Parasites and biological invasions: from individuals to interaction networks

Vincent Médoc, MCf UPMC
Elisa Thébault, CR CNRS
Institute of Ecology and Environmental Sciences - Paris

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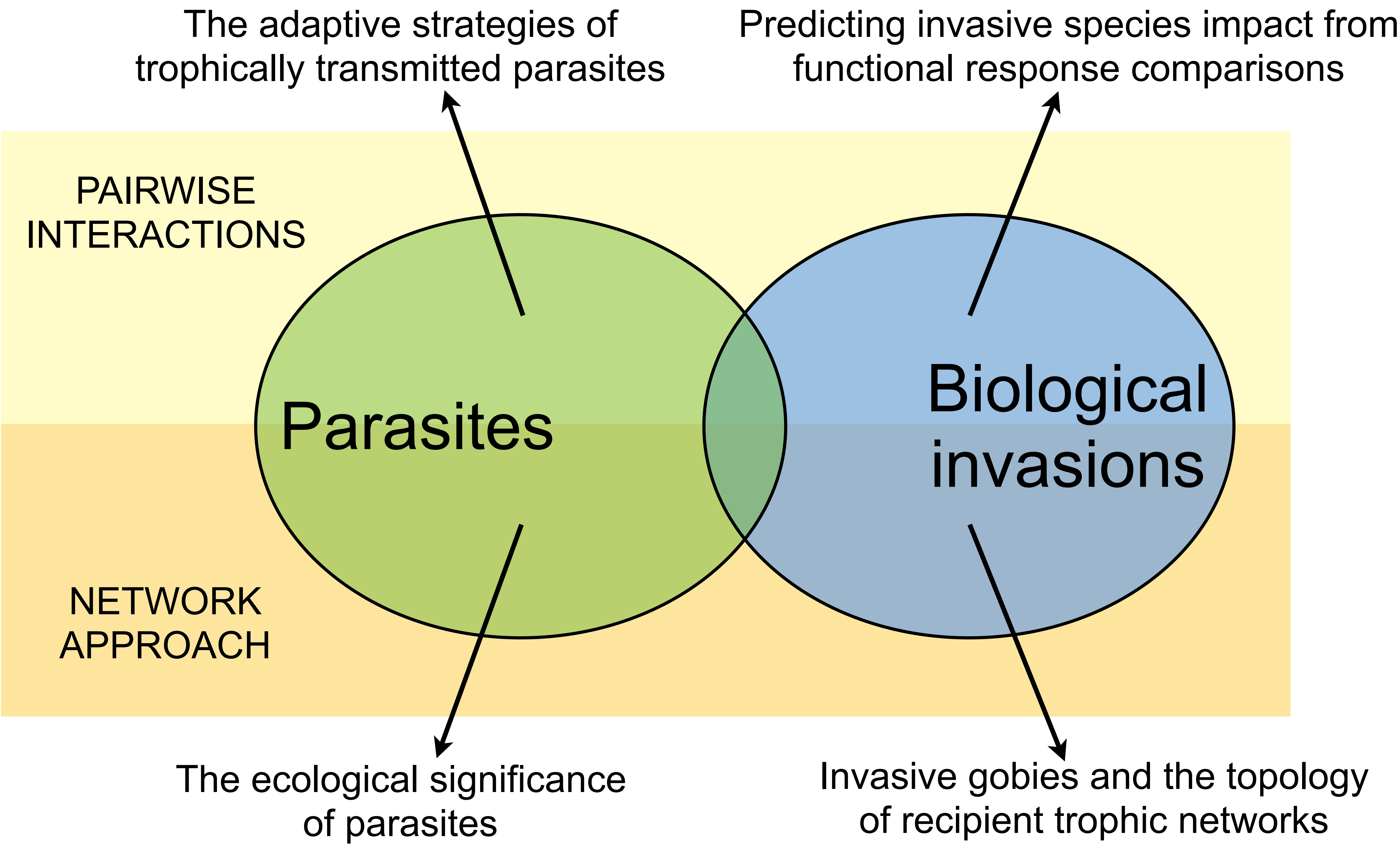
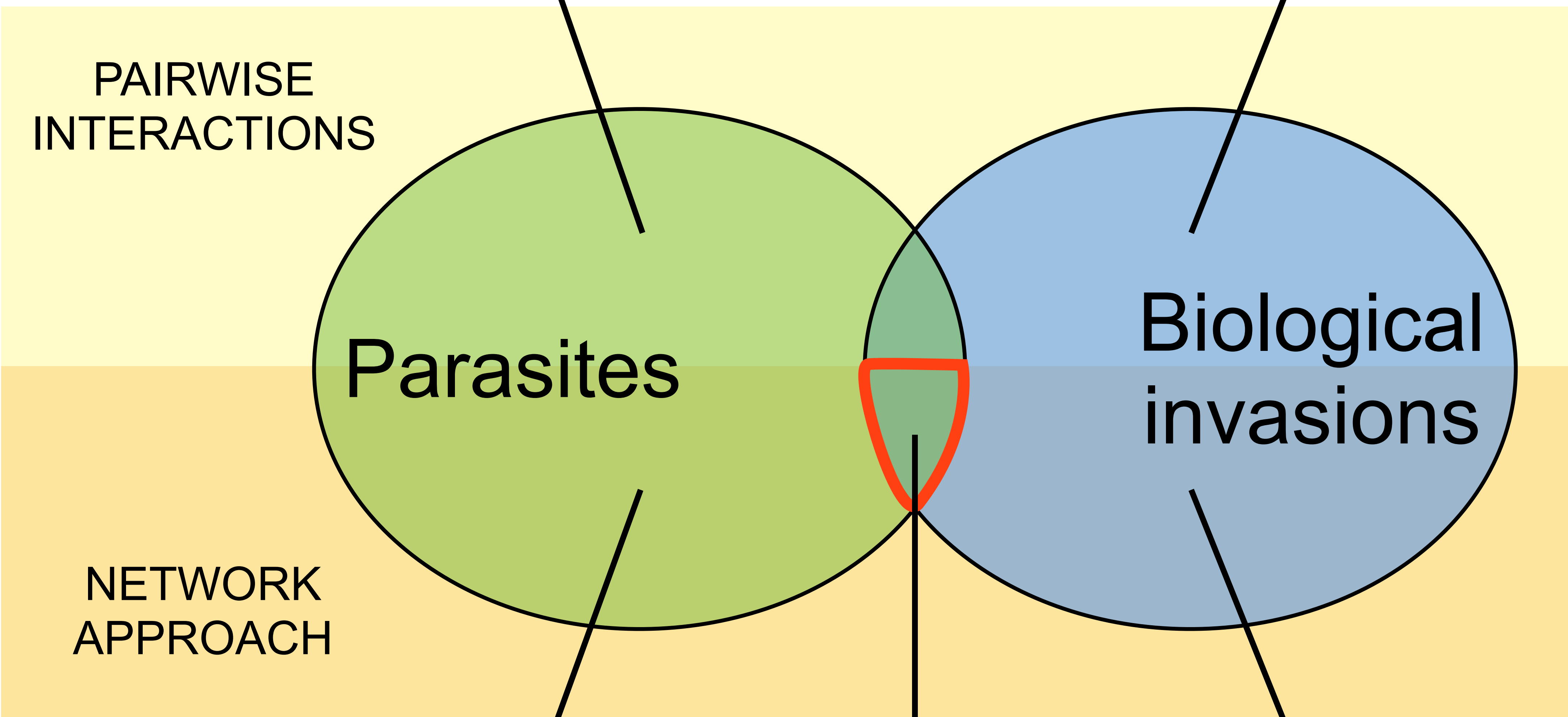
Ongoing projects



Ongoing projects

The adaptive strategies of
trophically transmitted parasites

Predicting invasive species impact from
functional response comparisons



The ecological significance
of parasites

Invasive gobies and the topology
of recipient trophic networks

**Parasites and biological invasions:
from individuals to interaction networks**

Outline

The framework

The diversity of parasite strategies

Parasites in invasion ecology

- The enemy release hypothesis
- Parasites as alien species
- Processes involving parasites

Parasites in trophic networks

- The network approach in ecology
    - Some topological descriptors
    - Linking network topology and community properties
- Including parasites in trophic networks
- Parasite - induced changes in topology
- Parasite - induced changes in community properties

Parasites in invaded networks

- Impact of introduced parasites on food-web structure
- Linking network structure and invasibility
- How invader-induced changes in topology affect parasites

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The framework

Native parasites
- life cycle
- host exploitation strategy
- virulence...

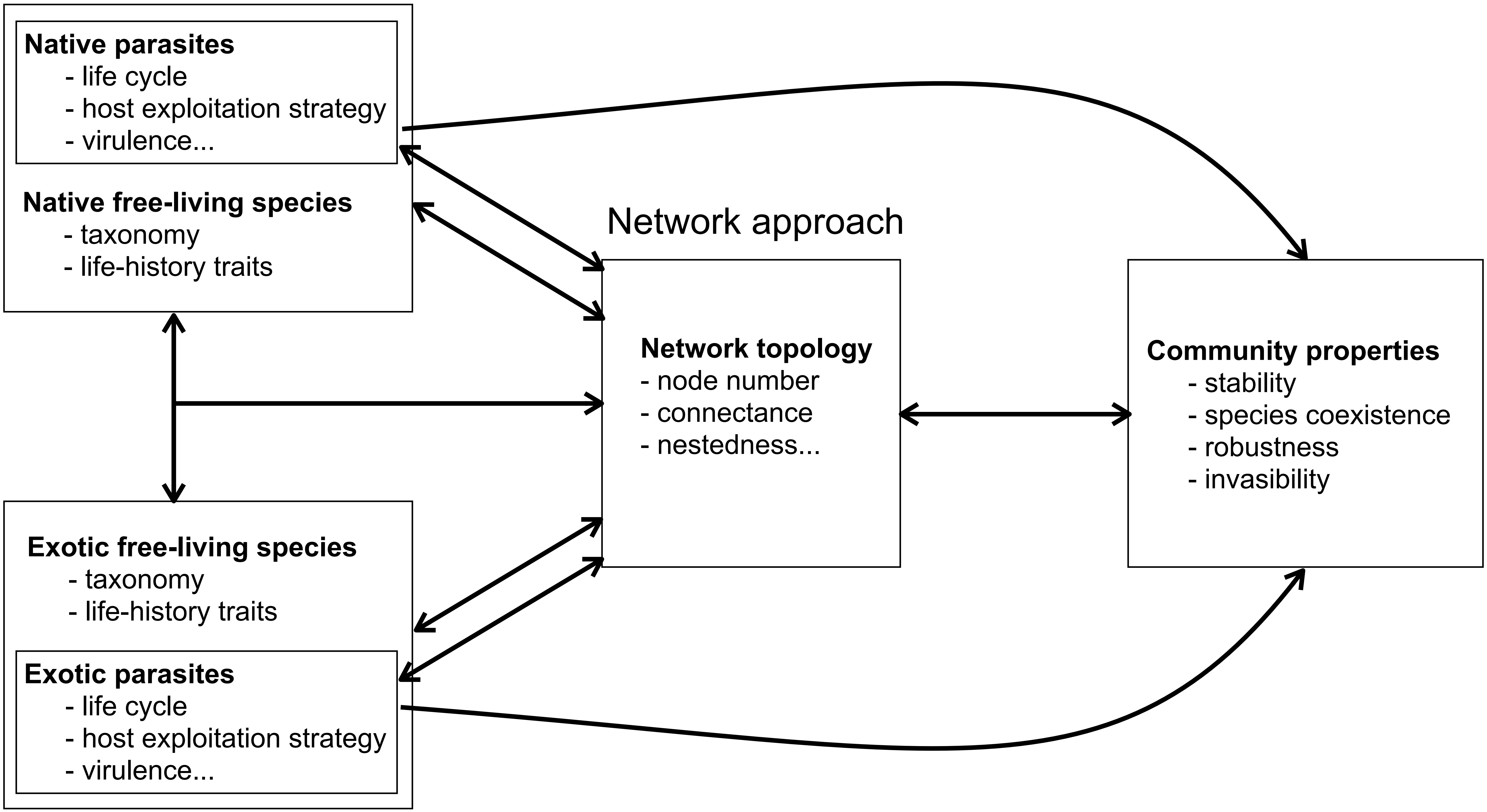
Native free-living species
- taxonomy
- life-history traits

Exotic free-living species
- taxonomy
- life-history traits

Exotic parasites
- life cycle
- host exploitation strategy
- virulence...

Community properties
- stability
- species coexistence
- robustness
- invasibility

The framework



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The diversity of parasite strategies

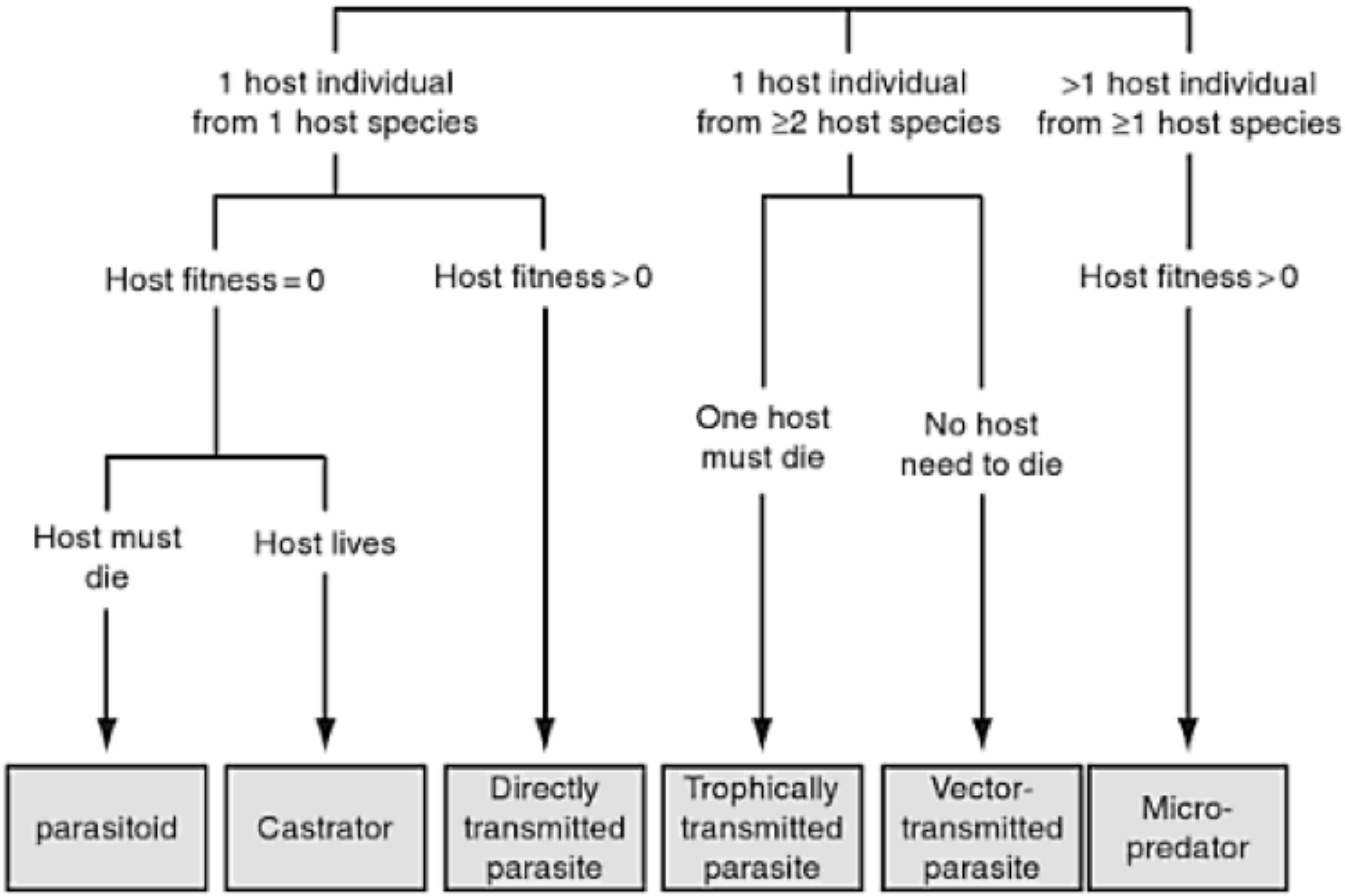

FIGURE 1.1 Classification tree of the six parasitic strategies considered here, and encompassing the vast majority of known parasite taxa. The first division is based on the number of hosts used, both in terms of species and individuals, by one full parasite generation; subsequent divisions are based on fitness impact on hosts.

