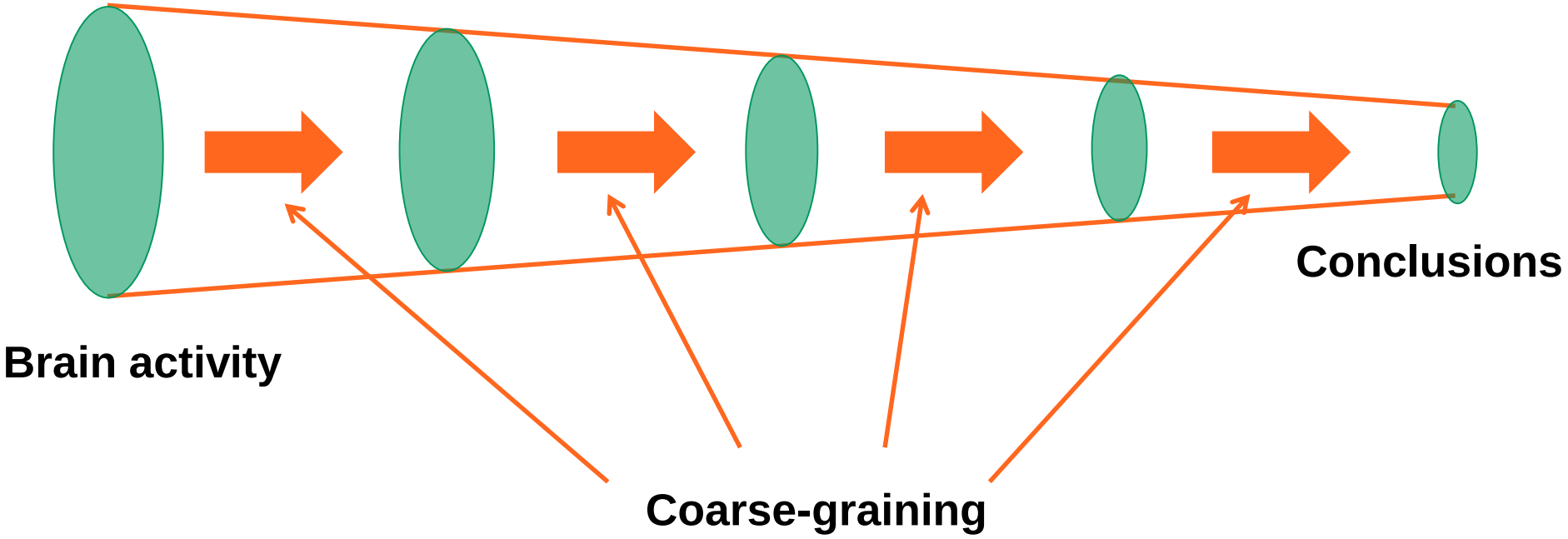
There and back again

What functional brain networks tell about brain function?

Onerva Korhonen
Network Neuroscience satellite at Networks 2021
30.6.2021

https://onlinelibrary.wiley.com/doi/full/10.1002/hbm.25462

There: From brain function to functional brain networks



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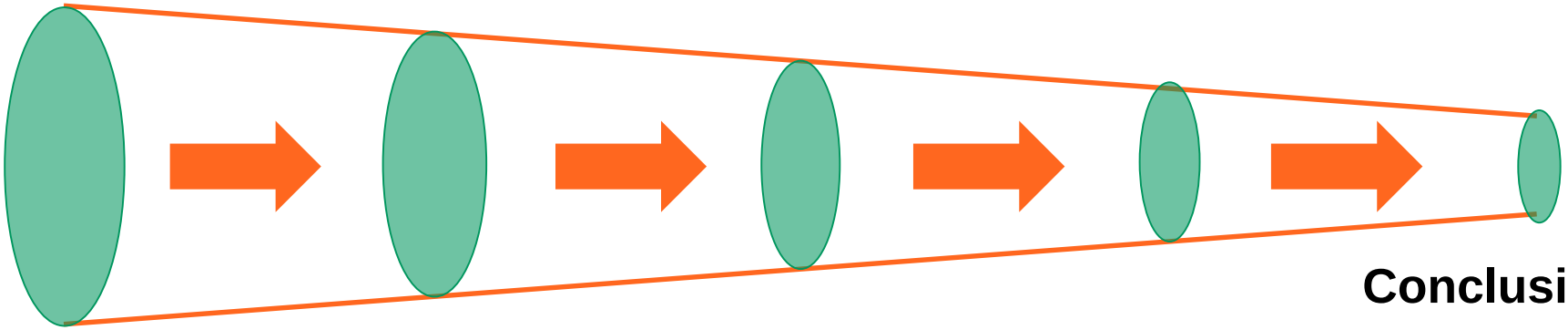
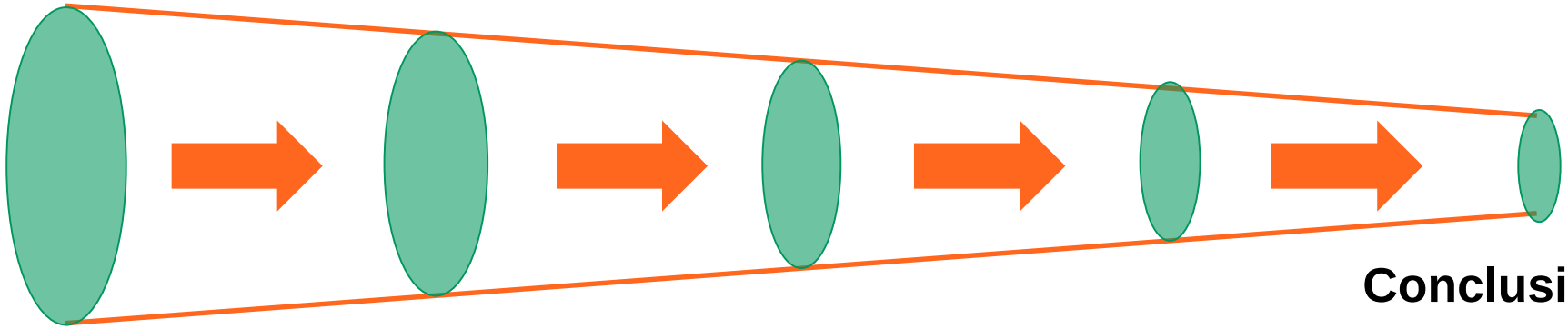


Brain activity:

- **What happens in the brain**
- **At the level of neurons**
- **Structure of dynamics**
- **Beyond measurement capacity (for now or forever)**

