

# **The effects of probiotics on risk and time preferences**

Dantas, A.M., Sack, A.T., Bruggen, E. et al., 2022 (Maastricht University, NL)

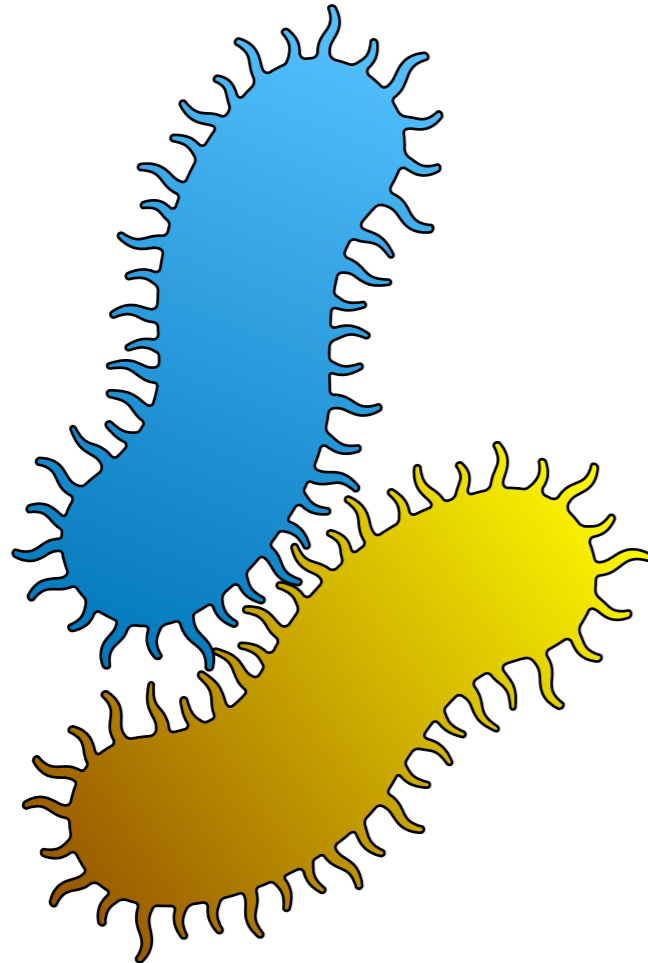
**“You are what you eat.”**

**“An apple a day keeps the doctor away”**

**“GIGO. Garbage In. Garbage out.”**

# Bacteria

## Background





**Bacteria: unicellular micro-organisms that can survive inside or outside a body**

An average male, 30 years old, 1.7m will be composed of ~30 trillion human cells and ~39 trillion bacterial cells

(Sender, Fuchs, Milo; 2016)

