The current state of knowledge for invertebrate underwater noise research

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Outline

-Biological importance of sound for invertebrates

-“Hearing” capabilities

- Assessing literature

-Potential effects of noise on invertebrates:
  - -Behaviour
  - -Physiology
  - - Physical

- New directions and priorities

Diversity

Phylopic

Importance of sound

Communication
Environmental sensing
Information gathering

Coral planulae orientate to reef sounds
- Lillis et al., (2018)

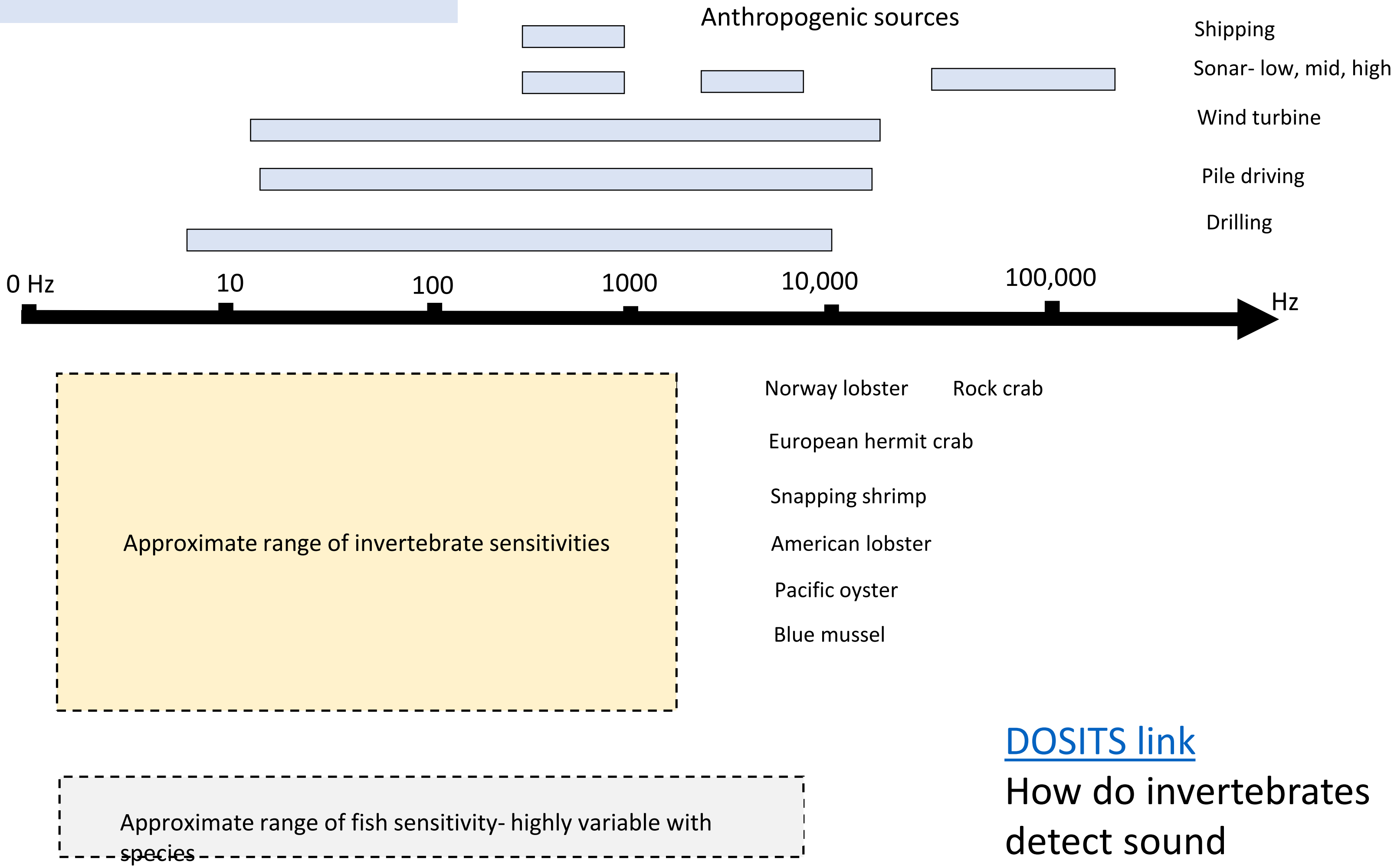
Zooplankton and polychaetes produce sounds
- Kühn et al (2022)
- Goto et al (2019)