There: From brain function to functional brain networks

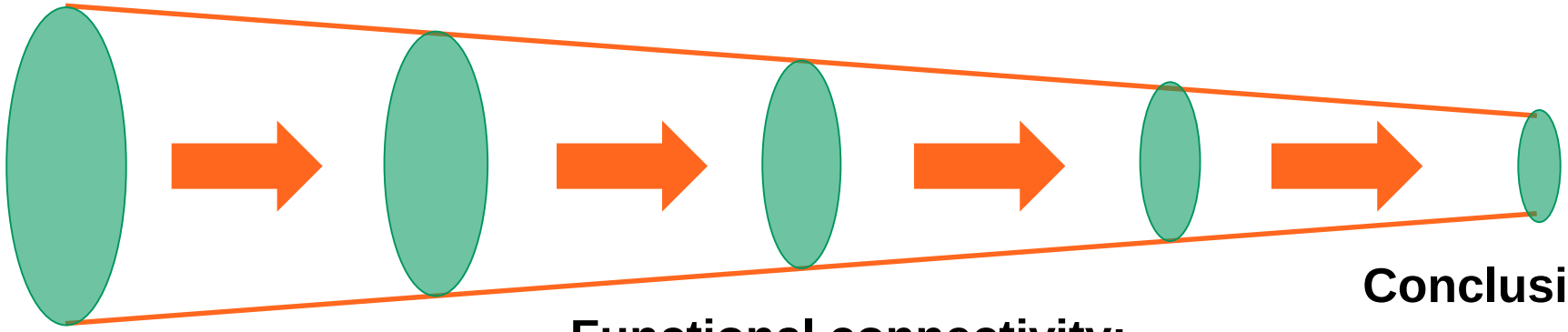


Brain activity

Measurable dynamics:

- **Observed with functional neuroimaging**
- **At the level of voxels/vertices/ROIs**
- ***Hopefully*** **preserve activity structure**

There: From brain function to functional brain networks



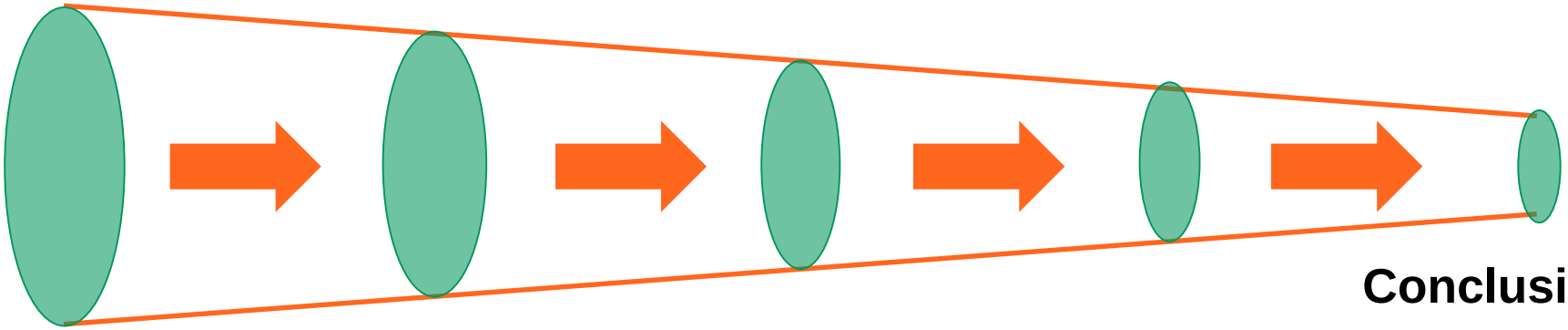
Conclusions

Brain activity

Functional connectivity:

- **Based on time-series similarity**
- ***Hopefully*** **preserves traces of activity in dynamics**
- **Construction issues: nodes, edges, thresholding, …**

There: From brain function to functional brain networks



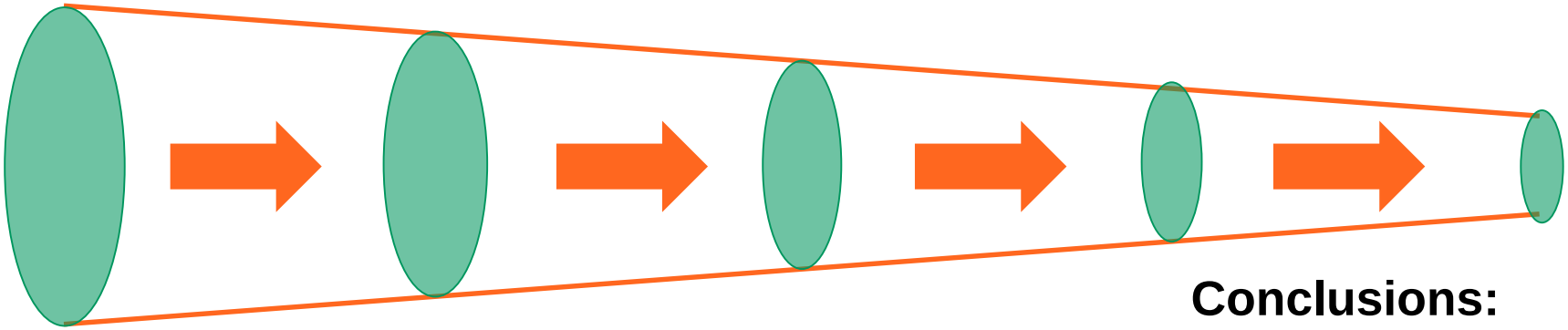
Conclusions

Brain activity

Network analysis:

- Classics: degree dists, node props (small-world), null models, …
- Network dynamics: links, nodes, links & nodes
- Multilayers, higher-order networks
- A good analysis catches the traces of activity

There: From brain function to functional brain networks



Brain activity

???

High degree = high activity

High degree = coordinator

???

Sparse/dense/modular networks cause Alzheimer's/epilepsy/ASD

???

???