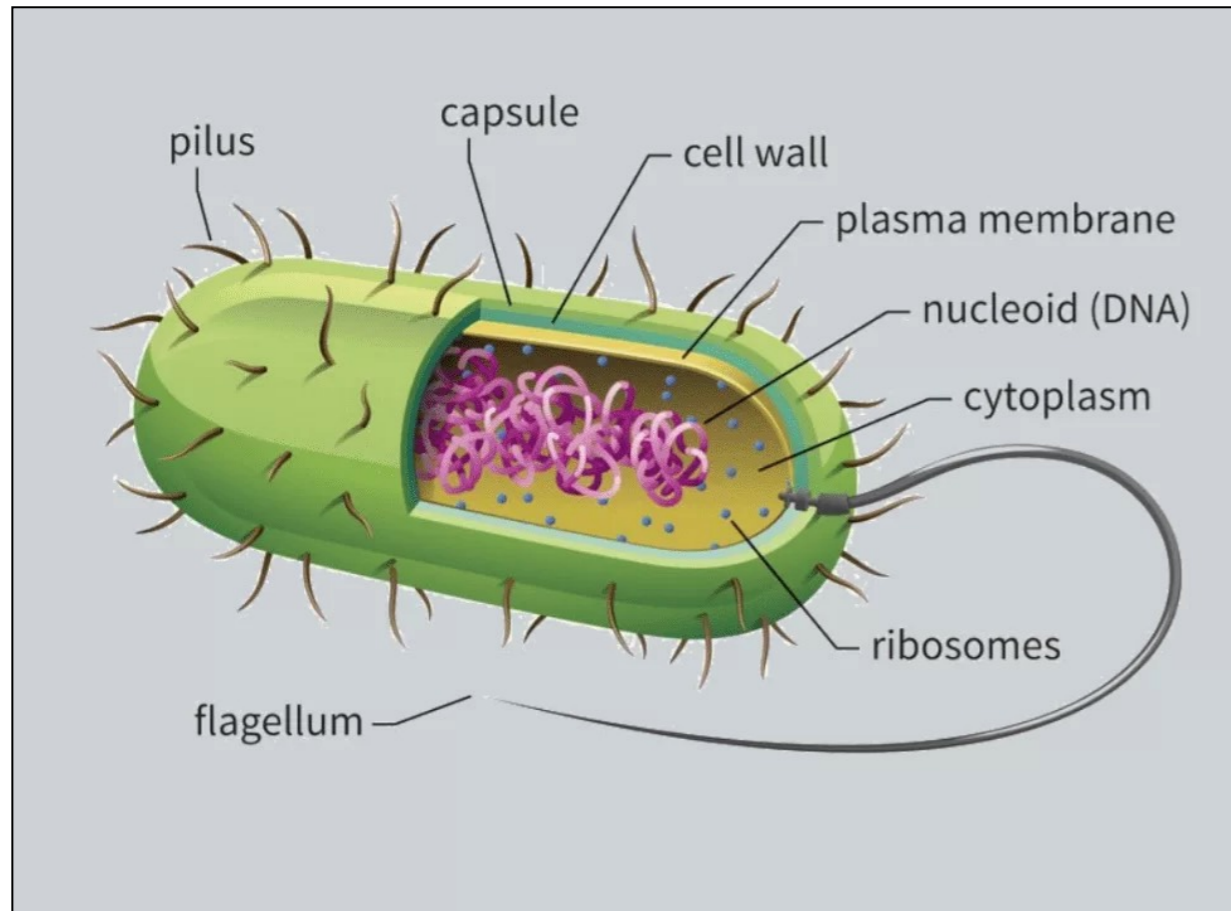
Some can have positive effects on our health, some can have negative effects

	
Digestion (breaking down food + storing the energy)	Infections
Vitamin synthesis	Diseases
Immune System (neutralise pathogens)	Allergies