Poulin (2011) Adv Parasitol 74

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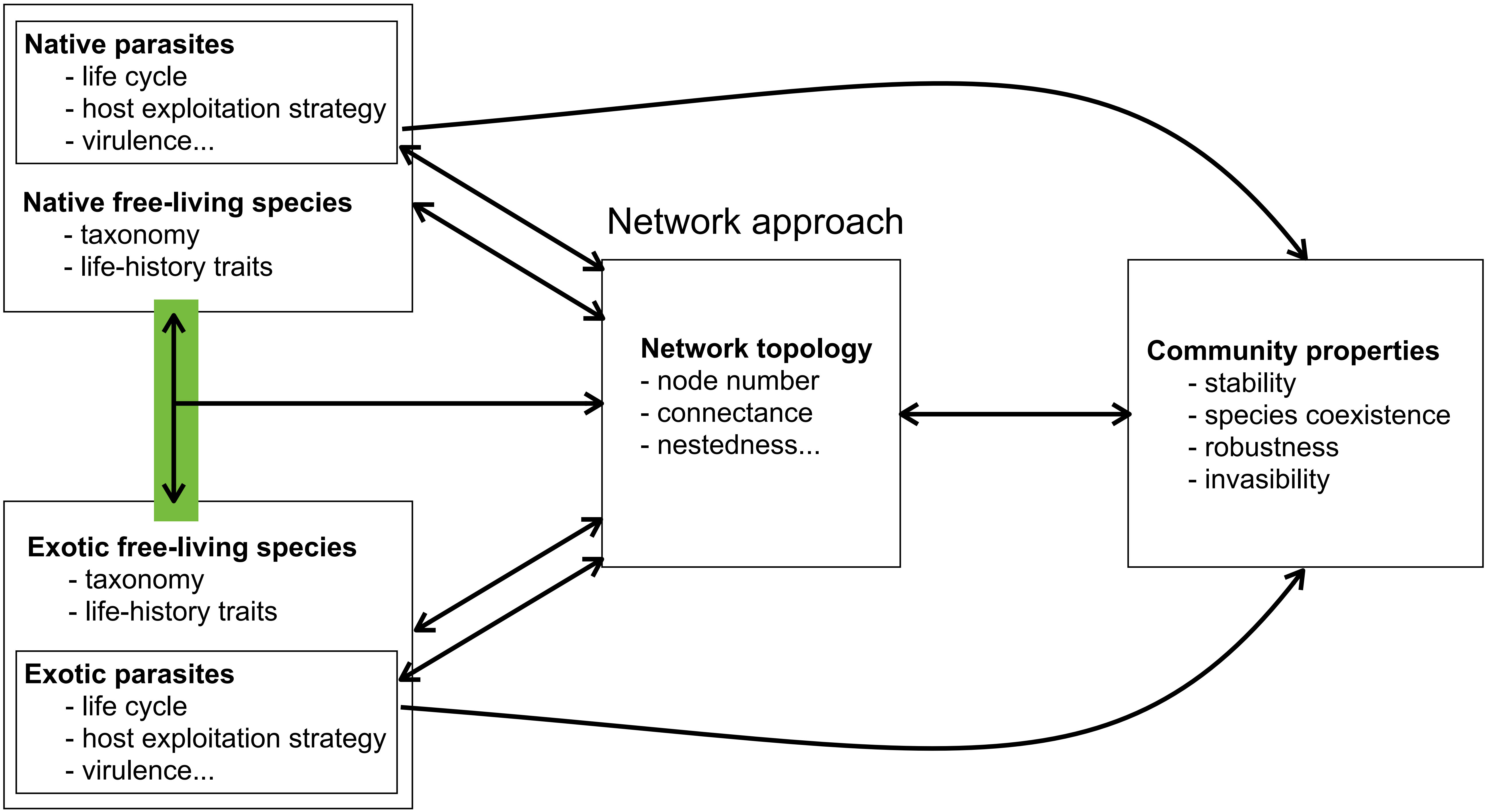
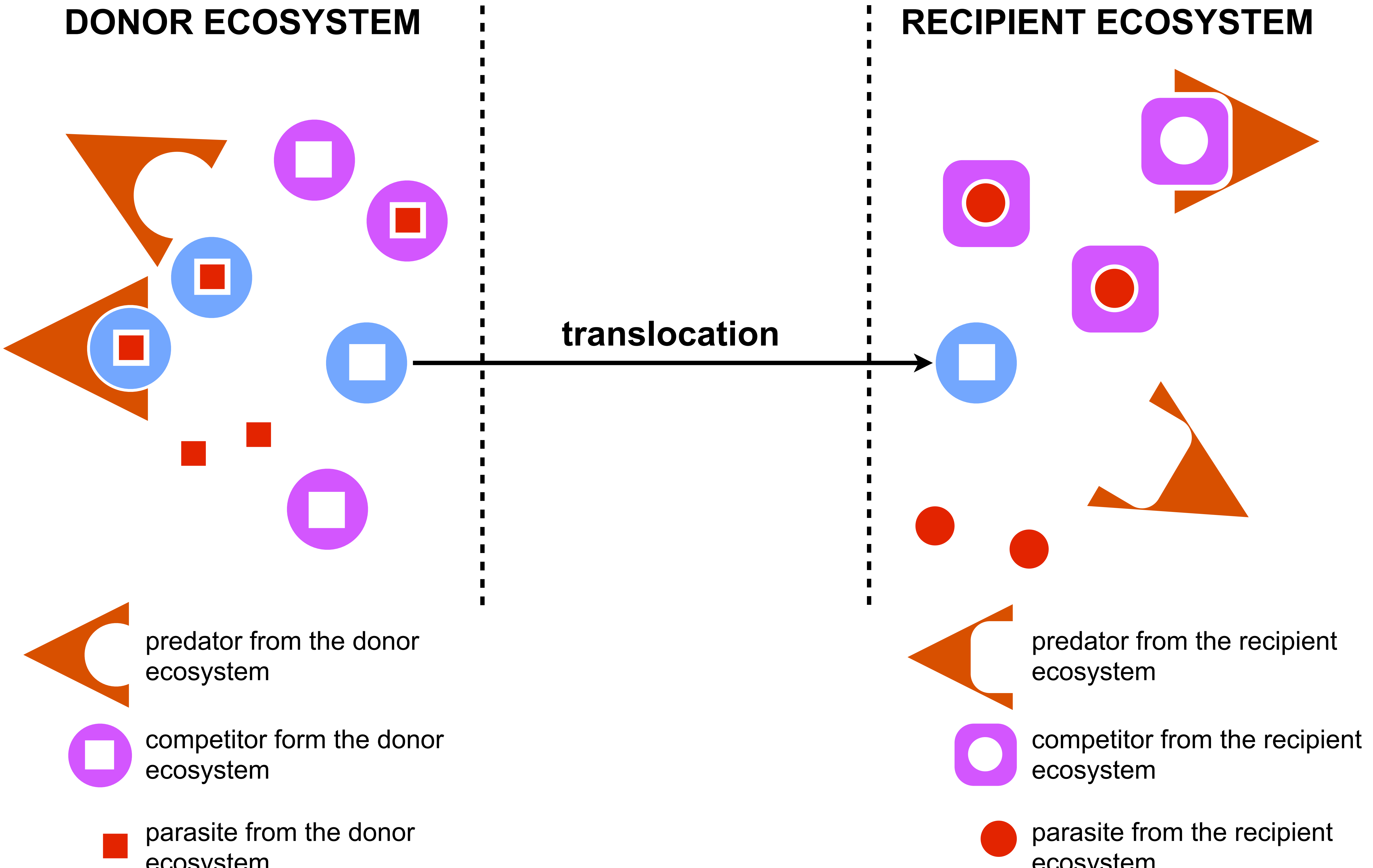
Parasites in invasion ecology



Parasites in invasion ecology

The enemy release hypothesis (Keane and Crawley 2002. Trends Ecol Evol 17)



Parasites in invasion ecology

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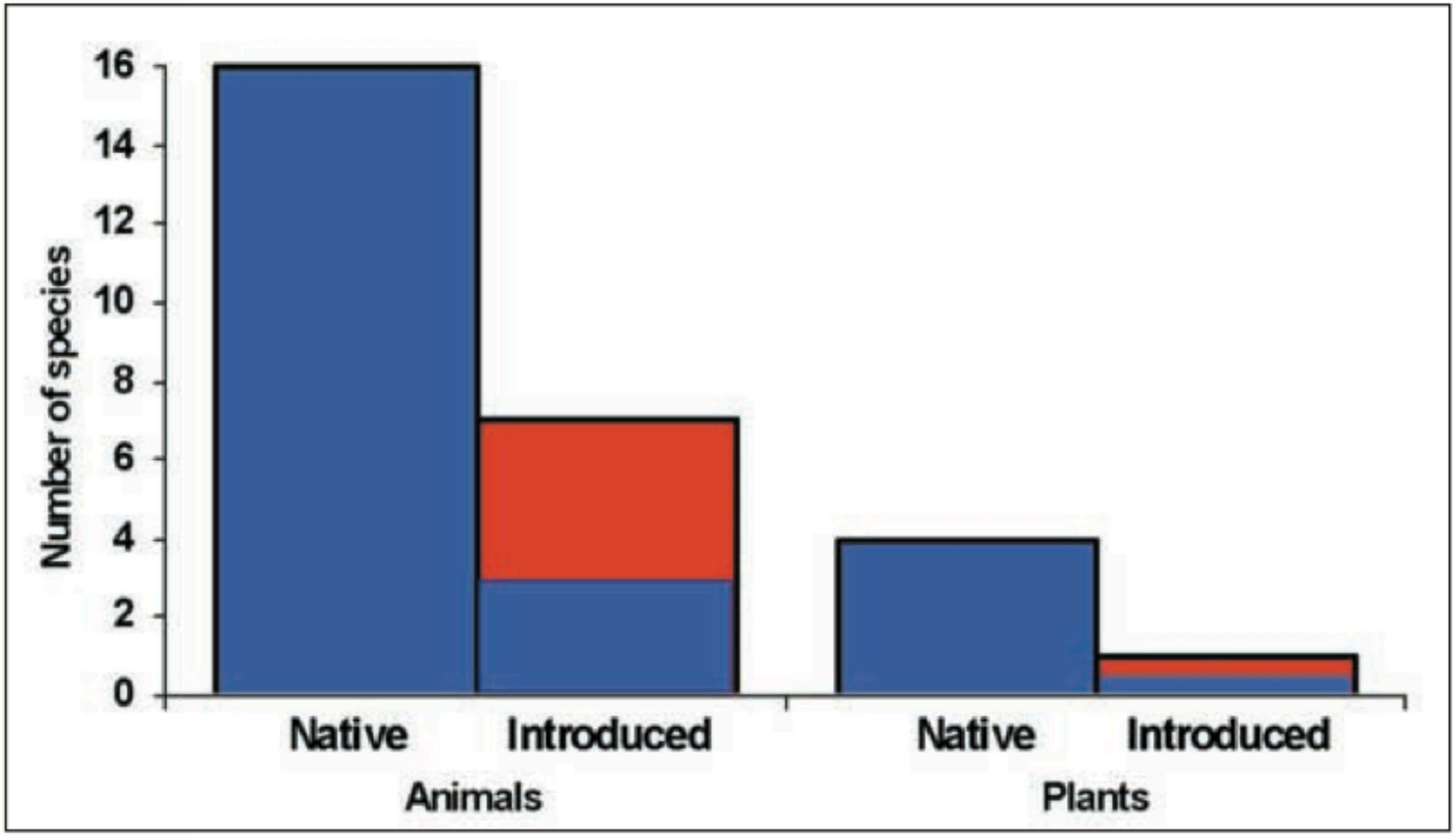
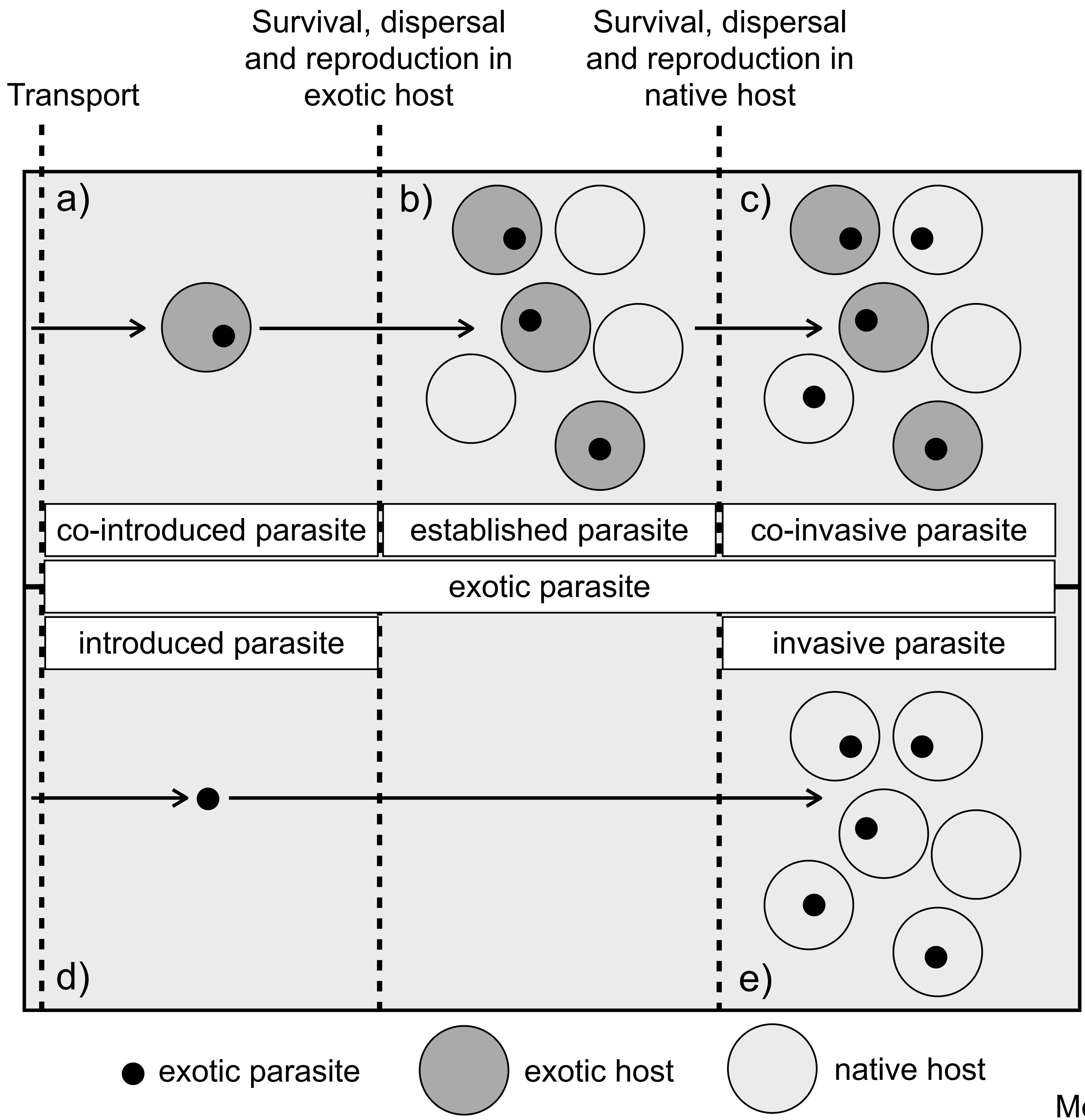