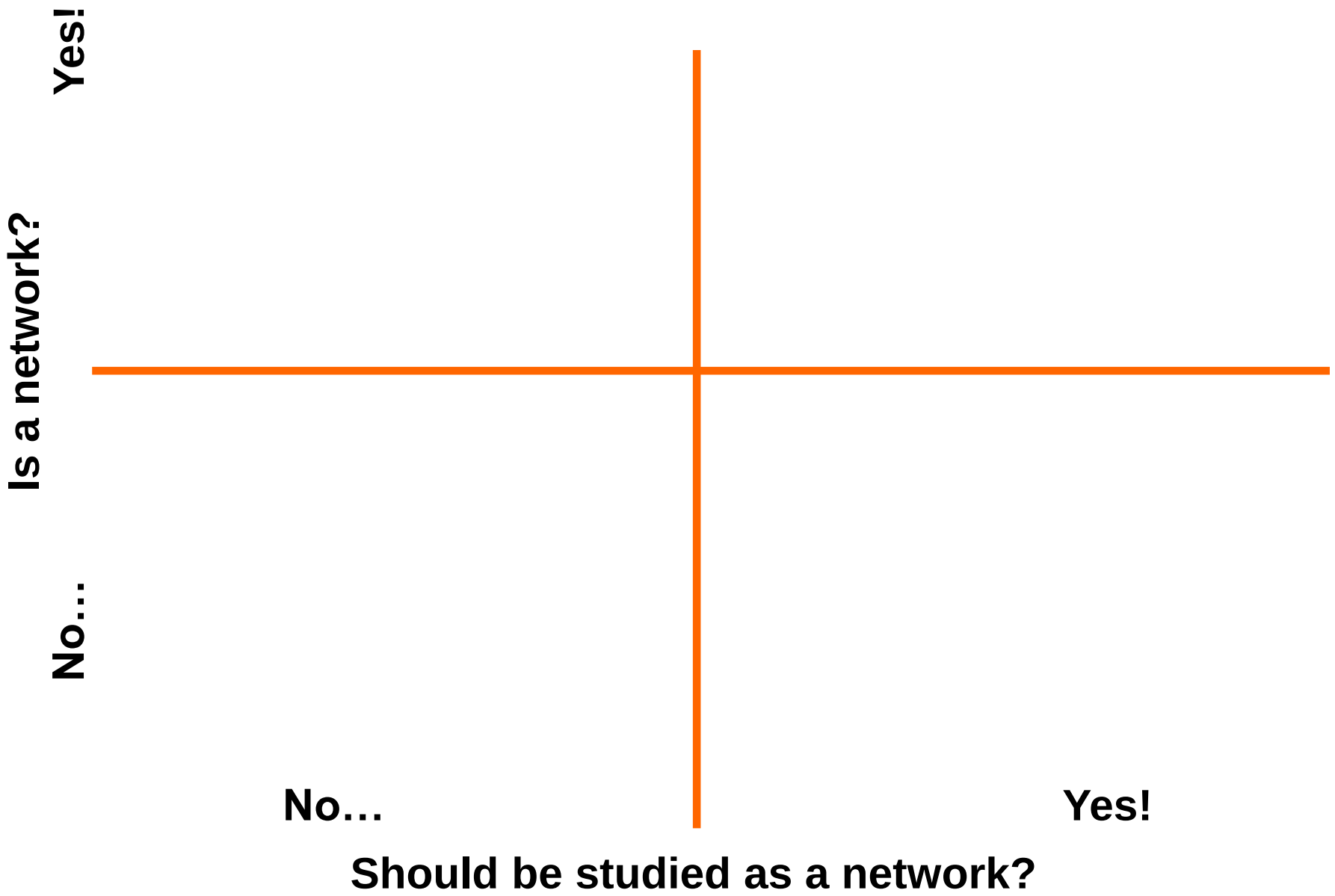
High degree = information spreader

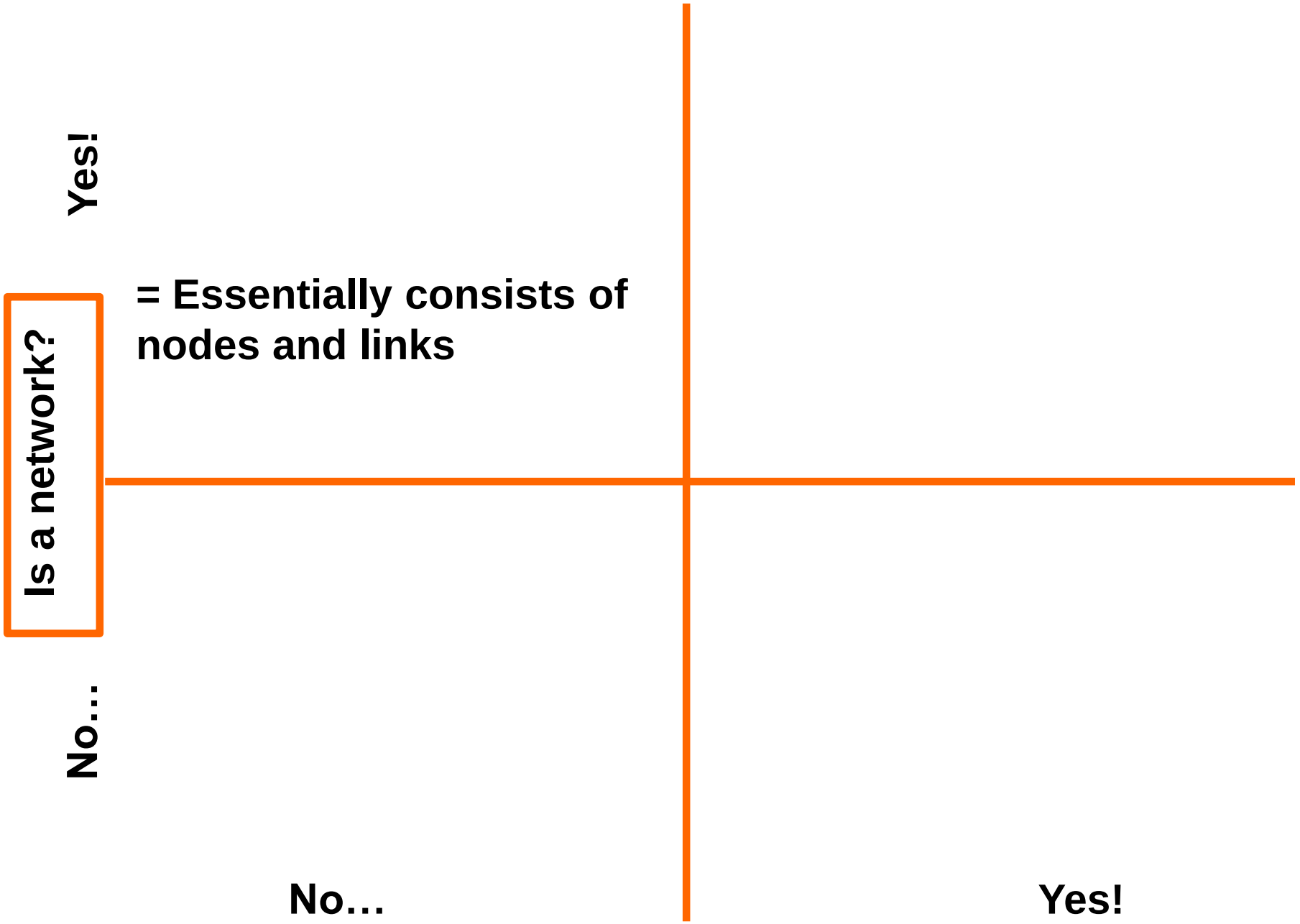
???