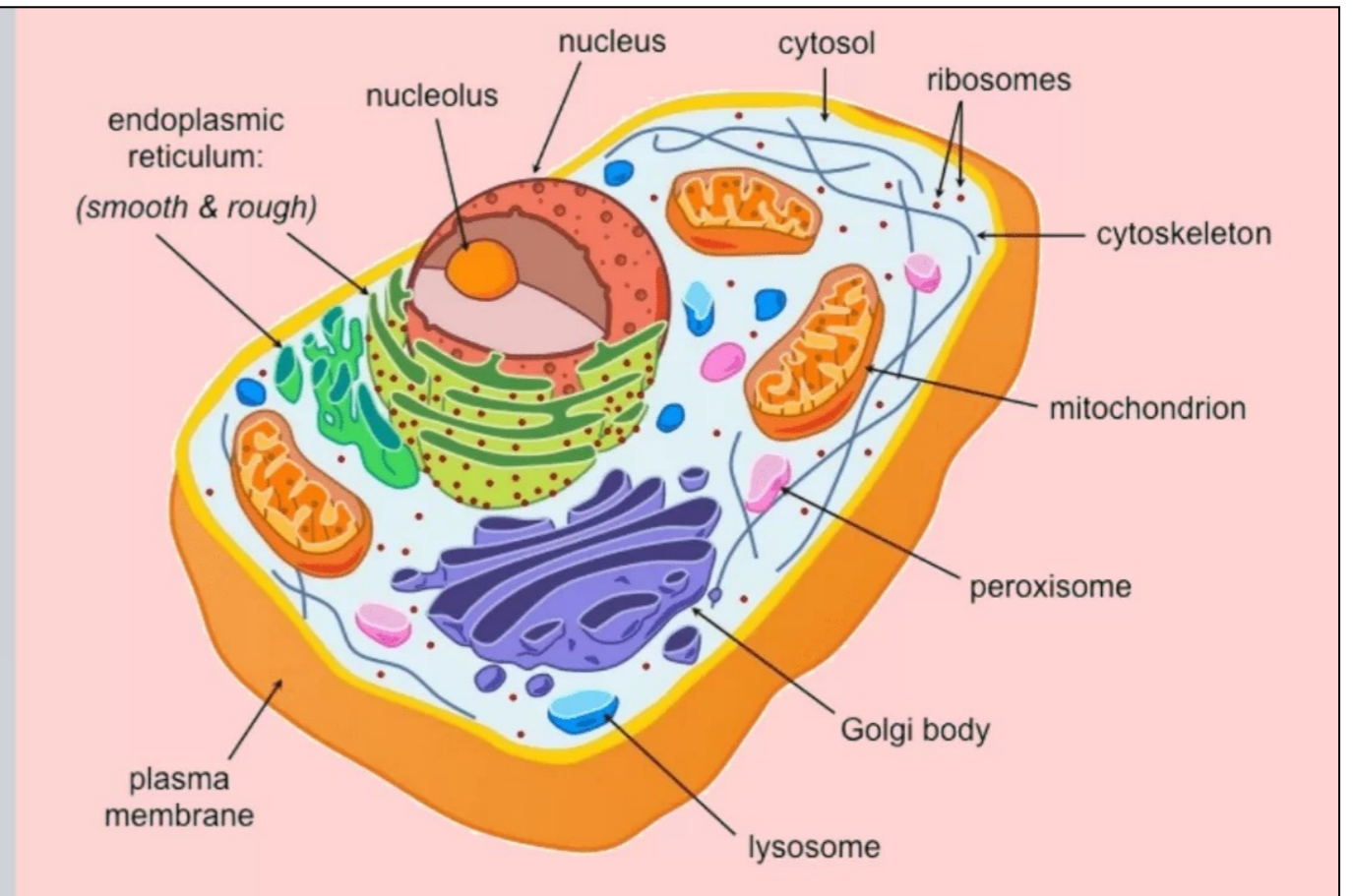
# Bacteria

## Background

Bacteria cell (Prokaryotic)



Human cell (Eukaryotic)



<https://microbiologynote.com>

### Notable differences:

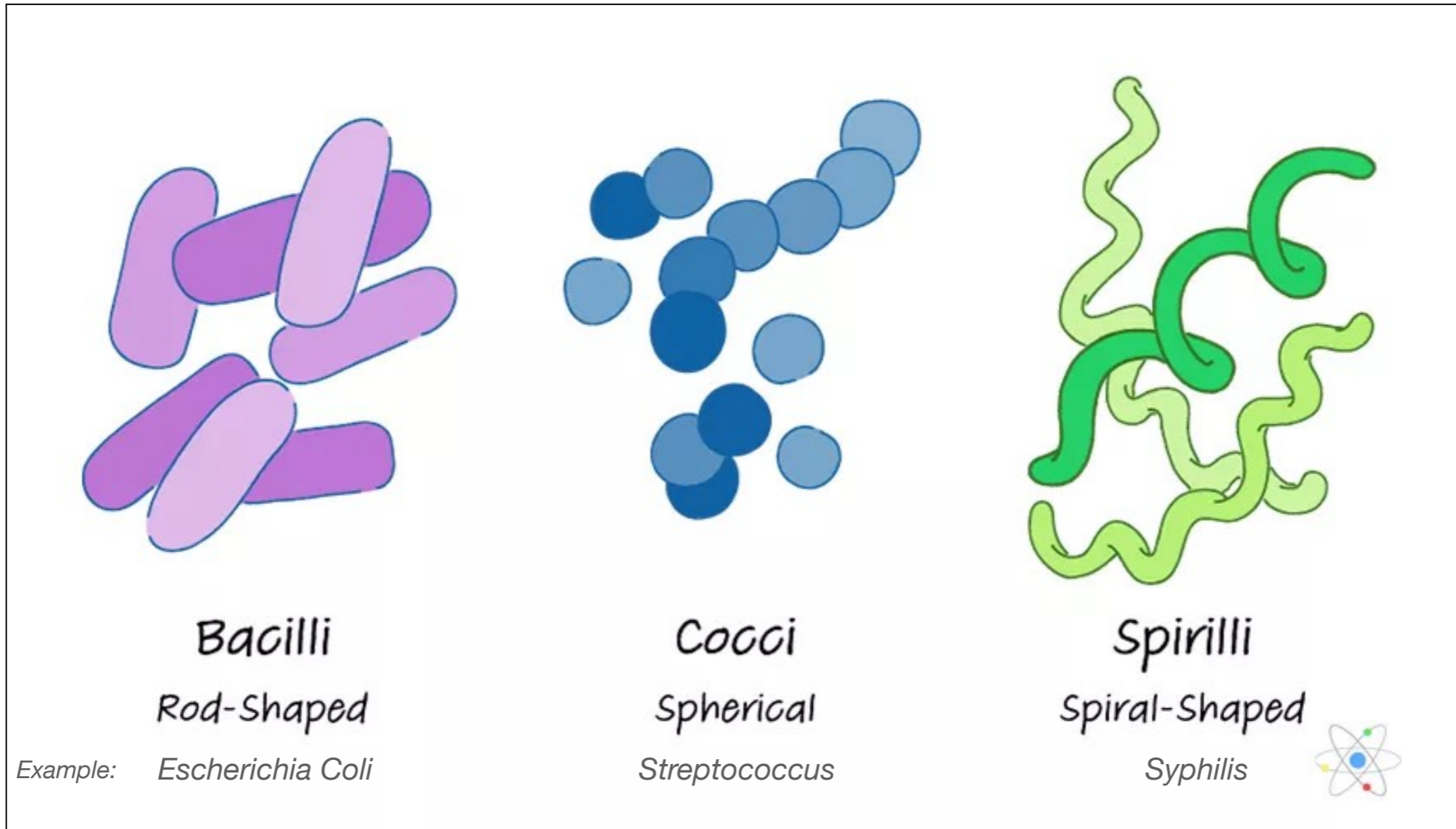
*In Bacteria, DNA is free and circular - not a double-helix form held inside a nucleus (human).*