DOSITS link
How do invertebrates produce sounds
DOSITS link
Snapping shrimp

Photo by Uwe Kils; Georges Jansoone;
Science magazine/youtube

“Hearing”

ACOUSTIC = pressure, water particle motion
VIBRATIONAL= substrate-borne vibration



[DOSITS link](#)
How do invertebrates detect sound

Reviewed in Roberts (2015); plus Charifi et al 2017;
Dinh and Radford (2021); Jezequel et al (2021)

Assessing literature

- Behaviour in tanks

- Acoustics in tanks is complex

- Variability in exposure types and contexts

- The 'relevant' stimulus: particle motion

- Limited species coverage

… difficult to draw conclusions or make comparisons.
Here discuss literature where ***particle motion*** *was measured*

Behaviour

Feeding change e.g. in bivalves

- Spiga et al., (2016)- pile driver in field; significantly higher feeding rate of mussels in noise

- Wale et al., (2019)- boat sound; captive mussels consumed fewer algal cells, increased valve gape

- Roberts et al., (2015) low frequency vibration; captive mussels valve closure and valve "flinch"

Locomotion change e.g. in crustaceans

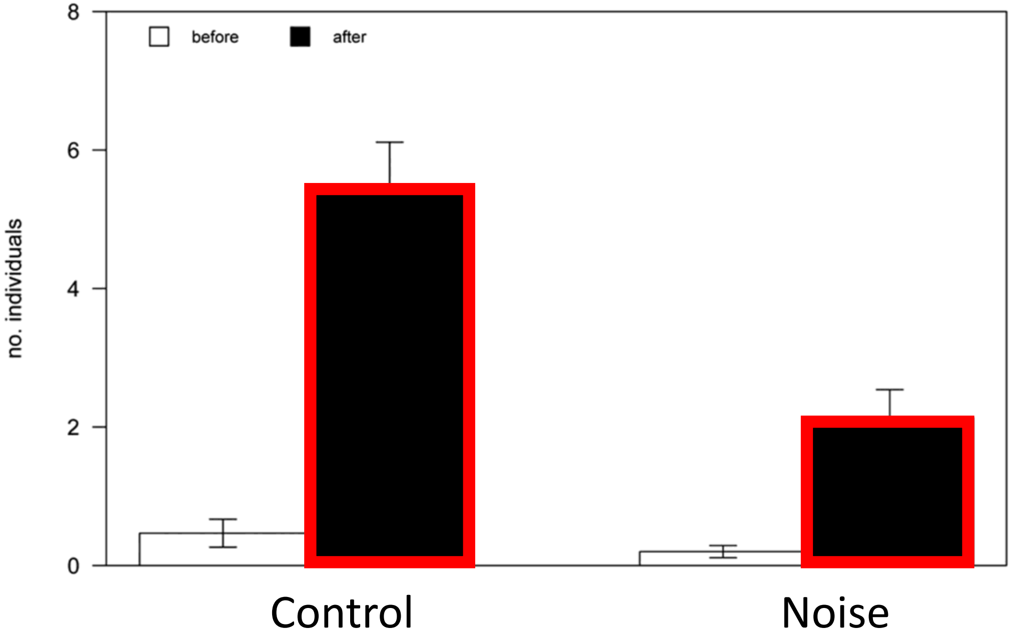
- Aimon et al., (2021)- 20 Hz "shake" higher activity and antennal beat in shore crabs

- Roberts et al. (2016)- low frequency vibration; hermit crabs burst of movements, flinching of legs, antennae movement, retraction

- Roberts and Laidre (2019)- small-scale pile mimic in field; fewer hermit crabs attracted to a chemical cue after noise compared to ambient.