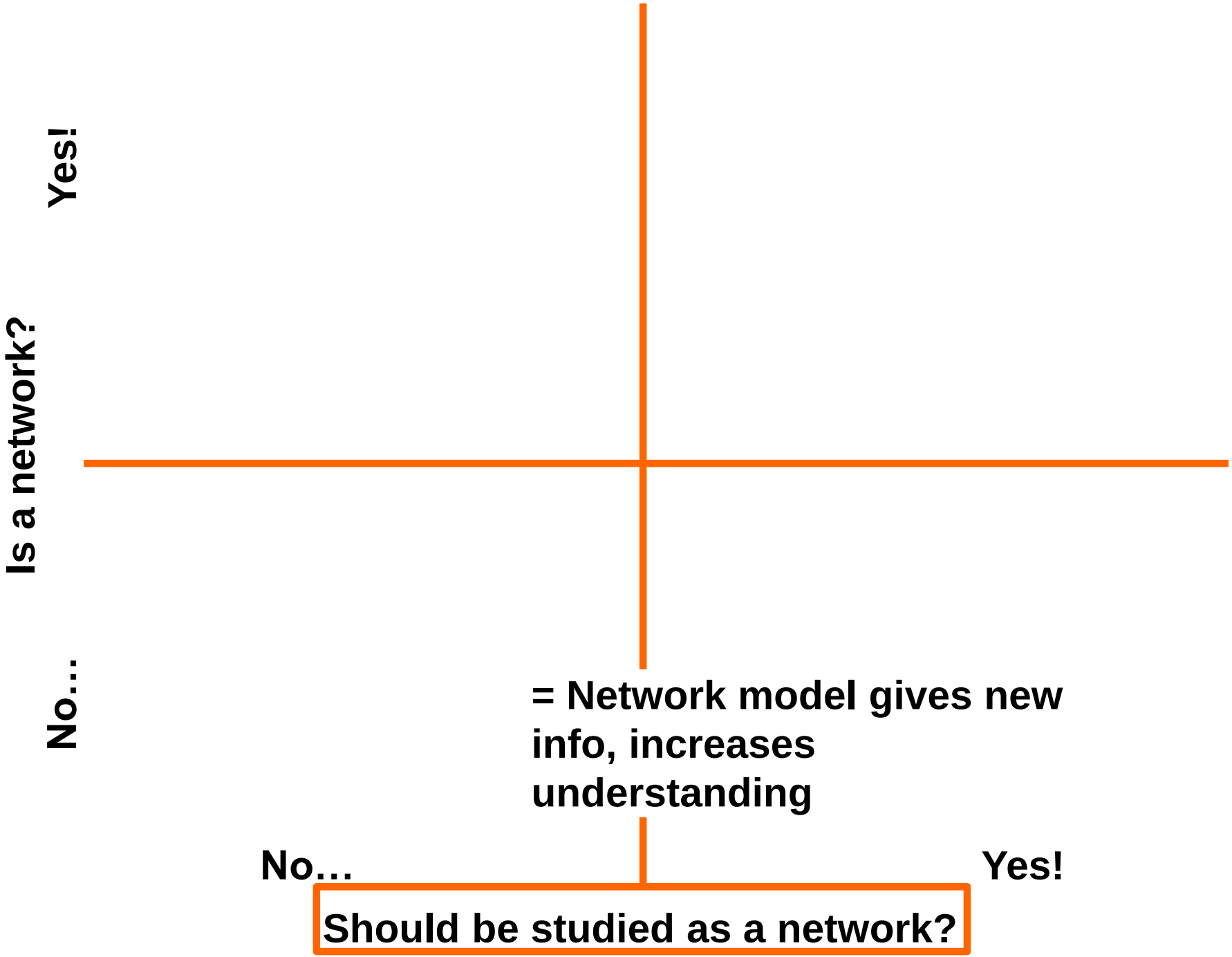
Conclusions:

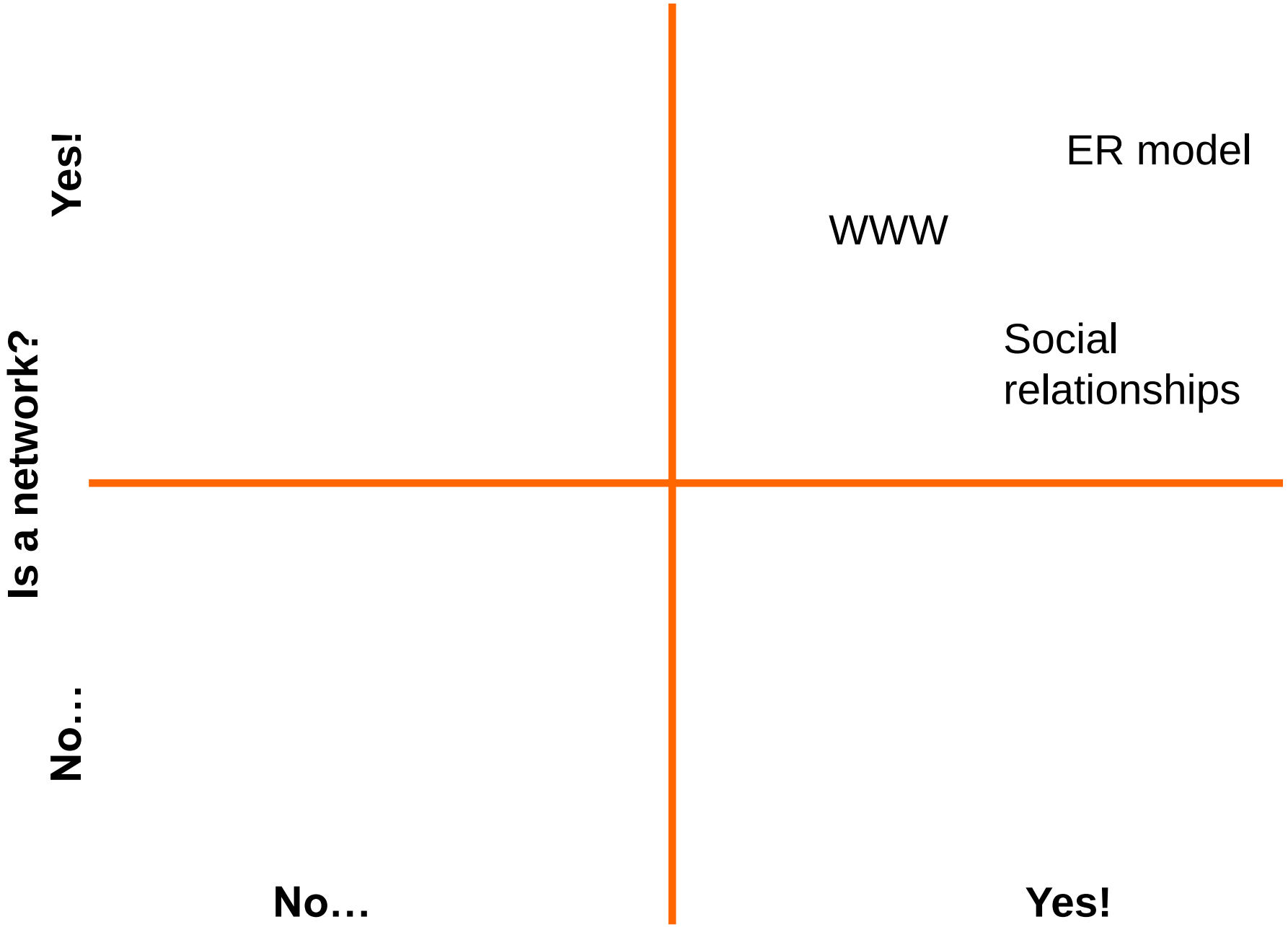
- **What the analysis outcomes tell about the brain?**