Figure 2. *Release from parasites as average number of parasites in native and introduced animals and average number of pathogens on native and introduced plants. Blue bars indicate parasites/pathogens from the invader's native region and red bars indicate novel parasites/ pathogens that were accumulated in the introduced region. Data are from Mitchell and Power (2003) and Torchin et al. (2003).*

Torchin and Mitchell (2004) Front Ecol Environ 2

Parasites in invasion ecology

Parasites as alien species



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Parasites in invasion ecology

Processes involving parasites

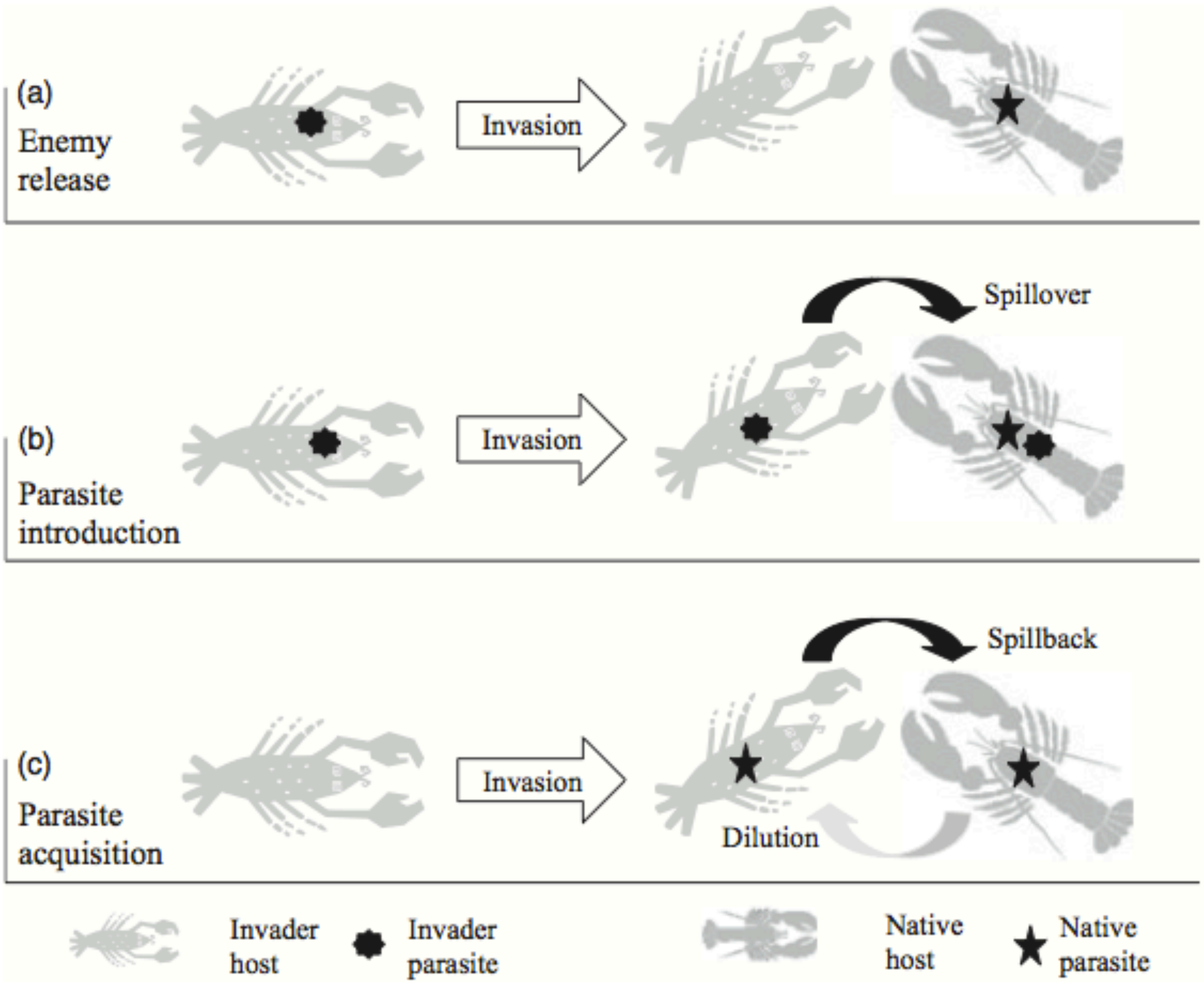

Fig. 1. The fate of parasites in the course of an invasion. Many invaders fail to establish. For invaders that succeed, the main outcomes for parasites are illustrated. (a) Enemy release; loss of parasites during the invasion process may benefit the invader. Parasites may be lost through the effects of sub-sampling or through selective pressures experienced during translocation or establishment. (b) Parasite introduction; parasites introduced with the invader may spillover to infect species in the invaded habitat. (c) Parasite acquisition; an invader may acquire parasites in the new habitat. If the invader is a less competent host, this may dilute the impact of the parasite (grey arrow). However, if the invader is a more competent host, spillback of parasites to native hosts may occur (black arrow).

Tompkins et al. (2011) J Anim Ecol 80

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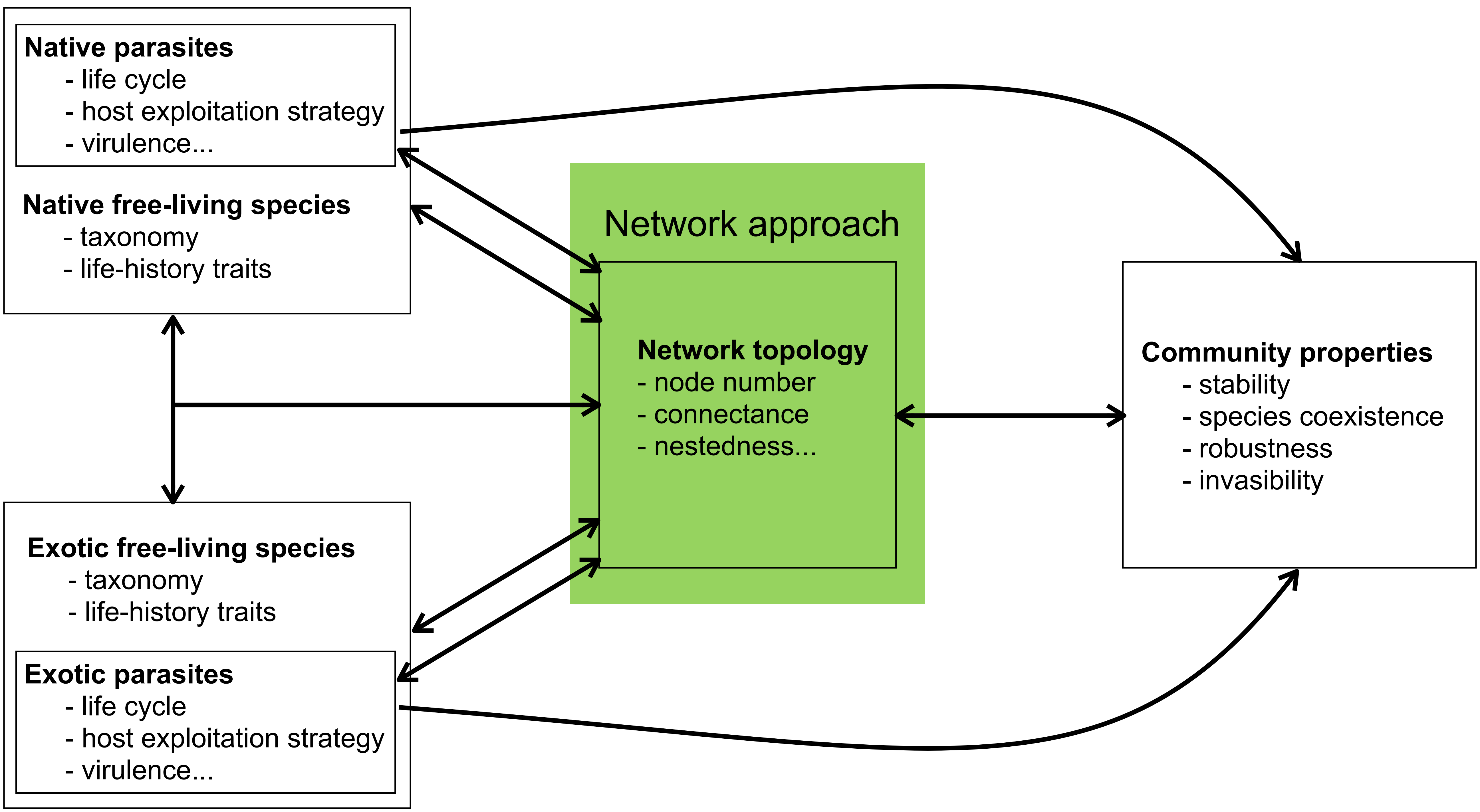
The network approach in ecology



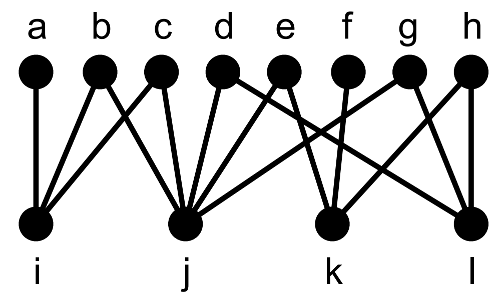
The network approach in ecology

matrix | **graph** (**qualitative**, **quantitative**)

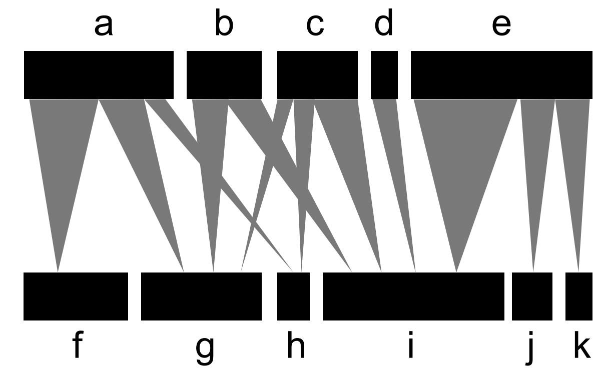
bipartite

	a	b	c	d	e	f	g	h
i	1	1	1	0	0	0	0	0
j	0	1	1	1	1	0	1	0
k	0	0	0	0	1	1	0	1
l	0	0	0	1	0	0	1	1

qualitative

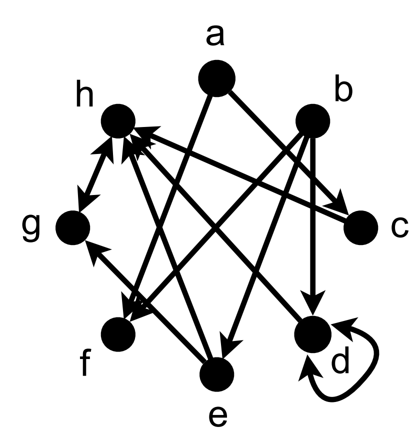


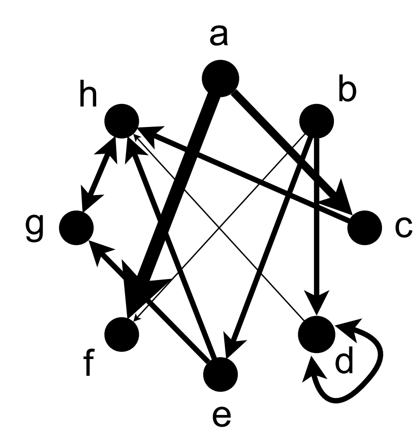
quantitative



full

	a	b	c	d	e	f	g	h
a	0	0	1	0	0	0	0	0
b	0	0	0	1	1	1	0	0
c	0	0	0	0	0	0	0	1
d	0	0	0	1	0	0	0	1
e	0	0	0	0	0	0	1	1
f	0	0	0	0	0	0	0	0
g	0	0	0	0	0	0	0	1
h	0	0	0	0	0	0	1	0





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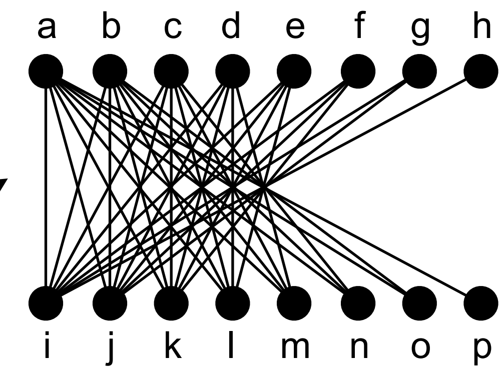
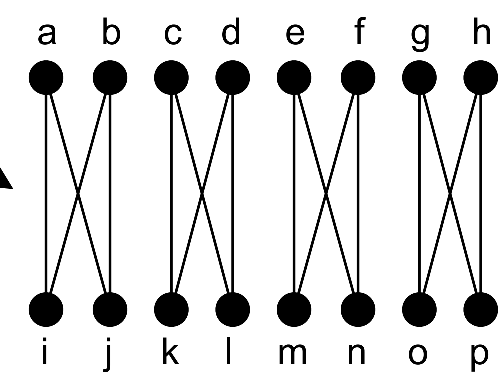
The network approach in ecology

Some topological descriptors:

Metric	Definition
Richness	Number of nodes
Connectance	Proportion of possible links that are realized
Link density	Mean number of links per node
Generality	Mean number of prey or host per predator of parasite species
Vulnerability	Mean number of predator or parasite per prey or host species
Omnivory	Proportion of taxa that feed on more than one trophic level
Chain length	Total number of trophic levels
Nestedness	Nonrandom pattern of link distribution where specialist taxa interact with a proper subset of the group of taxa with which generalists interact
Modularity	Nonrandom pattern of link distribution where taxa form groups of highly connected taxa (i.e. modules) with more links among themselves than with the taxa of other groups

For more details on the metrics, their quantitative versions and their calculation, see Bersier et al. (2002), Bascompte et al. (2003), Olesen et al. (2007) and Fortuna et al. (2010).