Behaviour

Impaired information use in hermit crabs



Number of hermit crabs (mean±s.e.m.) attracted to the chemical cue before and after a 5-min exposure to either a silent control or impulsive noise (*n*=30 for both)

Roberts and Laidre (2019)

Physiology

Oxygen consumption

- Wale et al., (2019)- boat sound; reduction in oxygen consumption; also evidence of DNA damage in captive mussels

- Aimon et al. (2021)- 20 Hz "shake"; no significant oxygen consumption change in captive crabs

Stress biochemistry

- Day et al. (2022) – airguns; lobsters had increased intermolt duration thought to be linked to slow development, growth and stress

- Fitzbiggon et al., (2017)- airguns; impaired immune system function in lobsters

- Day et al. (2017) – airguns; lobsters reduced osmoregulation capacity and increased mortality

Physiology

Reduced oxygen consumption in mussels

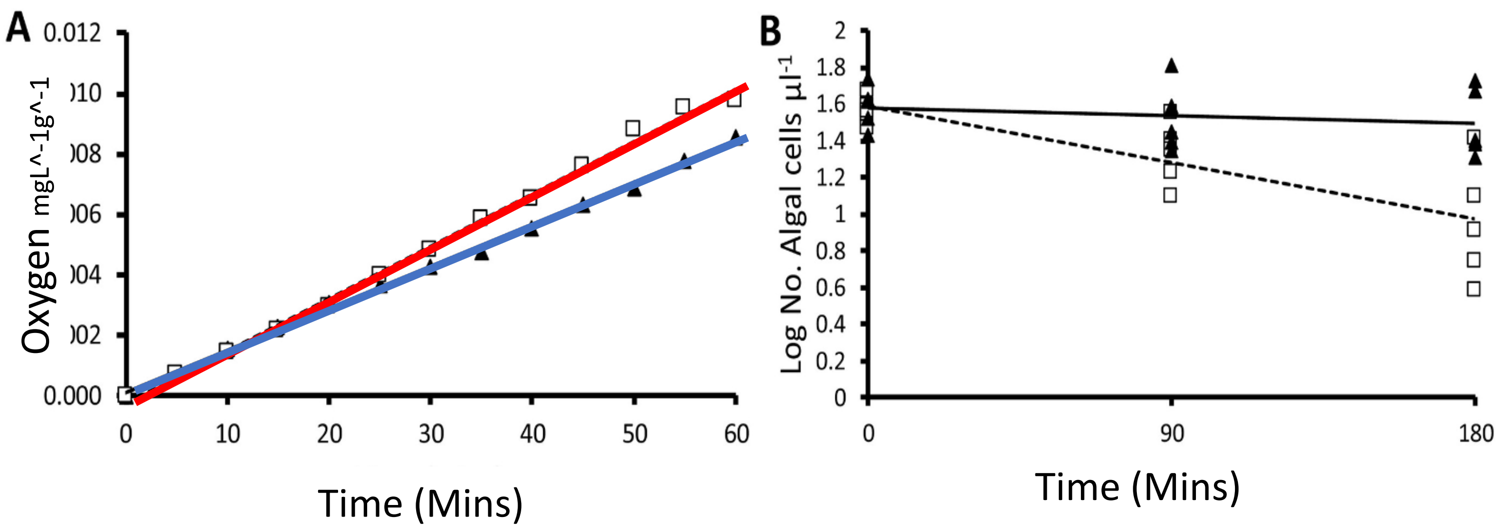
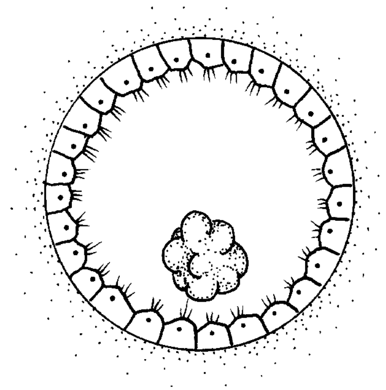