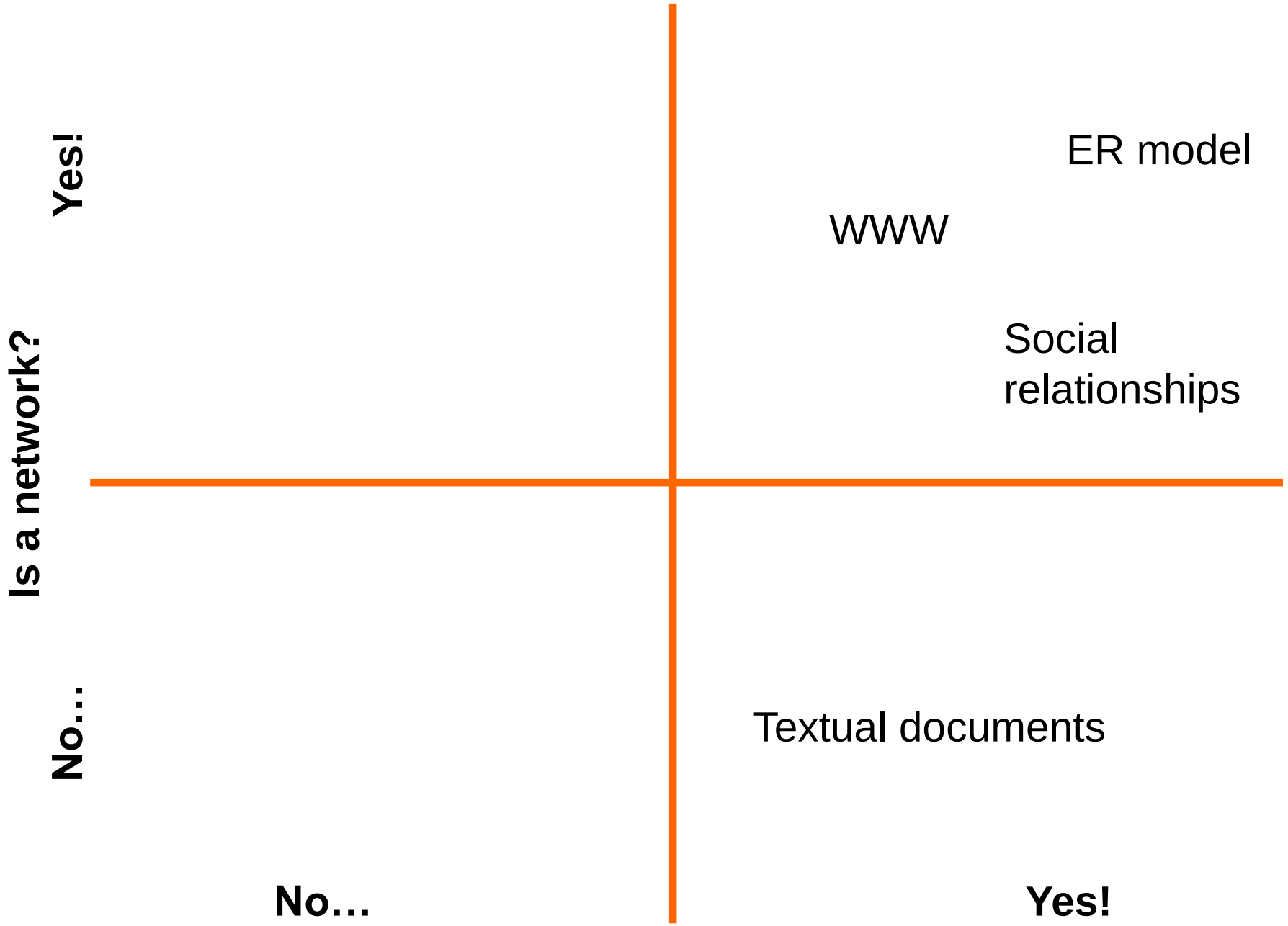
And back again: Is the brain a network?




Yes!
= Essentially consists of nodes and links
Is a network?
No…
No…
Yes!
Should be studied as a network?


Yes!
Is a network?
No…
= Network model gives new info, increases understanding
No…
Yes!
Should be studied as a network?