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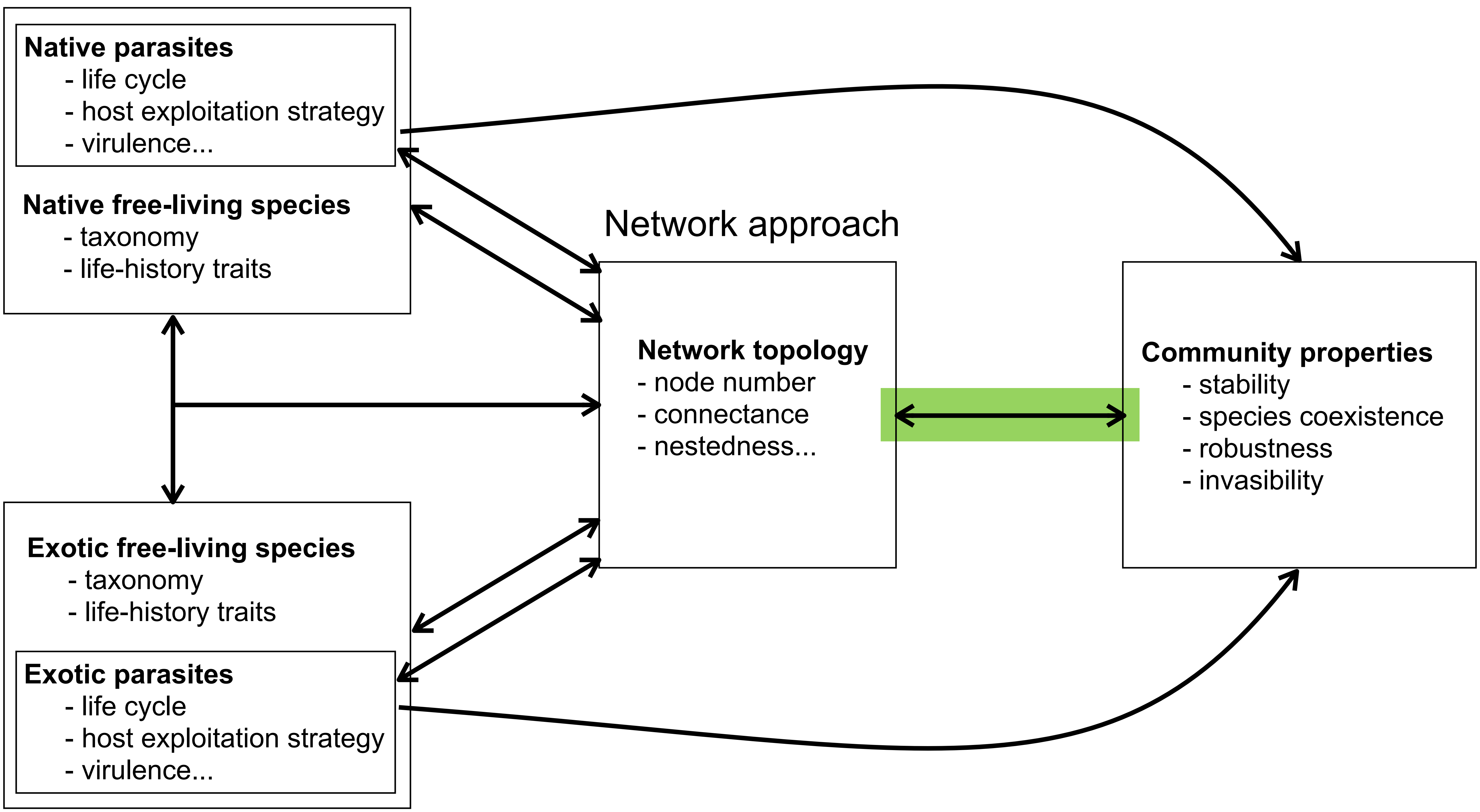
Parasites in trophic networks

The network approach in ecology

Linking network topology and community properties



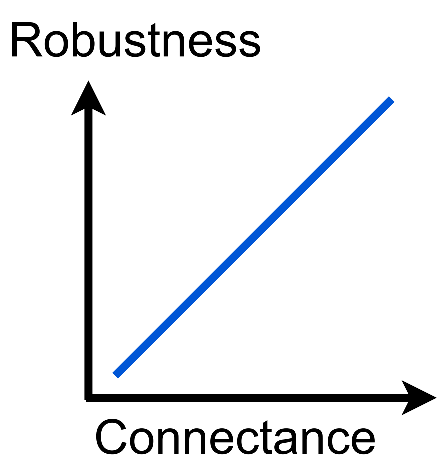
Parasites in trophic networks

The network approach in ecology

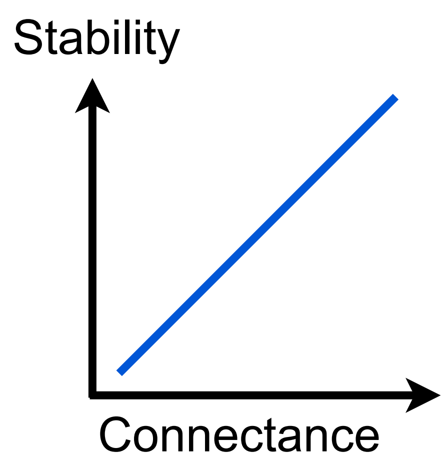
Linking network topology and community properties

Connectance and stability / robustness

Dunne et al. (2002) Ecol Lett 5
Tylianakis et al. (2010) Biol Conserv 143

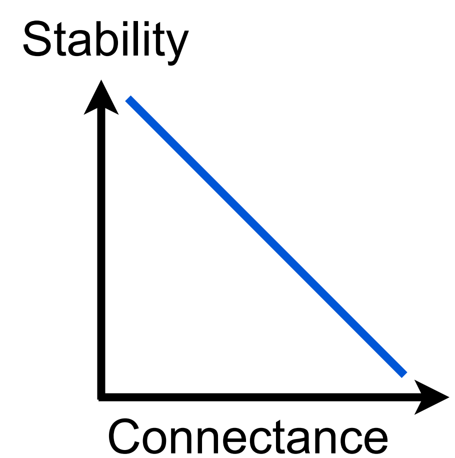


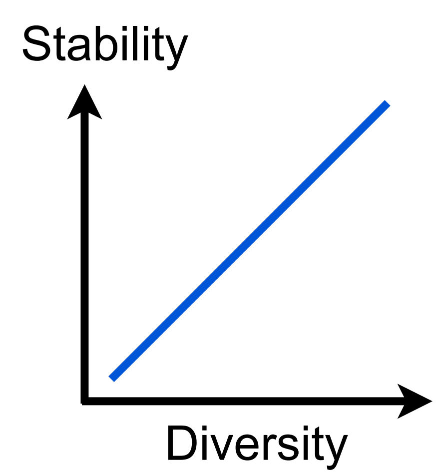
buffer in the response of predators to fluctuating prey abundances

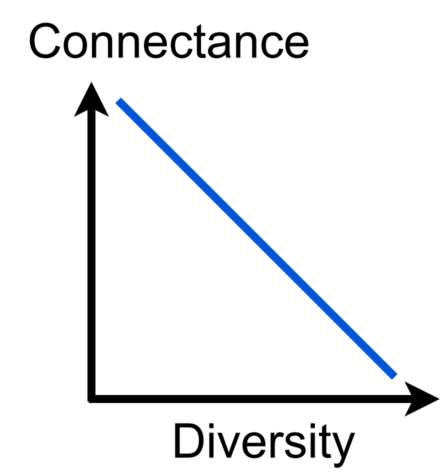


increased generalism which stabilizes the rate of ecosystem processes

Thébault and Fontaine (2010) Science 80







greater negative effect of apparent competition in highly connected webs

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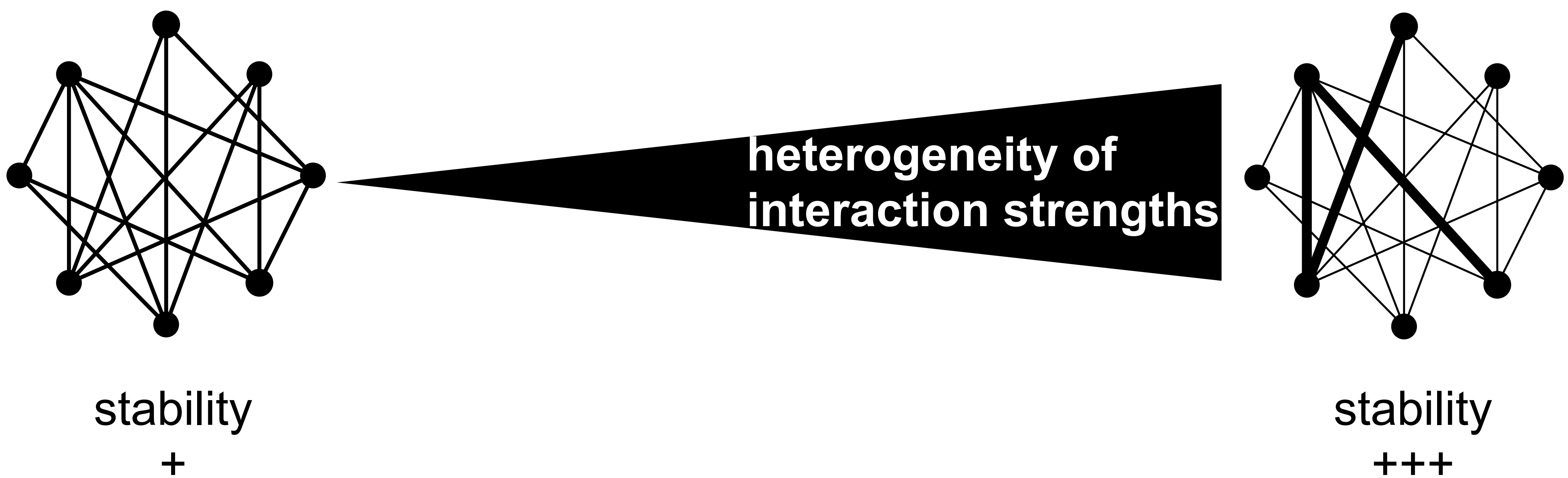
The network approach in ecology

Linking network topology and community properties

Distribution of interaction strengths and stability

McCann et al. (1998) Nature 395
Rooney and McCann (2012) Trends Ecol Evol 27



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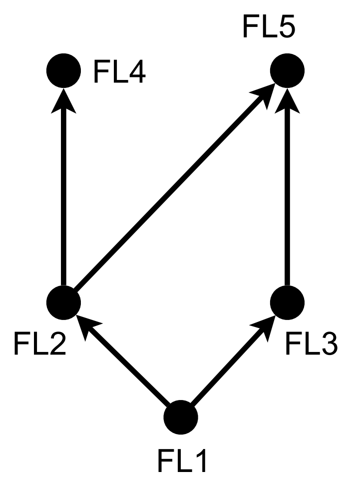
Including parasites in trophic networks

trophic network



	FL1	FL2	FL3	FL4	FL5
FL1	0	1	1	0	0
FL2	0	0	0	1	1
FL3	0	0	0	0	1
FL4	0	0	0	0	0
FL5	0	0	0	0	0

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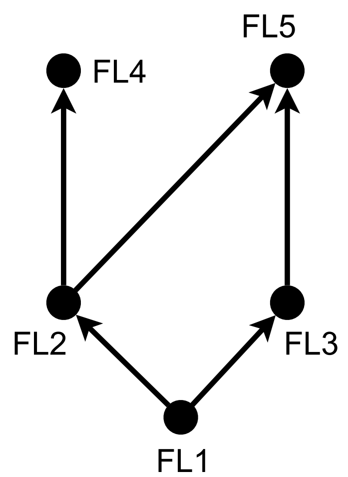
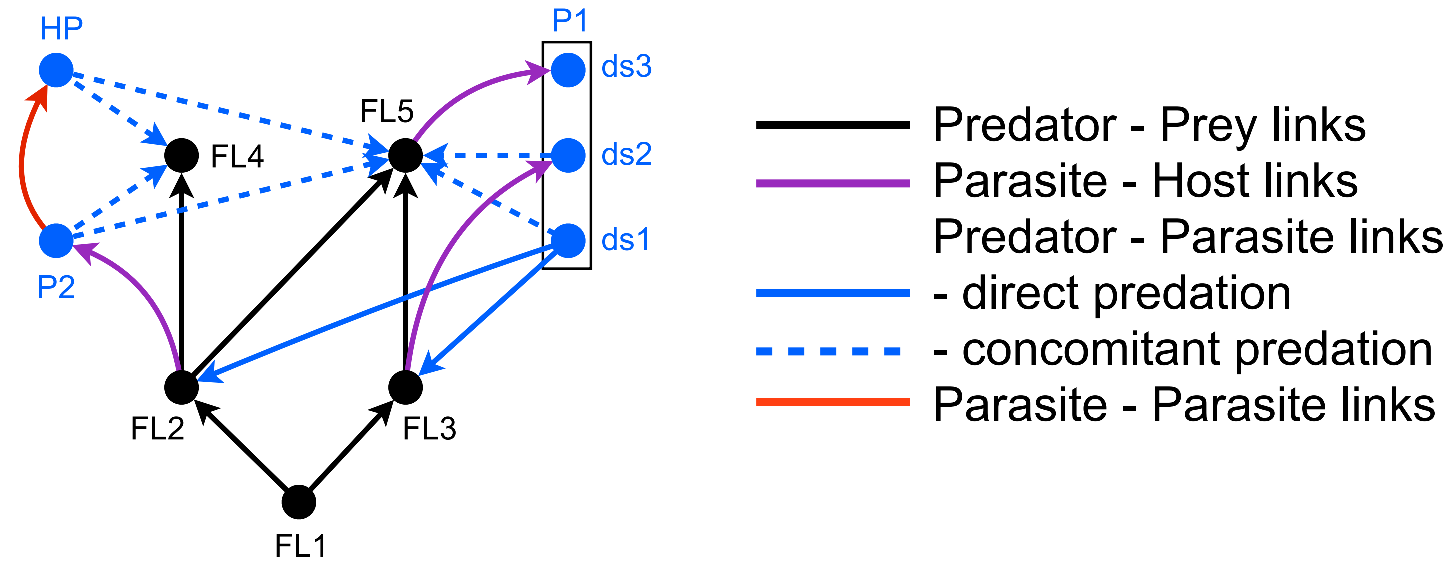
Parasites in trophic networks