Fig. 3. Effects of ship-noise playbacks on the behavior and physiology of *Mytilus edulis*. (A) Oxygen consumed (mg L^{-1}) per g of *M. edulis* tissue* over 1 h of noise or control exposure (n = 10 for both treatments). (B) Consumed algal cells μl^{-1} seawater*** ($n = 5$ for both treatments). (C) Mean ± Stdev valve gape* ($n = 6$ for noise, $n = 8$ for control). (D) Mean ± Stdev seconds with valve open (n = 6 for noise, n = 8 for control).

Wale et al. (2019)

Anatomical damage



Damage to sensory structures

- Sole et al. (2017) sinusoidal sounds; common cuttlefish in the field, damaged and missing sensory hairs in statocyst.

- Day et al. (2022) airguns; found statocyst damage in rock lobsters exposed in the field and impaired righting ability, no mortality

Developmental changes

- Nedelec et al. (2014) boat sound; sea hare in the field, embryo development reduced and increased mortality

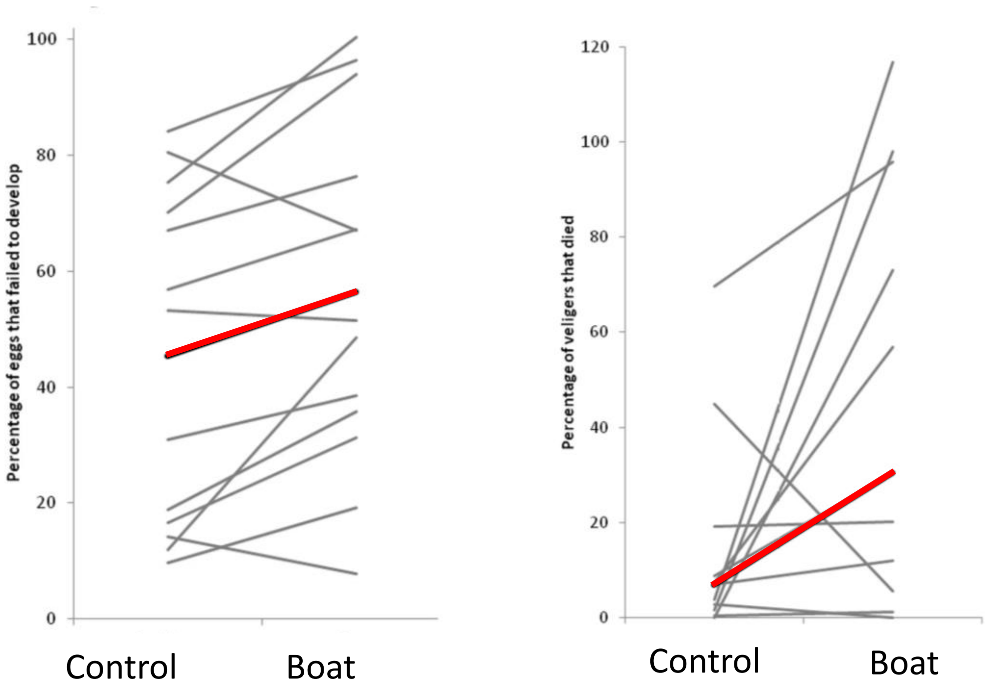
- Aguilar de Soto et al. (2013) seismic pulse; scallop larvae in lab body abnormalities and developmental delays

No significant effects

- Przelawki et al. (2018) airguns; exposed scallop, no signs of damage

Anatomical damage

Reduction in successful embryo development and increased mortality of sea hare larvae