Yes!
Is a network?
No…
ER model
WWW
Social
relationships
No…
Yes!
Should be studied as a network?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Textual documents
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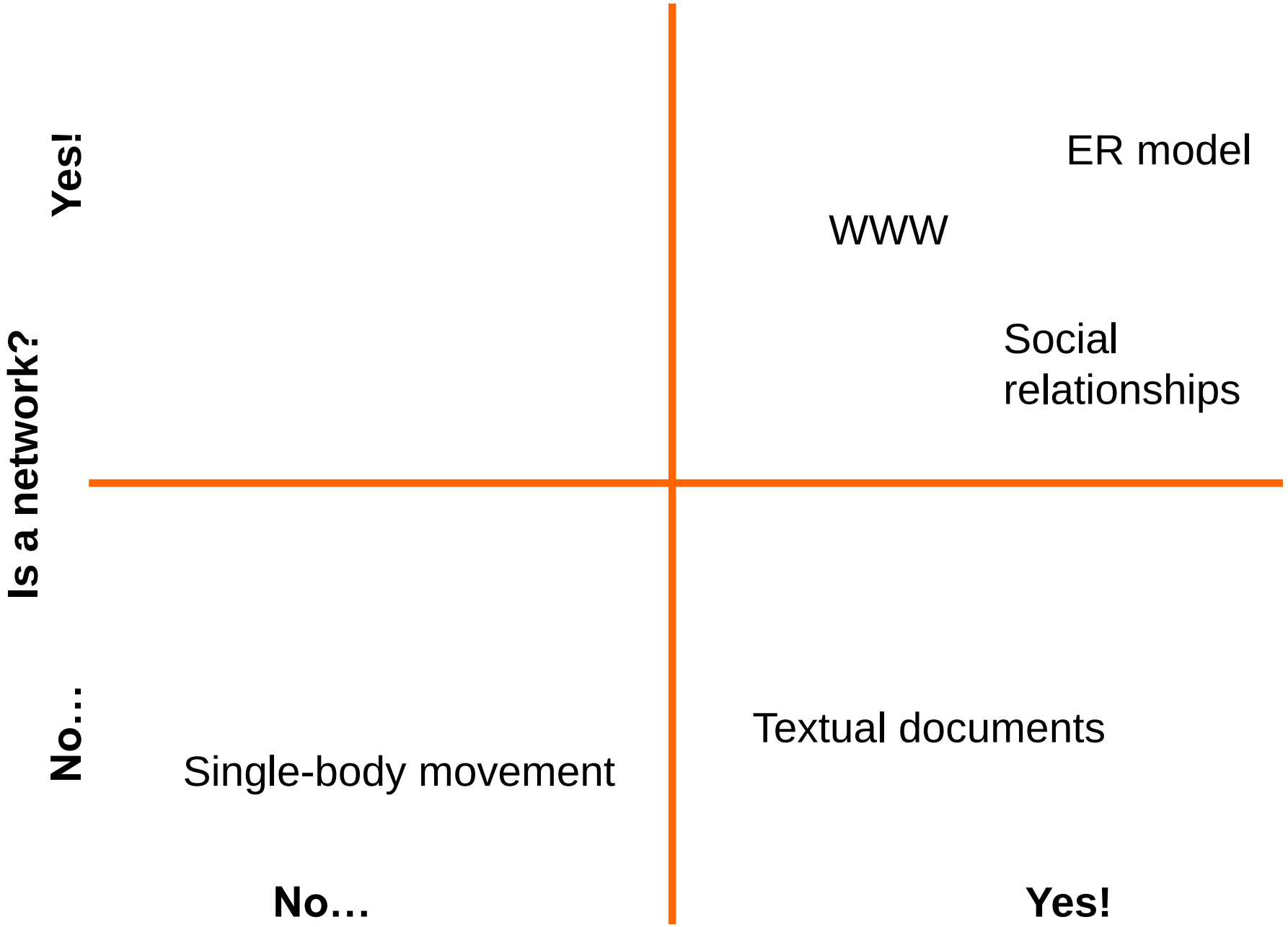
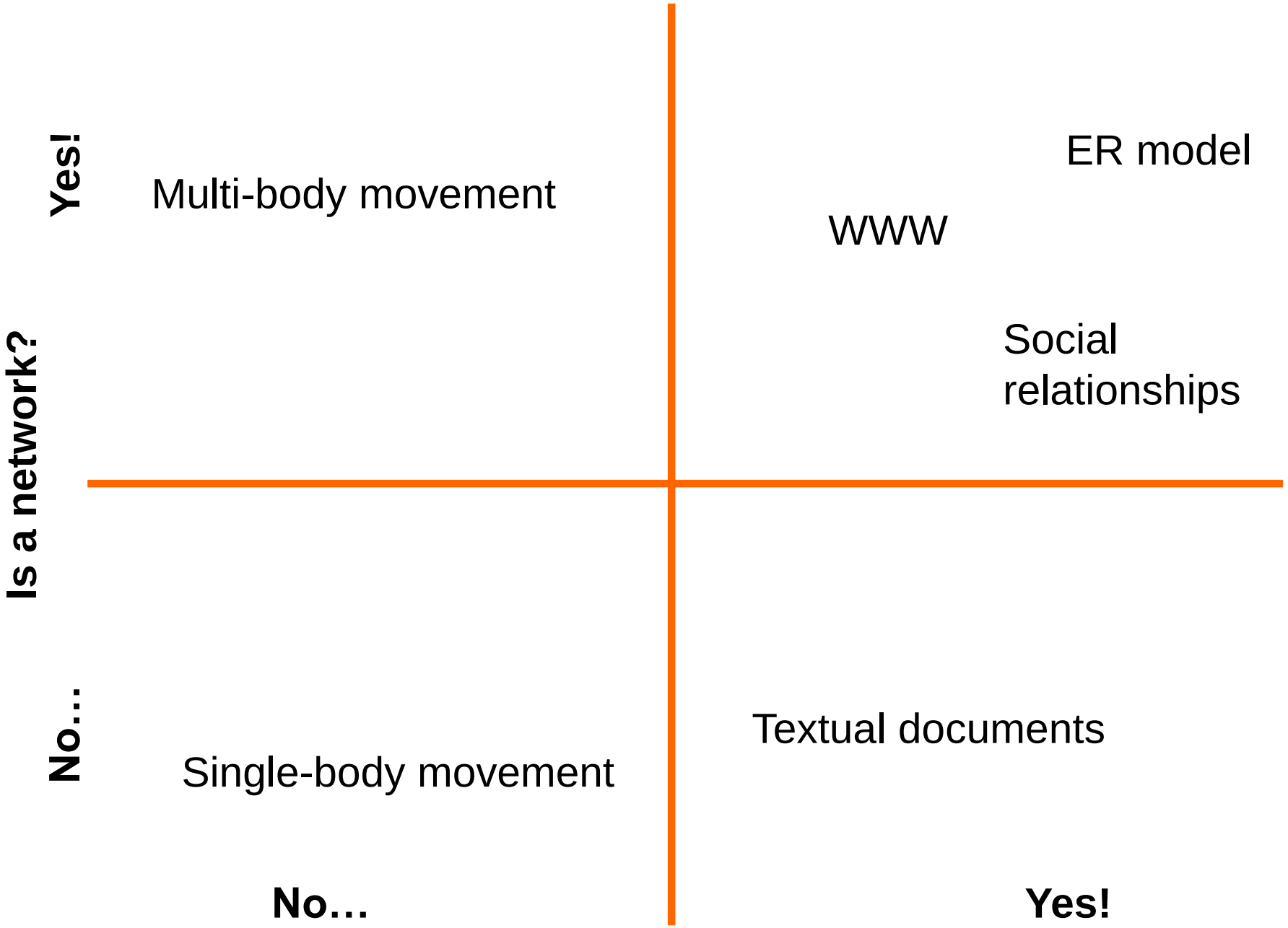

Yes!
Is a network?
No…
ER model
WWW
Social relationships
Textual documents
Single-body movement
No…
Yes!
Should be studied as a network?