Including parasites in trophic networks

trophic network



'full' trophic network or 'infectious' network



	FL1	FL2	FL3	FL4	FL5
FL1	0	1	1	0	0
FL2	0	0	0	1	1
FL3	0	0	0	0	1
FL4	0	0	0	0	0
FL5	0	0	0	0	0

predator - prey subweb

parasite - host subweb

predator - parasite subweb

parasite - parasite subweb

	FL1	FL2	FL3	FL4	FL5	P1	P2	HP
FL1	0	1	1	0	0	0	0	0
FL2	0	0	0	1	1	0	1	0
FL3	0	0	0	0	1	1	0	0
FL4	0	0	0	0	0	0	0	0
FL5	0	0	0	0	0	1	0	0
P1	0	1	1	0	1	0	0	0
P2	0	0	0	1	1	0	0	1
HP	0	0	0	1	1	0	0	0

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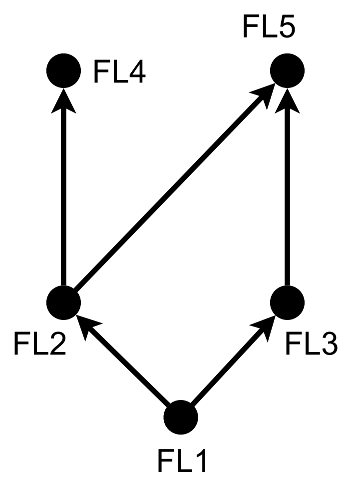
Parasites in trophic networks

Including parasites in trophic networks

trophic network



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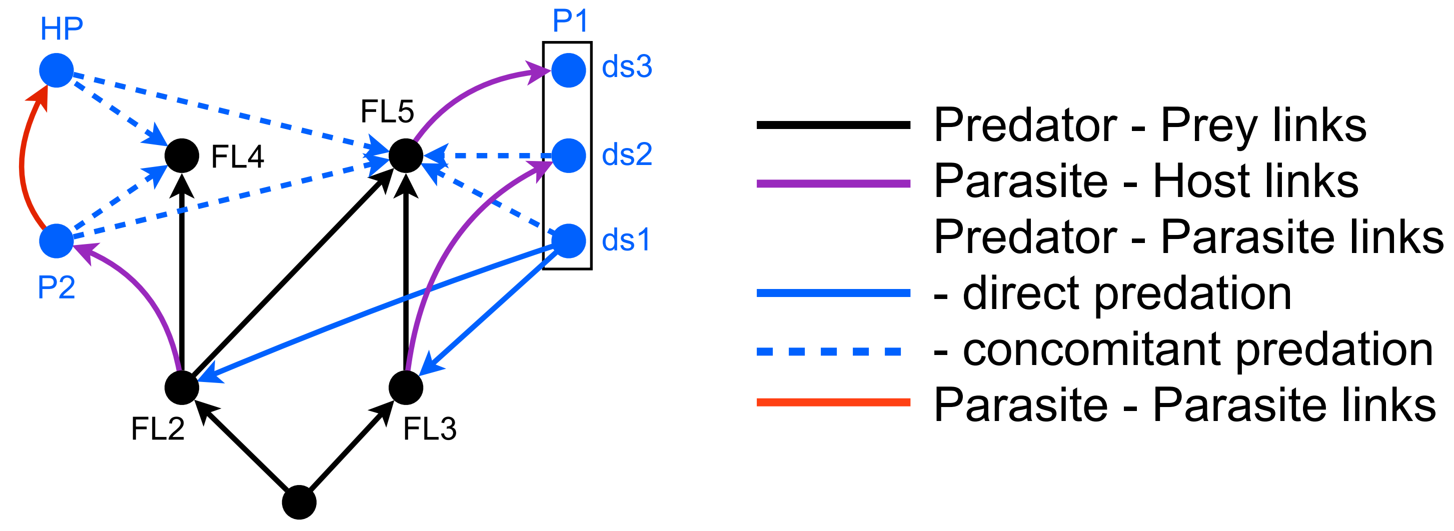

the node resolution issue:

	FL1	FL2	FL3	FL4	FL5
FL1	0	1	1	0	0
FL2	0	0	0	1	1
FL3	0	0	0	0	1
FL4	0	0	0	0	0
FL5	0	0	0	0	0

nodes = taxonomic species

	FL1	FL2	FL3	FL4	FL5	P1	P2	HP
FL1	0	1	1	0	0	0	0	0
FL2	0	0	0	1	1	0	1	0
FL3	0	0	0	0	1	1	0	0
FL4	0	0	0	0	0	0	0	0
FL5	0	0	0	0	0	1	0	0
P1	0	1	1	0	1	0	0	0
P2	0	0	0	1	1	0	0	1
HP	0	0	0	1	1	0	0	0

nodes = developmental stages

	FL1	FL2	FL3	FL4	FL5	ds1	ds2	ds3	P2	HP
FL1	0	1	1	0	0	0	0	0	0	0
FL2	0	0	0	1	1	0	0	0	1	0
FL3	0	0	0	0	1	0	1	0	0	0
FL4	0	0	0	0	0	0	0	0	0	0
FL5	0	0	0	0	0	0	0	1	0	0
ds1	0	1	1	0	1	0	0	0	0	0
ds2	0	0	0	0	1	0	0	0	0	0
ds3	0	0	0	0	0	0	0	0	0	0
P2	0	0	0	1	1	0	0	0	0	1
HP	0	0	0	1	1	0	0	0	0	0

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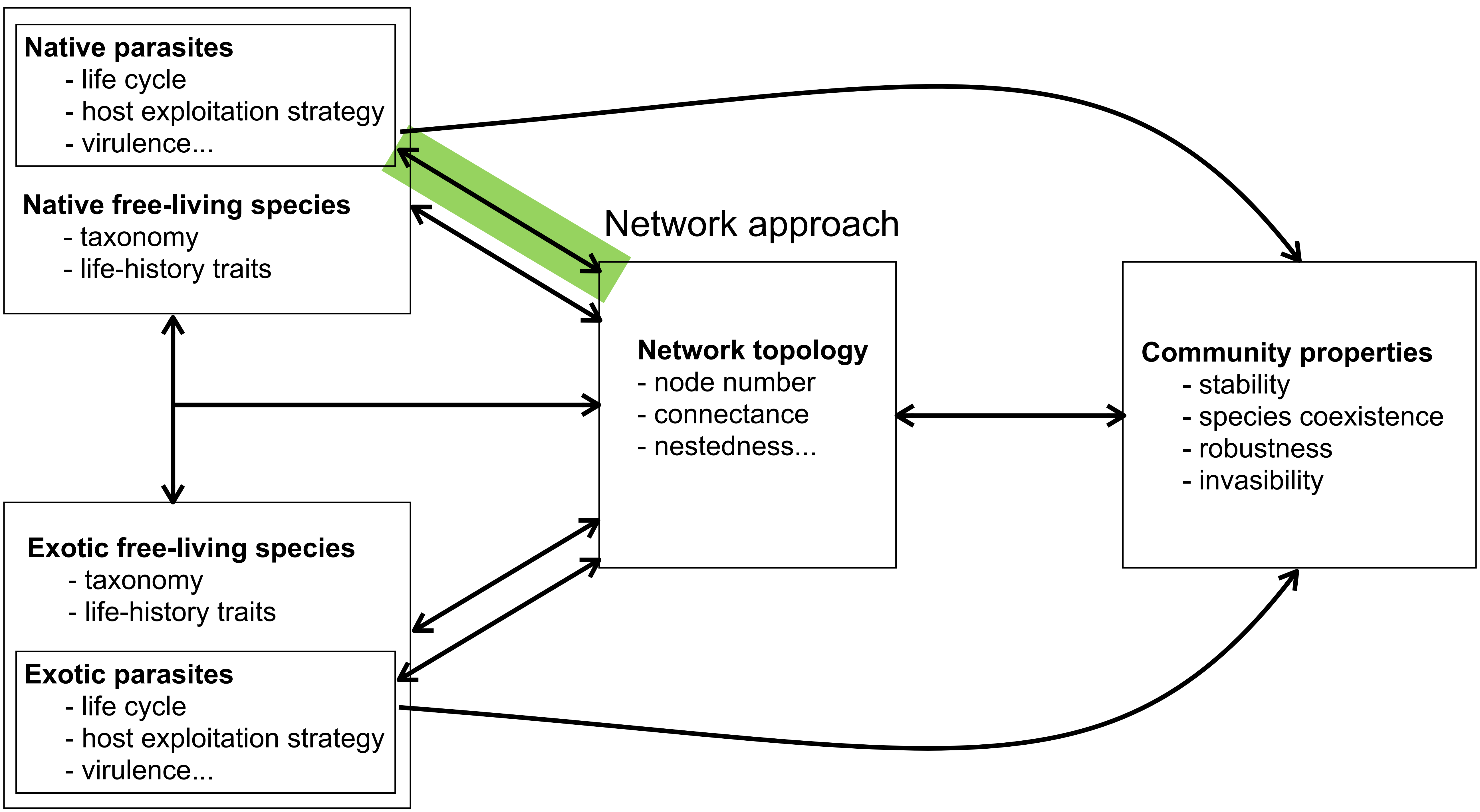
Parasites in trophic networks

Parasite - induced changes in topology



Parasites in trophic networks

Parasite - induced changes in topology

Name	Location	References
Loch Leven	United Kingdom	Huxham et al. (1995)
Ythan Estuary	United Kingdom	Huxham et al. (1995)
Broom fauna at Silwood Park	United Kingdom	Memmott et al. (2000)
Otago Harbour	New Zealand	Thompson et al. (2005) and Mouritsen et al. (2011)
Carpinteria Salt Marsh	USA, California	Lafferty et al. (2006), Kuris et al. (2008) and Hechinger et al. (2011)
Estero de Punta Banda	Mexico	Kuris et al. (2008) and Hechinger et al. (2011)
Bahía Falsa	Mexico	Kuris et al. (2008) and Hechinger et al. (2011)
Muskingum Brook	USA, New Jersey	Hernandez and Sukhdeo (2008)
Lake Takvatn	Norway	Amundsen et al. (2009, 2013)
Flensburg Fjord	Germany/Denmark	Zander et al. (2011)
Sylt Tidal Basin	Germany/Denmark	Thieltges et al. (2011)

Increased complexity:

- ⬆ Richness
- ⬆ Chain length
- ⬆ Linkage density

- ⬆ Nestedness
- ⬆ Connectance

When parasites are included as taxonomic species

Importance of concomitant predation

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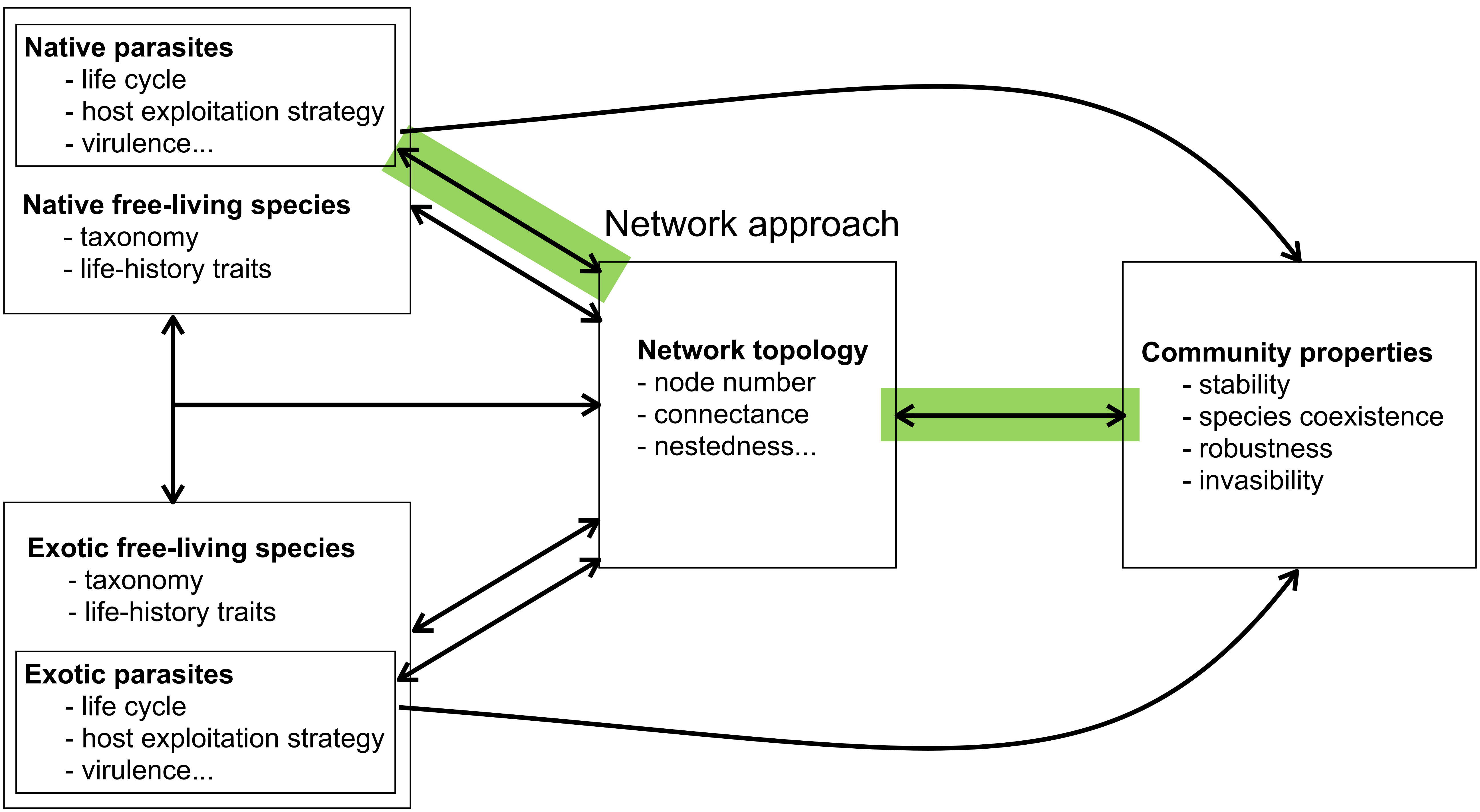
Parasites in trophic networks