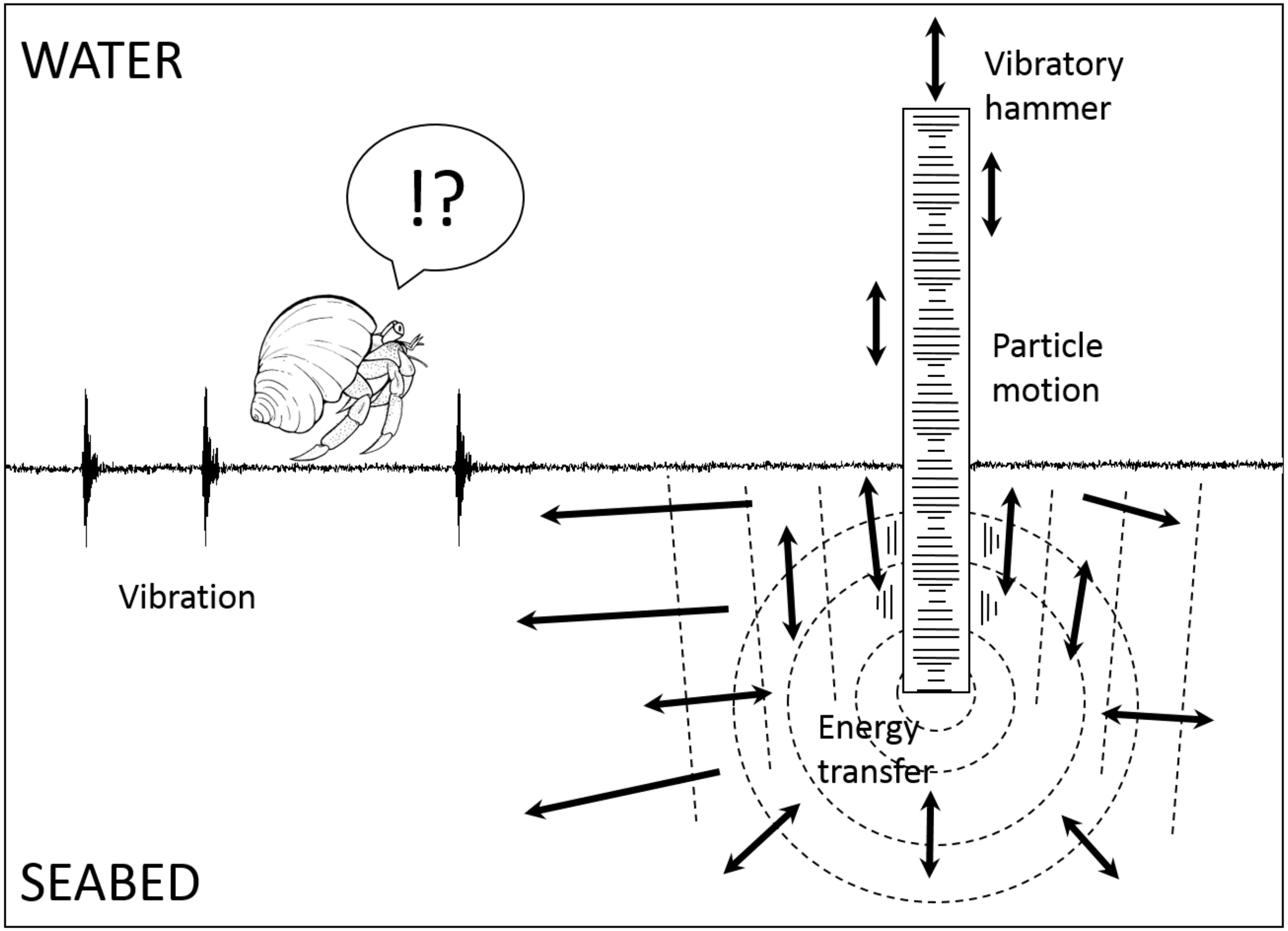


Arcsin square root transformed percentage of egg capsules that (a) failed to develop and (b) were unhatched in each treatment. The thick black line represents the overall effect (mean for each treatment), whereas the grey lines connect values for the two treatments for each mother. N = 13 mothers. (c) Number of veligers that died as a percentage of egg capsules that hatched per treatment. The thick black line represents the overall effect (median for each treatment), whereas the grey lines connect values for the two treatments for each mother. N = 11 mothers.