Yes!
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Multi-body movement
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Social relationships
Textual documents
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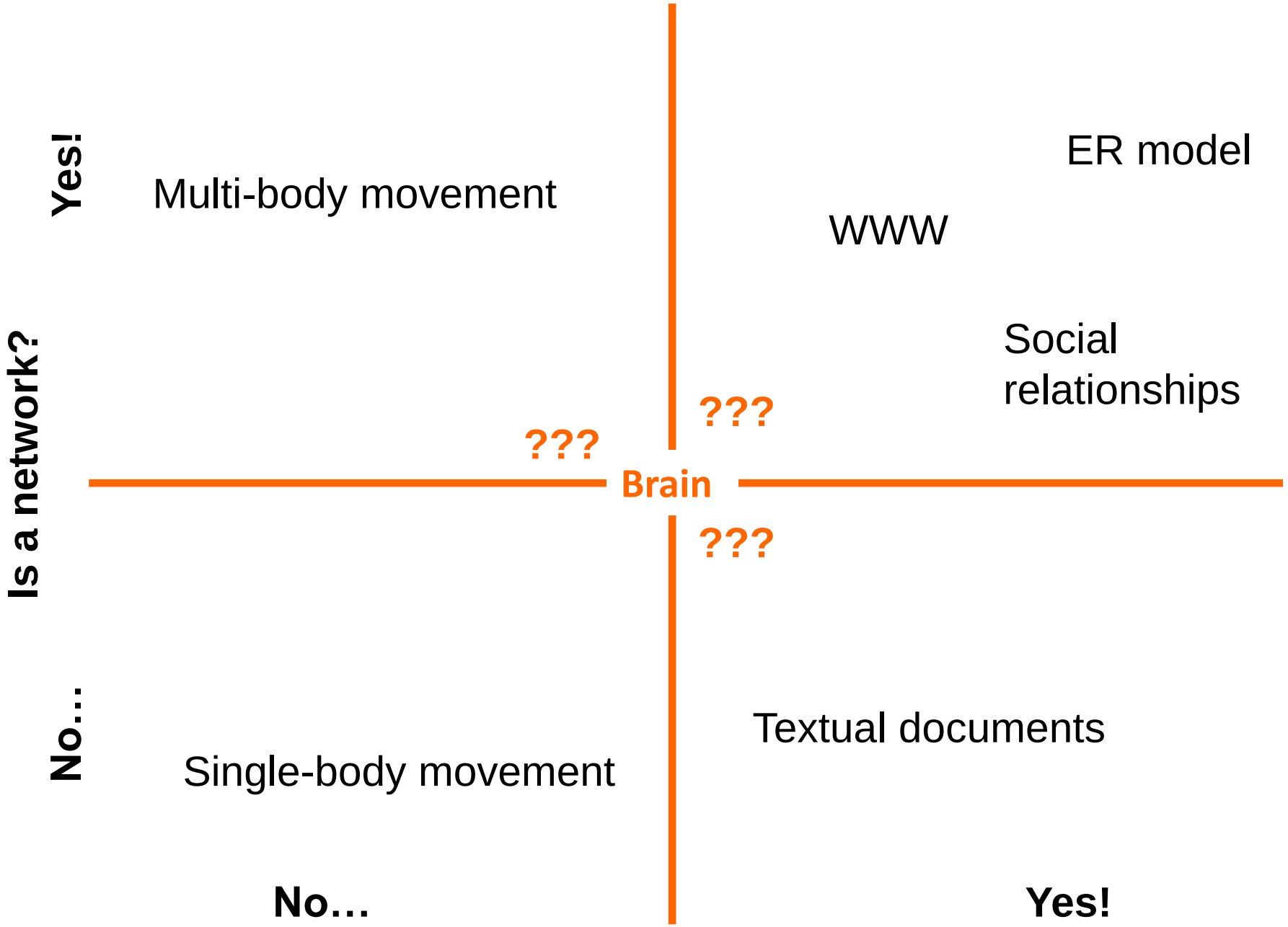
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Brain
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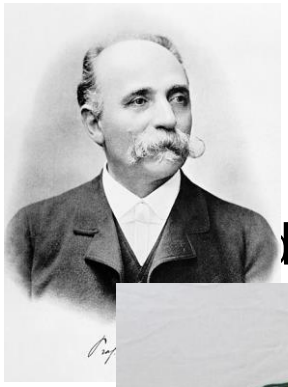
Figs: Wikimedia Commons, public domain



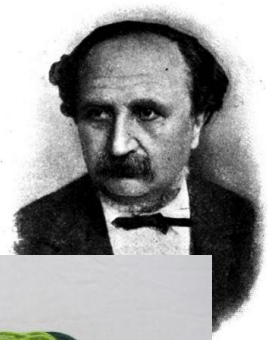


Photo: Milja Heikkinen

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Is a network?

No…

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WWW

Social relationships

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Single-body movement

Textual documents

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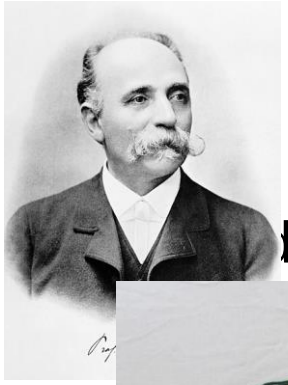

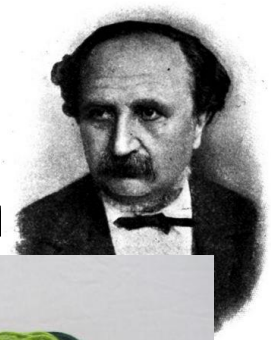

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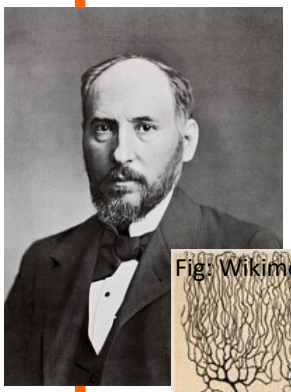

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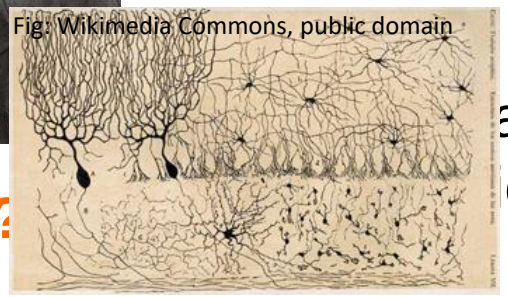

Yes!

ly I

ER model

WWW

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onships

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Brain

???

Is a network?

No…

Single-body movement

Textual documents

No…

Yes!

Should be studied as a network?

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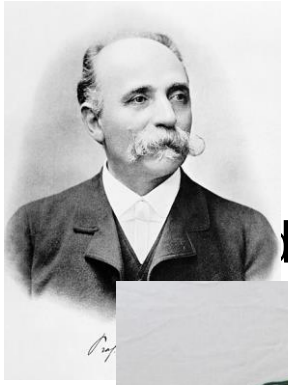

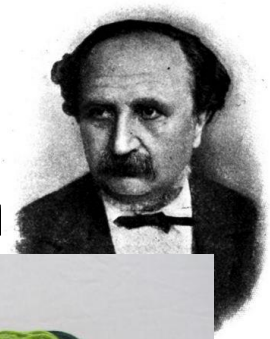

Yes!