*Cell division is entirely different (binary fission vs mitosis).*

*Human cells have membrane-bound organelles.*

# Bacteria

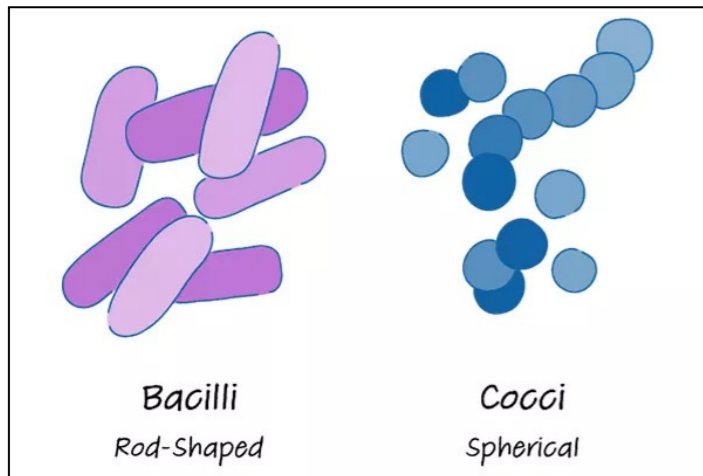
## Types of Bacteria (by shape)



<https://sciencing.com>

# Bacteria

## Sub-types of Bacteria (by cell wall composition)

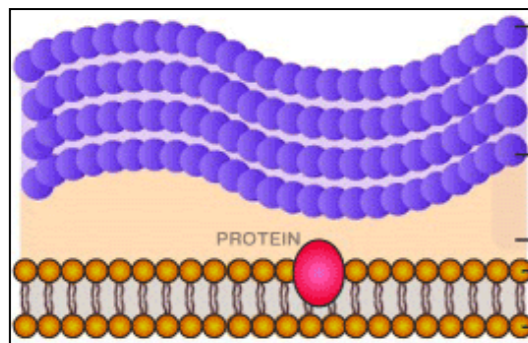


Carrying out a **Gram staining test**, Bacilli and Cocci can be split into groups:

G+ (Gram Positive)

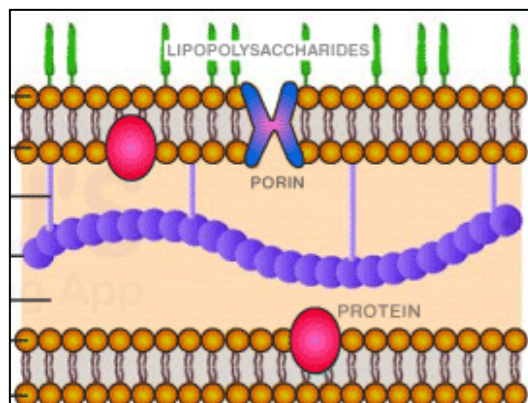
G- (Gram Negative)