Nedelec et al. (2014)

New directions: seabed vibration

Benthic animals are also susceptible to VIBRATIONS



Roberts and Elliott (2017)

New directions: seabed vibration

Aimon et al. (2021)

Roberts and Laidre (2019a; 2019b);
Roberts et al., (2017);
Roberts et al. (2016).

Cote et al. (2020);
Morris et al. (2018)

Fitzgibbon et al. (2017);
Day et al. (2019);
Day et al. (2022)

Berghahn et al. (1995)

Roberts and Howard (2022)

Roberts et al. (2017);
Roberts et al. (2015);
Spiga et al. (2016);
Mosher (1972)

Day et al. (2017);
Mosher (1972).

R.Kuiter; C. Minguel; Wikimedia; Slowmotiongli; Dreamstime

Research priorities

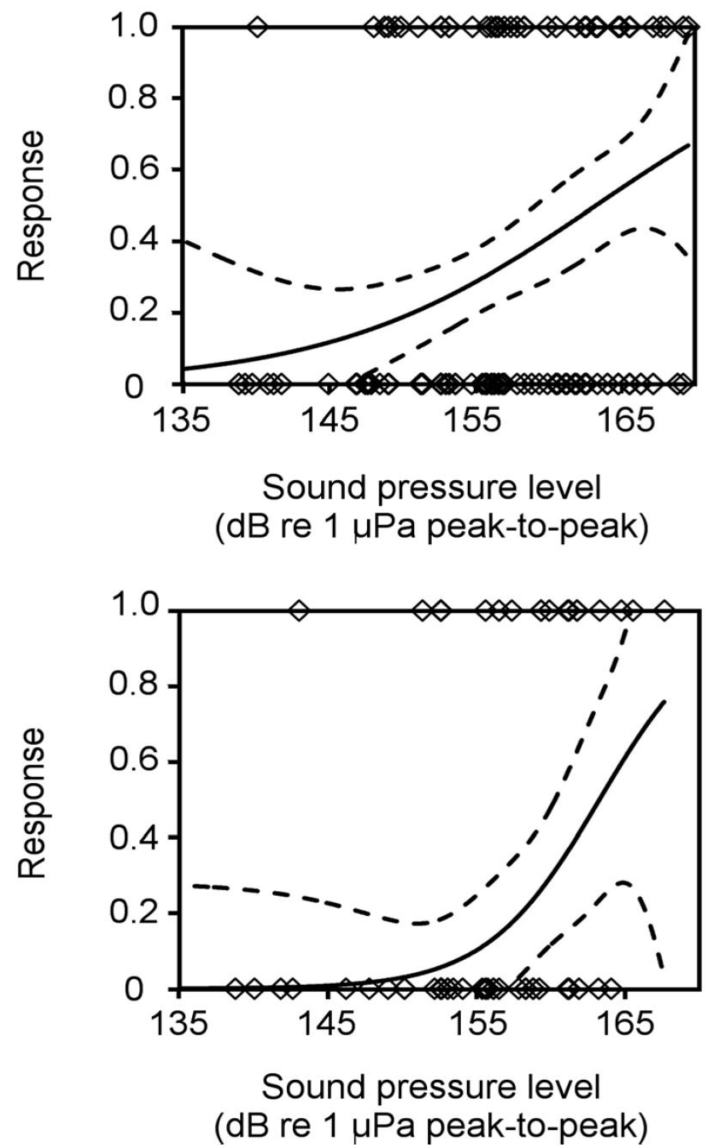
Particle motion sensitivities

Behavioural/physiological tests

- free-ranging animals
- fully characterized sources
- greater species coverage

… dose response

Basic seabed vibrational studies



Hawkins et al. (2014) ***JASA***

Many thanks and any questions…

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