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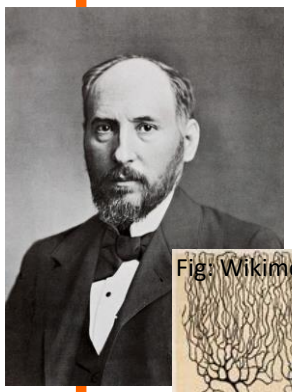
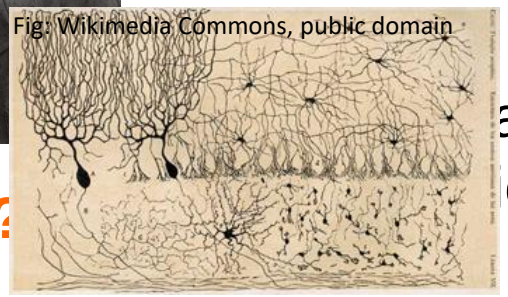


ER model

WWW



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Brain

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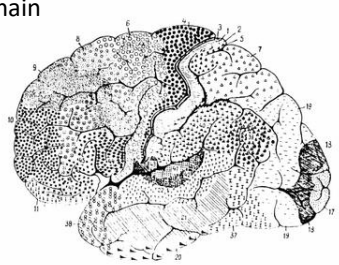

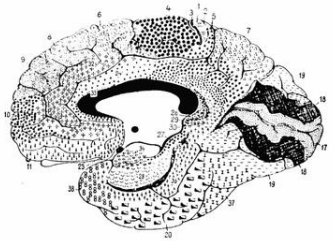

Is a network?

No..

Textual documents

Yes!

Should be studied as a network?

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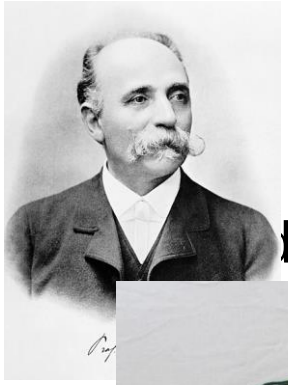

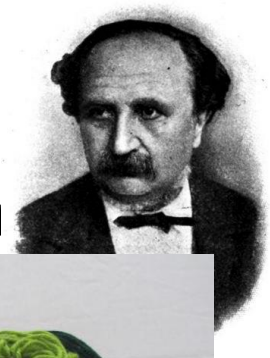

Yes!

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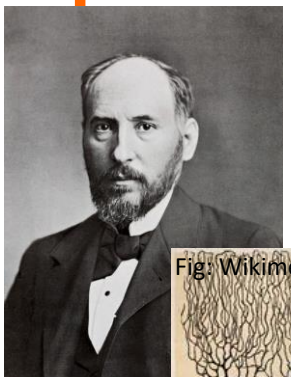

ER model

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White et al. 1968: *C. elegans*

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Brain

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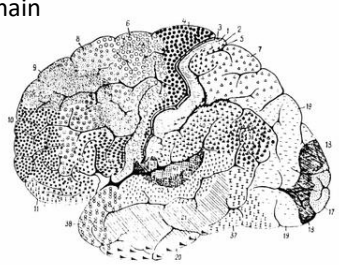

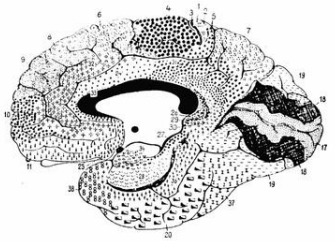

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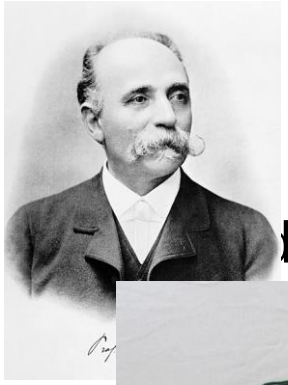

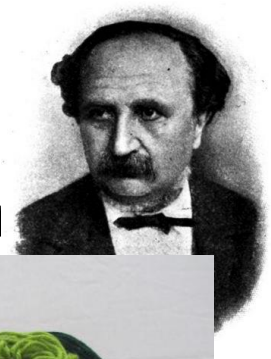

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Fig: Wikimedia Commons, public domain

Bassett & Muldoon 2016, Bassett & Sporns 2017: network neuroscience

Sporns et al. 2005, Hagmann 2005: connectomics, connectome

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Brain

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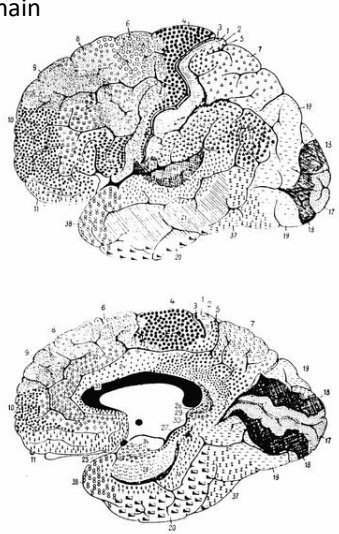

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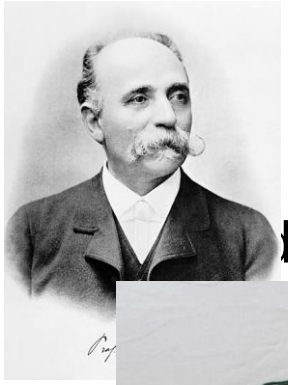

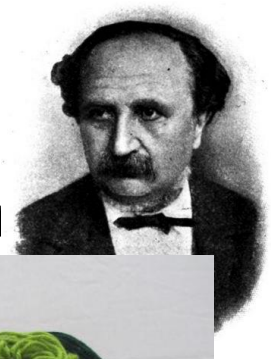

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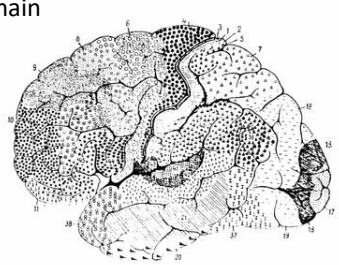

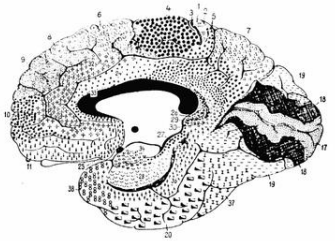

No..

???

how to define nodes/links?

structure/function?

correlation = causation?

Yes!

Should be studied as a network?

Conclusions

- **There**
  - From brain activity to analysis outcomes (and interpretations): a path of compromises and coarse-graining
  - A good analysis preserves as many activity traces as possible
- **… and back again:**
  - Not all that glitters is a network – is the human brain?
  - The network model is a valuable tool for neuroscience
  - However, system and model can have same outputs without functioning in the same way
- **Needed: critical thinking & discussion**

Thank you!

Questions, comments?

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Twitter: @OnervaKorhonen

https://github.com/onerva-korhonen/presentations/blob/master/networkneurosci21.pdf