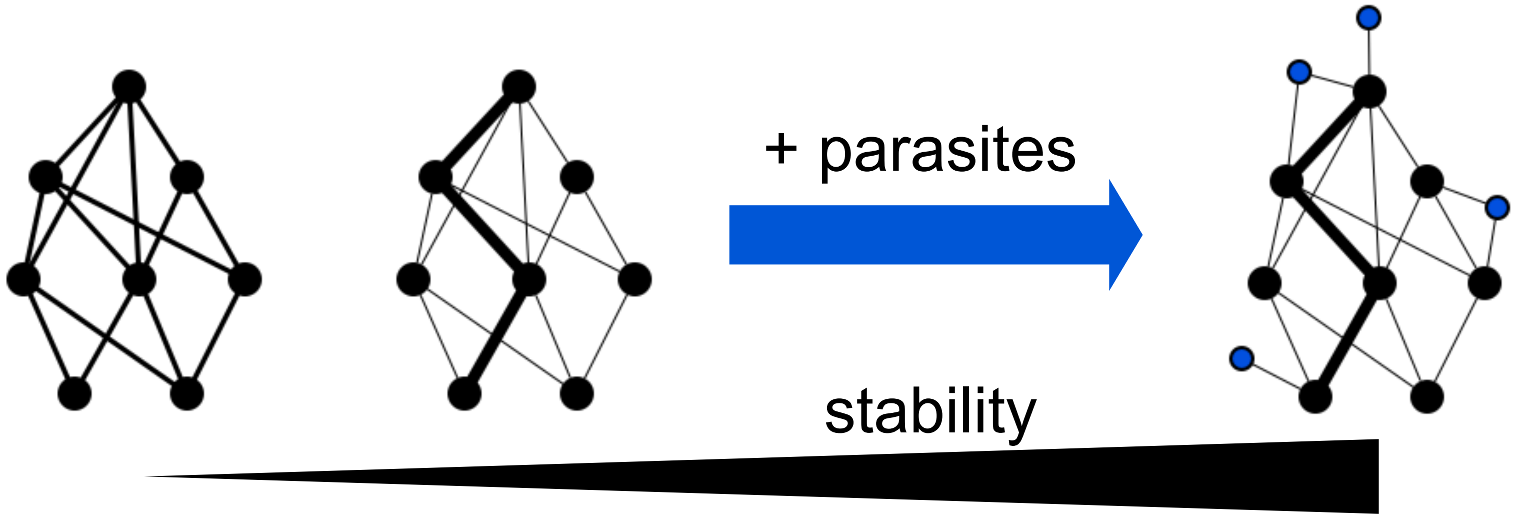
Parasite - induced changes in community properties



Parasite - induced changes in community properties

Parasites and stability

Following McCann et al. (1998), including parasites should promote stability because they add weak interactions to the network



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Parasite - induced changes in community properties

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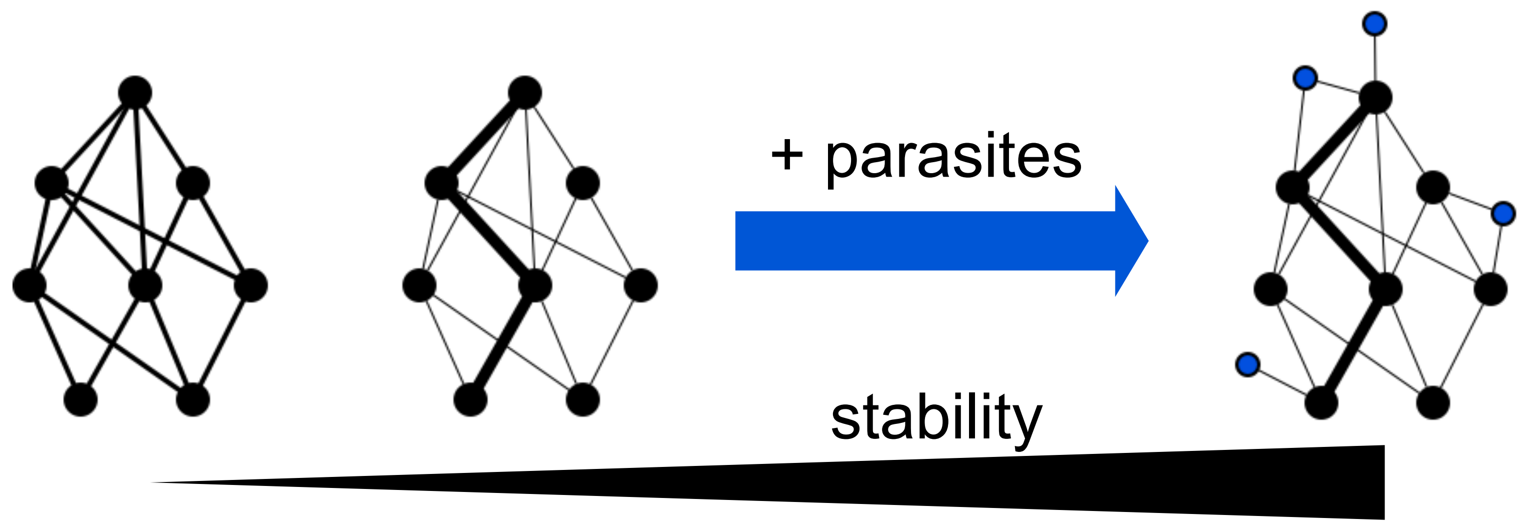
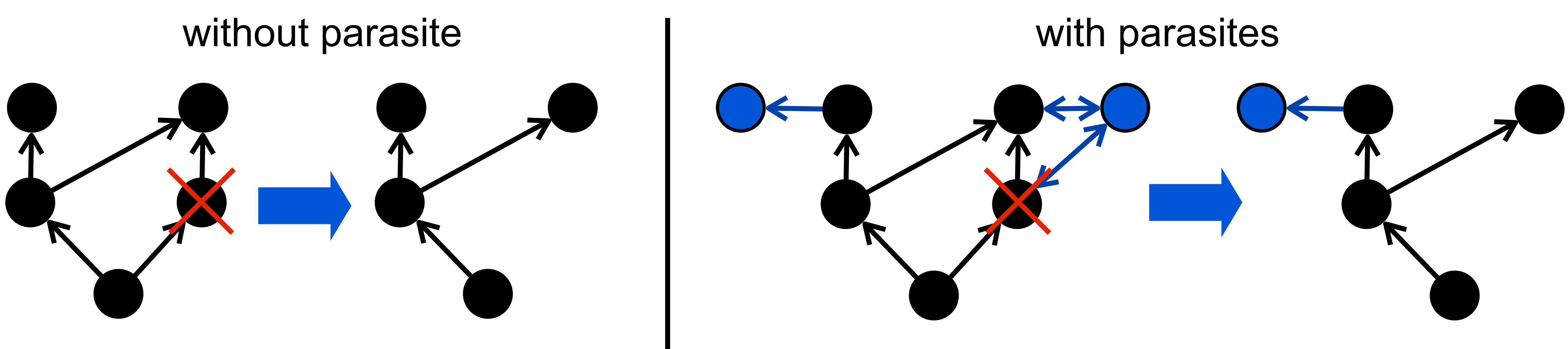


Parasites and robustness

Parasites should decrease robustness because they increase the risk of secondary extinctions



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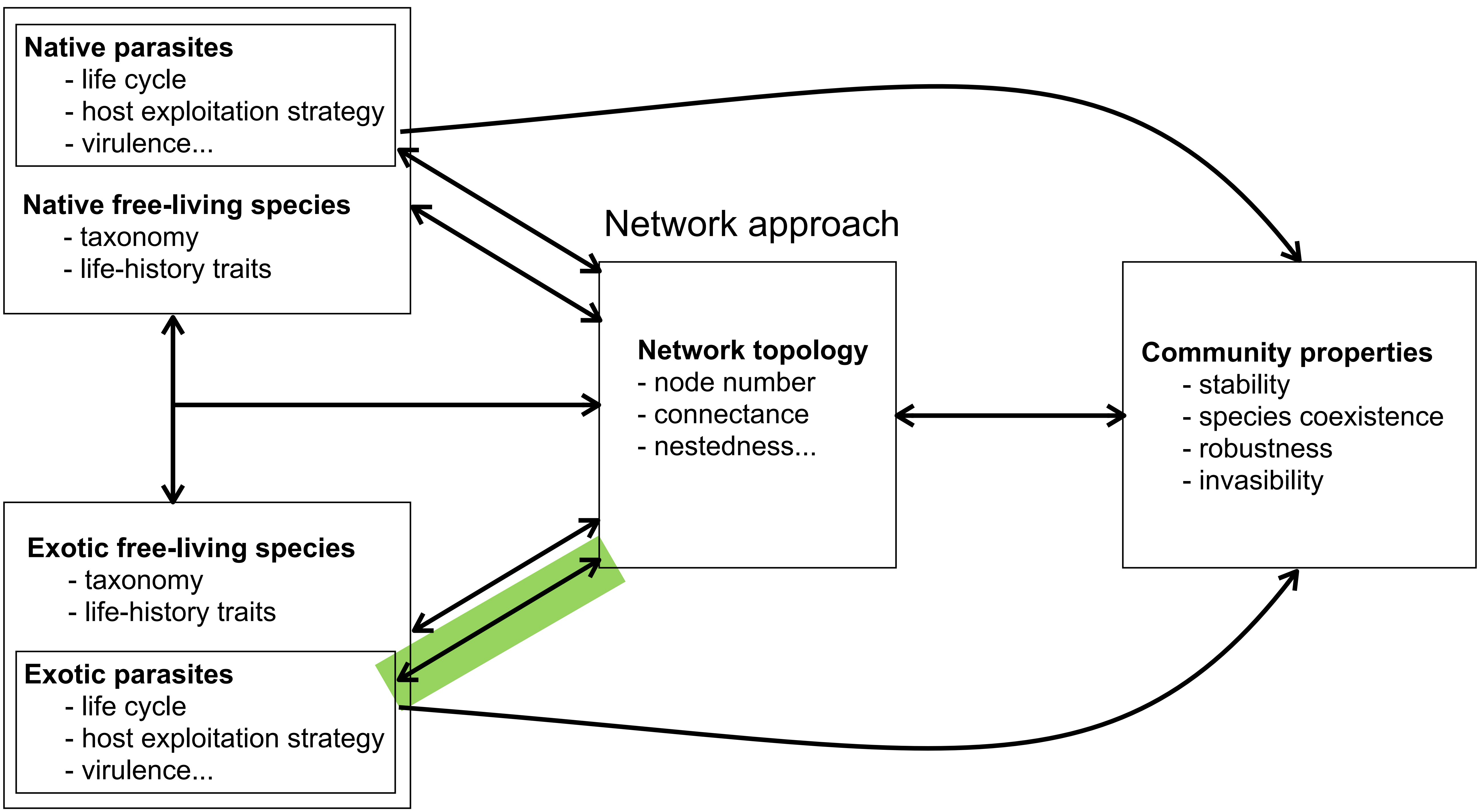
Parasites in invaded networks

Impact of introduced parasites on food-web structure



Parasites in invaded networks

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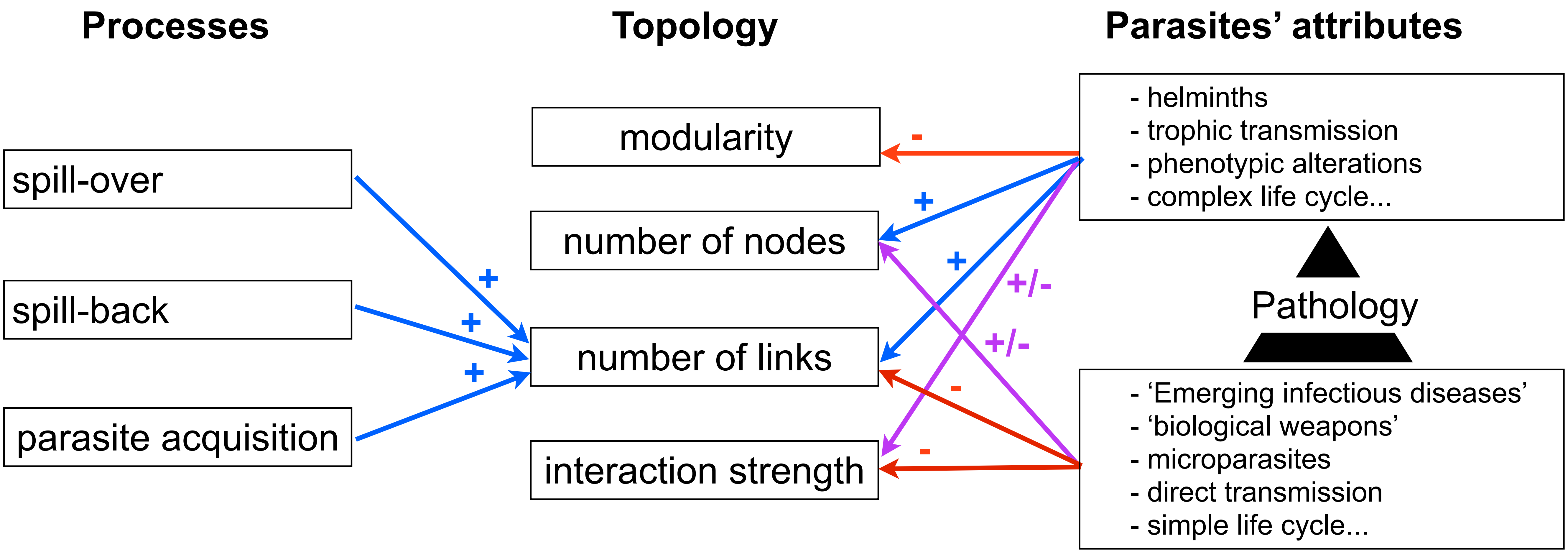

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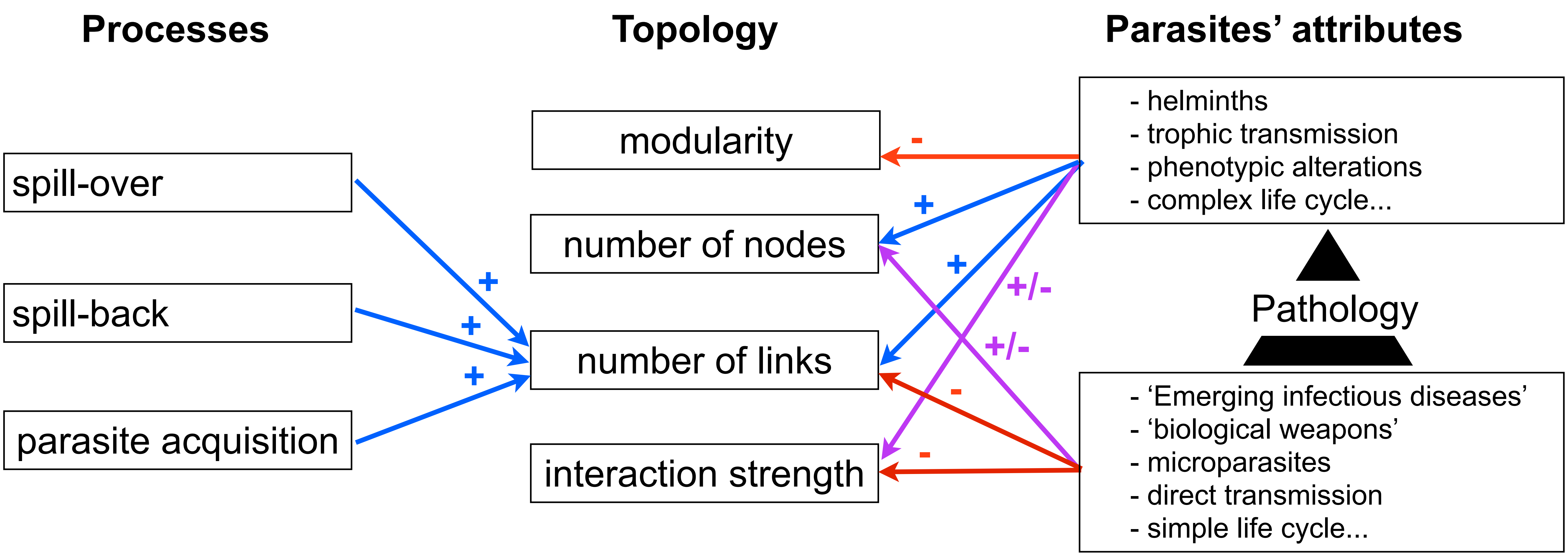
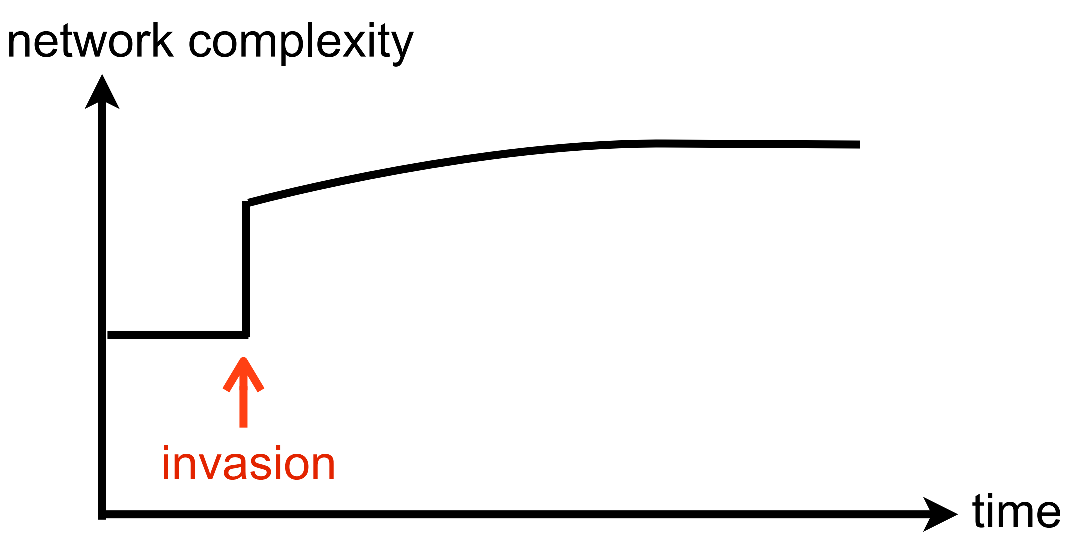
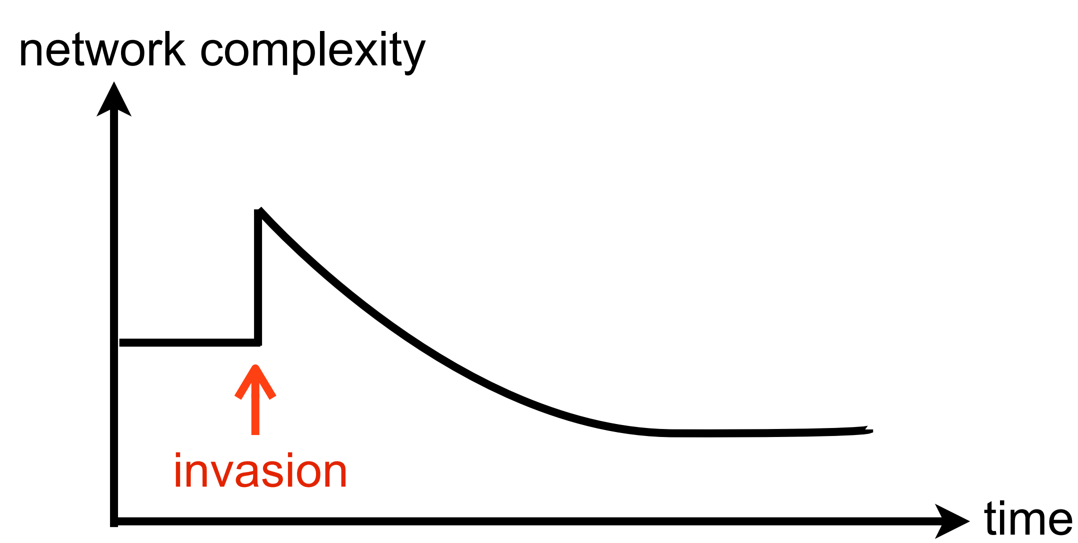


Parasites with low pathogenicity



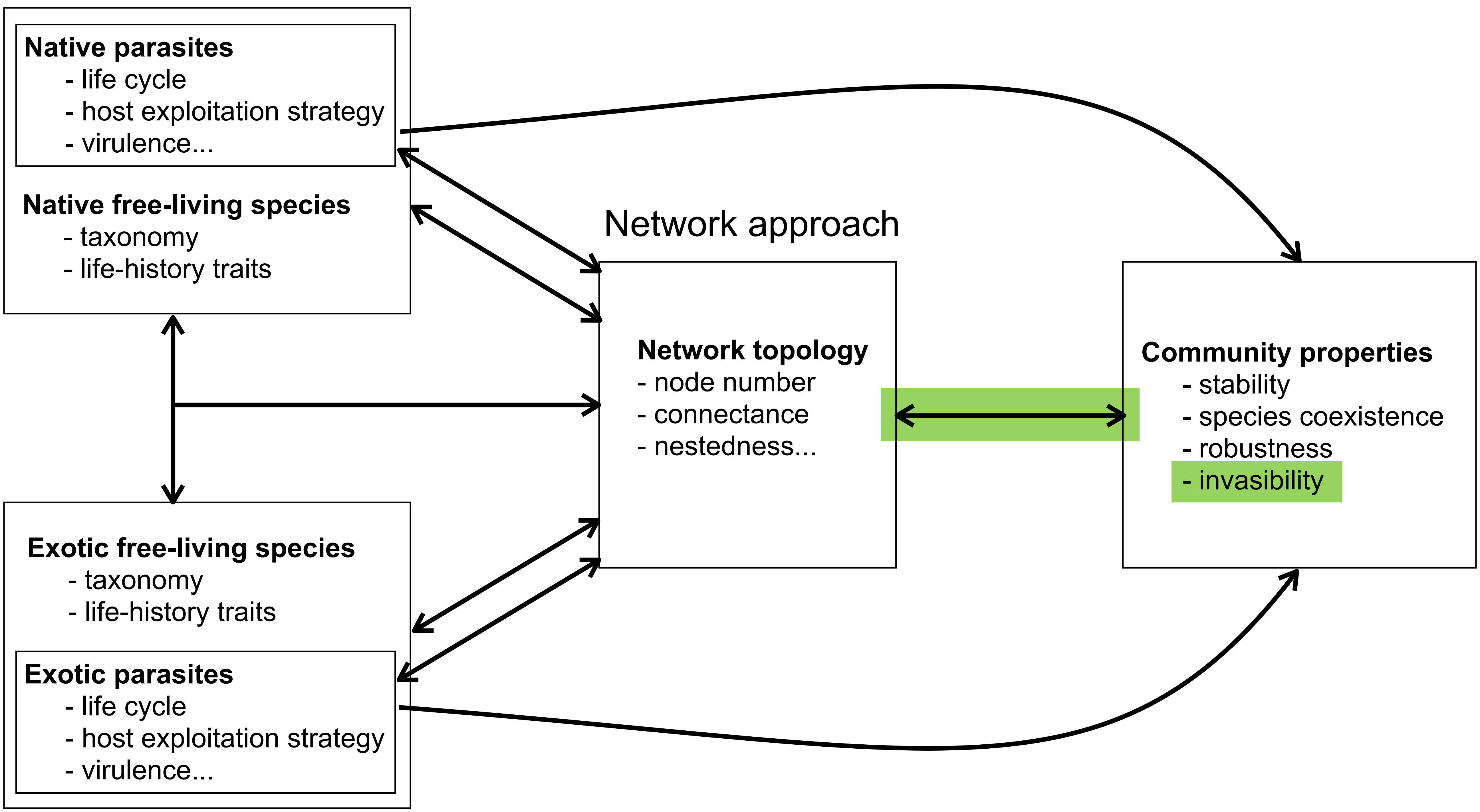
Parasites with high pathogenicity



Médoc et al. (2017) Adv Ecol Res 57

Parasites in invaded networks

Linking network structure and invasibility

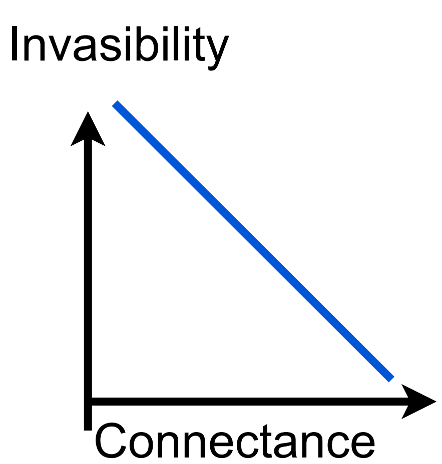


Parasites in invaded networks

Linking network structure and invasibility

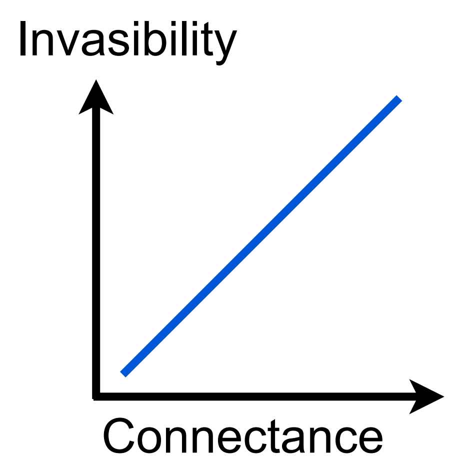
Connectance and invasibility by free living species

Romanuk et al. (2009) Philos Trans R Soc Lond B Biol Sci 364
Wei et al. (2015) Nat Commun 6

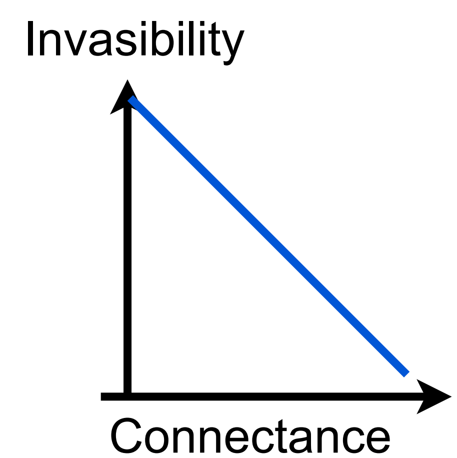


Baiser et al. (2010) Oikos 119
Vermaat et al. (2009) Ecology 90

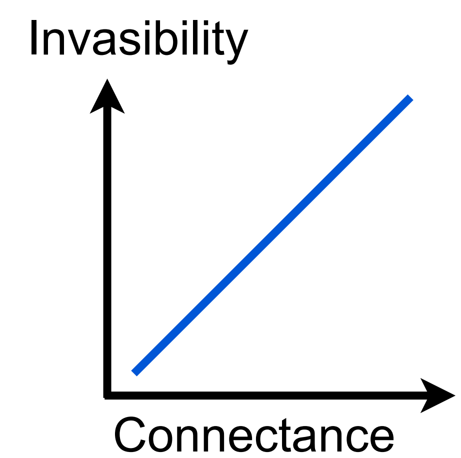
For exotic top predators



For exotic herbivores



Lurgi et al. (2014) Front Ecol Evol 2
Hui et al. (2016) Biol Invasions 18



Opposite predictions...

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Parasites in invaded networks

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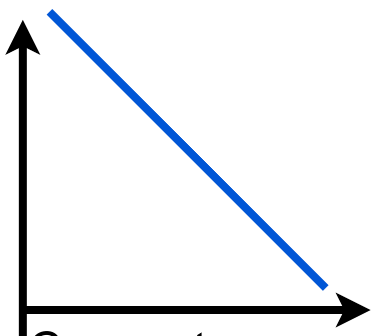
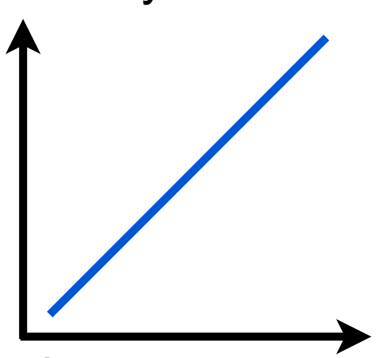


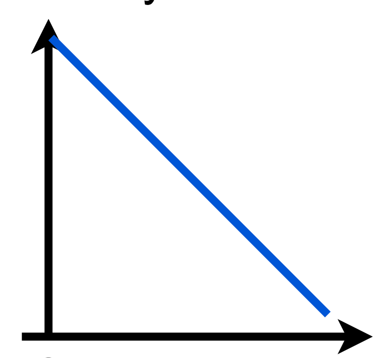
Increased competition and a crowded niche space

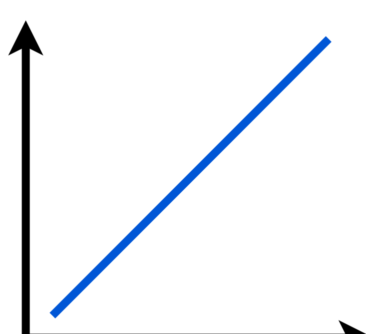
Baiser et al. (2010) Oikos 119
Vermaat et al. (2009) Ecology 90

For exotic top predators



For exotic herbivores





Lurgi et al. (2014) Front Ecol Evol 2
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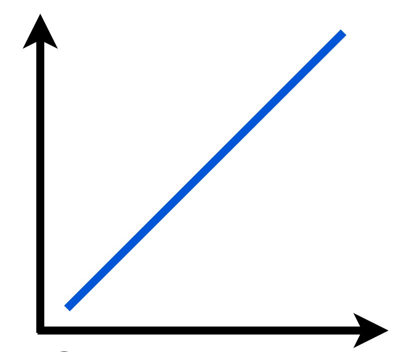

between-species feedbacks: they are more important in highly connected webs and create opportunity niches for invasion

species diversity:
- *diversity confers resistance to invasion*
- *more connected webs are often less diverse*

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Parasites in invaded networks

Linking network structure and invasibility

Connectance and invasibility by co-introduced parasites

Connectance	Species diversity	Invasibility by the co-introduced host	Invasibility by the co-introduced parasite
Low	High	Decreased	Promoted
High	Low	Promoted	Decreased

Antagonistic effects

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High	Low	Promoted	Decreased

Antagonistic effects

Spill-over to native hosts may allow cointroduced parasites to establish in the recipient food web even when its structure constrains invasibility by their cointroduced host.

The invasion success of parasites with complex life cycles should decrease with the level of host specificity and the number of successive hosts involved in the cycle.

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Parasites in invaded networks

Linking network structure and invasibility

Modularity and invasibility by parasites

Highly compartmentalized networks are formed by clearly bounded modules, with few interactions between modules, corresponding to spatially or temporally partitioned niches and habitats that are potentially available.

Complex life cycle parasites experiencing strong ontogenetic niche shifts are more likely to invade highly modular networks, where their probability to meet life cycle requirements in terms of successive hosts and transmission pathways is higher.

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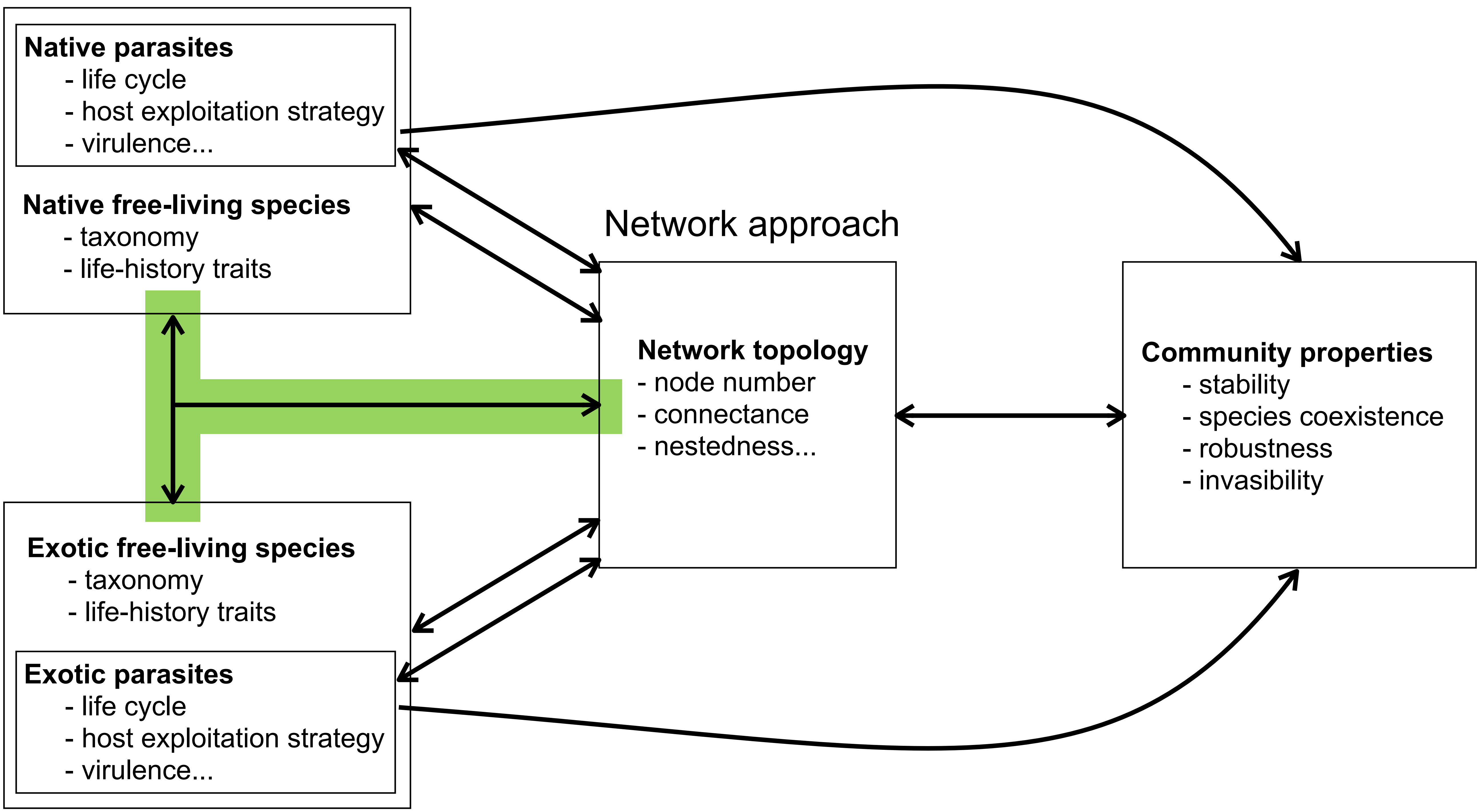
Parasites in invaded networks

How invader-induced changes in topology affect parasites



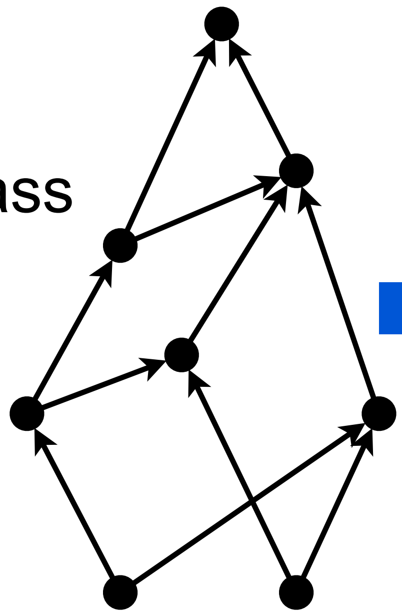
Parasites in invaded networks

How invader-induced changes in topology affect parasites

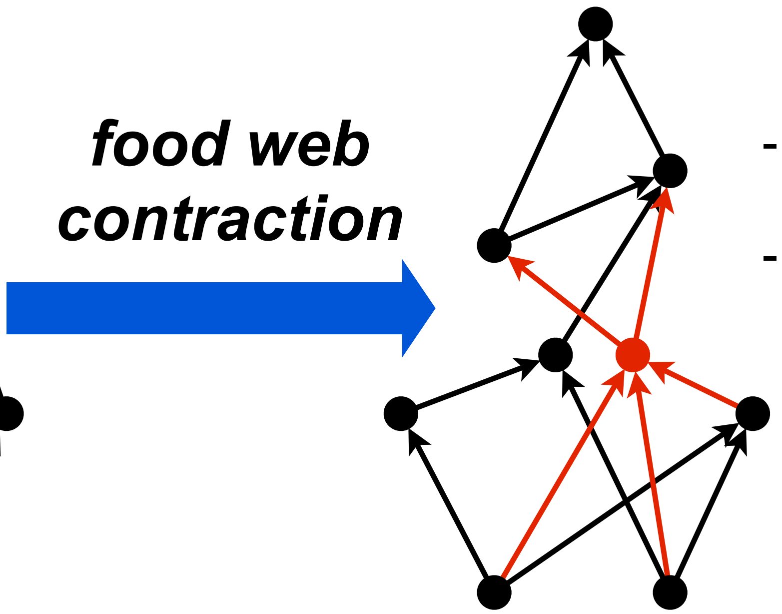
Invasive species:
bio-ecological attributes:
- high abundance and biomass
- broad diet

topological attributes:
- high generality
- high vulnerability

'hubs'



food web contraction



- increased connectivity around the invasive species
- reduced connectivity among native species

Parasites in invaded networks

How invader-induced changes in topology affect parasites

Invasive species:
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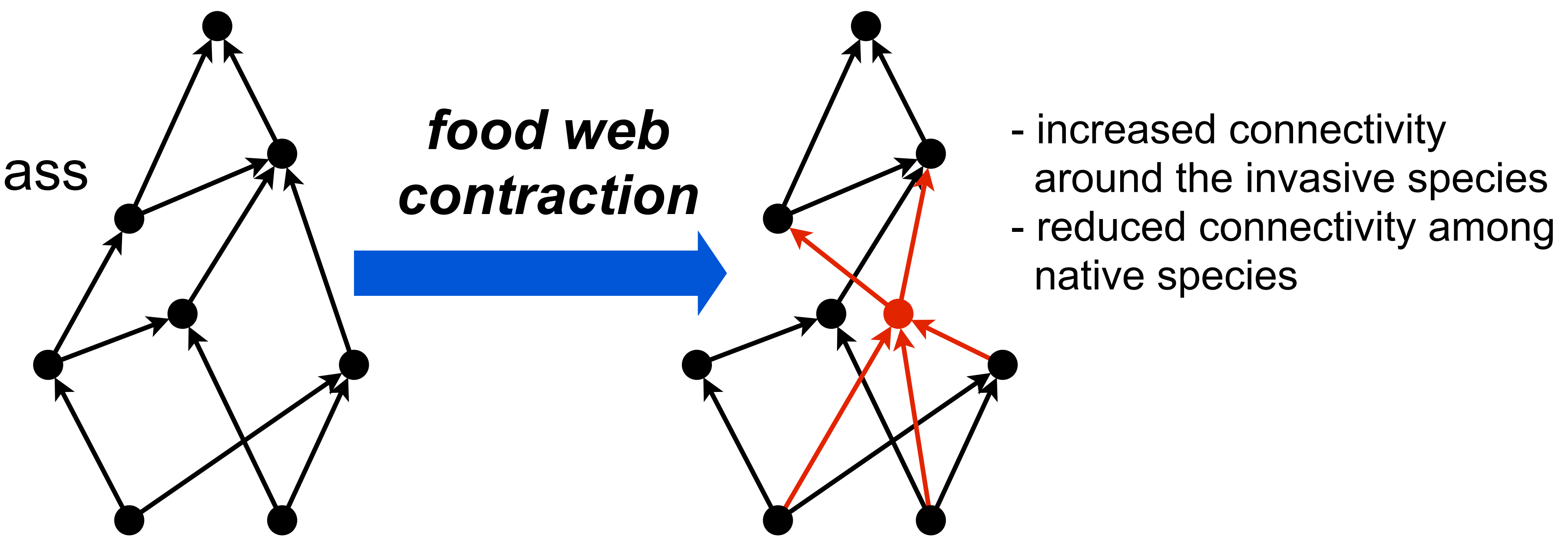

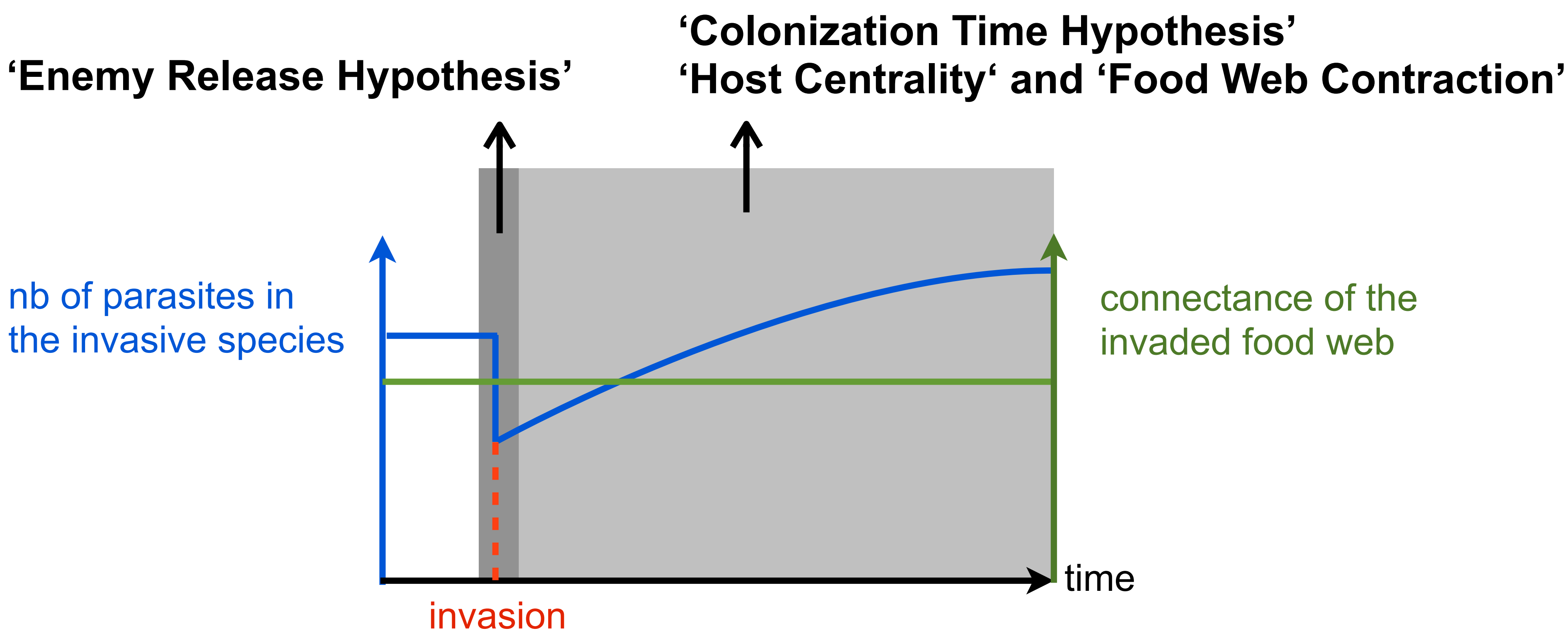

Invasive species should become important drivers of parasites in recipient ecosystems.

Thanks!