4-step process: *Crystal Violet ; Iodine ; Alcohol wash ; Safranin*



G+ bacteria have a thick peptidoglycan outer membrane

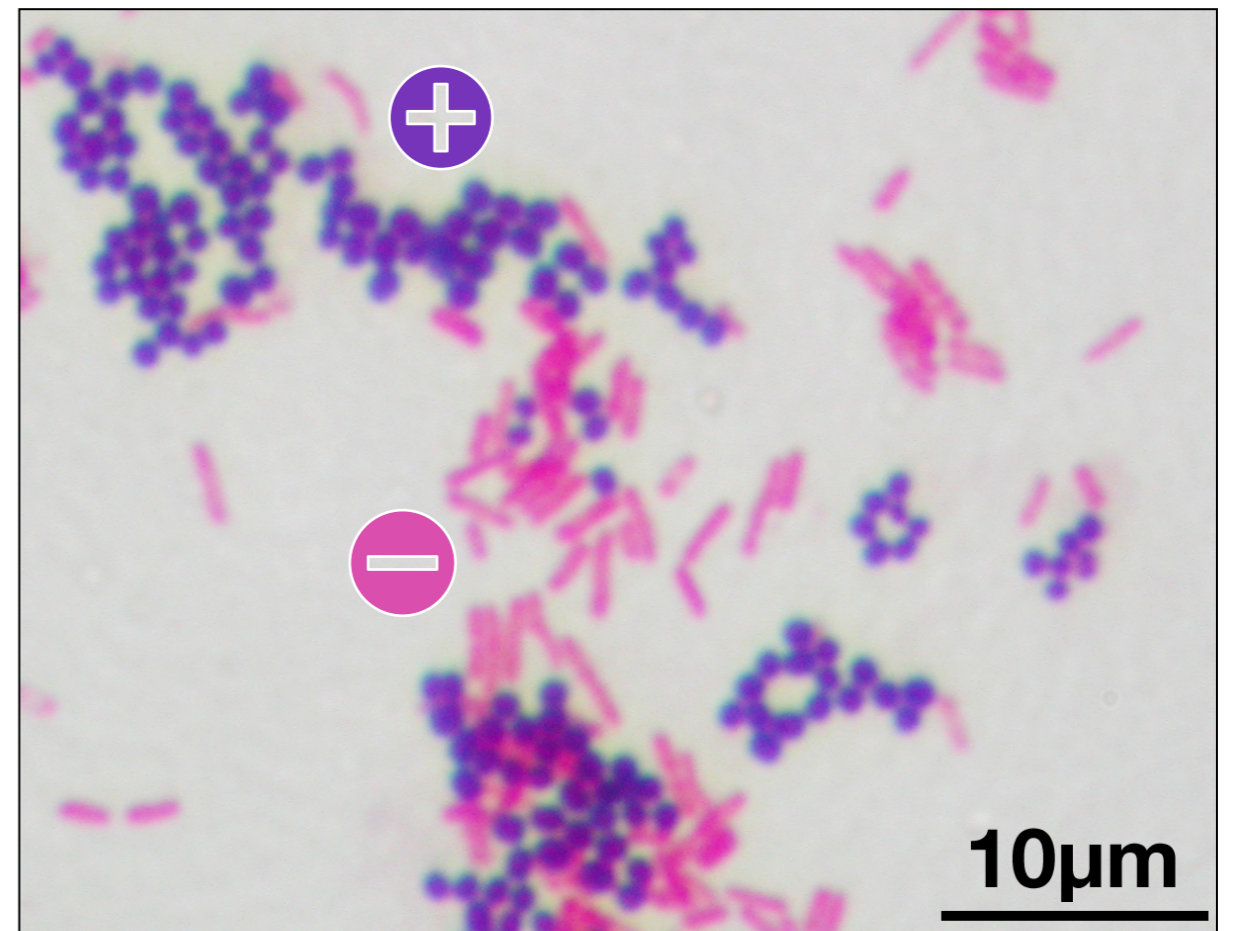
▷ *The stain is retained underneath to give the violet colour*



G- bacteria have a thin peptidoglycan outer membrane

▷ *The stain is mostly washed away*

Byju's ([link](#))



Wikimedia ([link](#))

# Bacteria

## -biotics, microbiota, microbiome

**Prebiotics:** substances that fuel current bacteria growth in the gut

**Probiotics:** live, micro-organisms (bacteria) that complement the current bacteria composition of the gut

**Antibiotics:** medication used to fend off bacterial infections by killing bacteria

**Microbiota:** all micro-organisms living in the gut (bacteria, fungi, viruses)

**Microbiome:** the collective genomes of the microbiota + the habitat in which they live

Proactive

Reactive

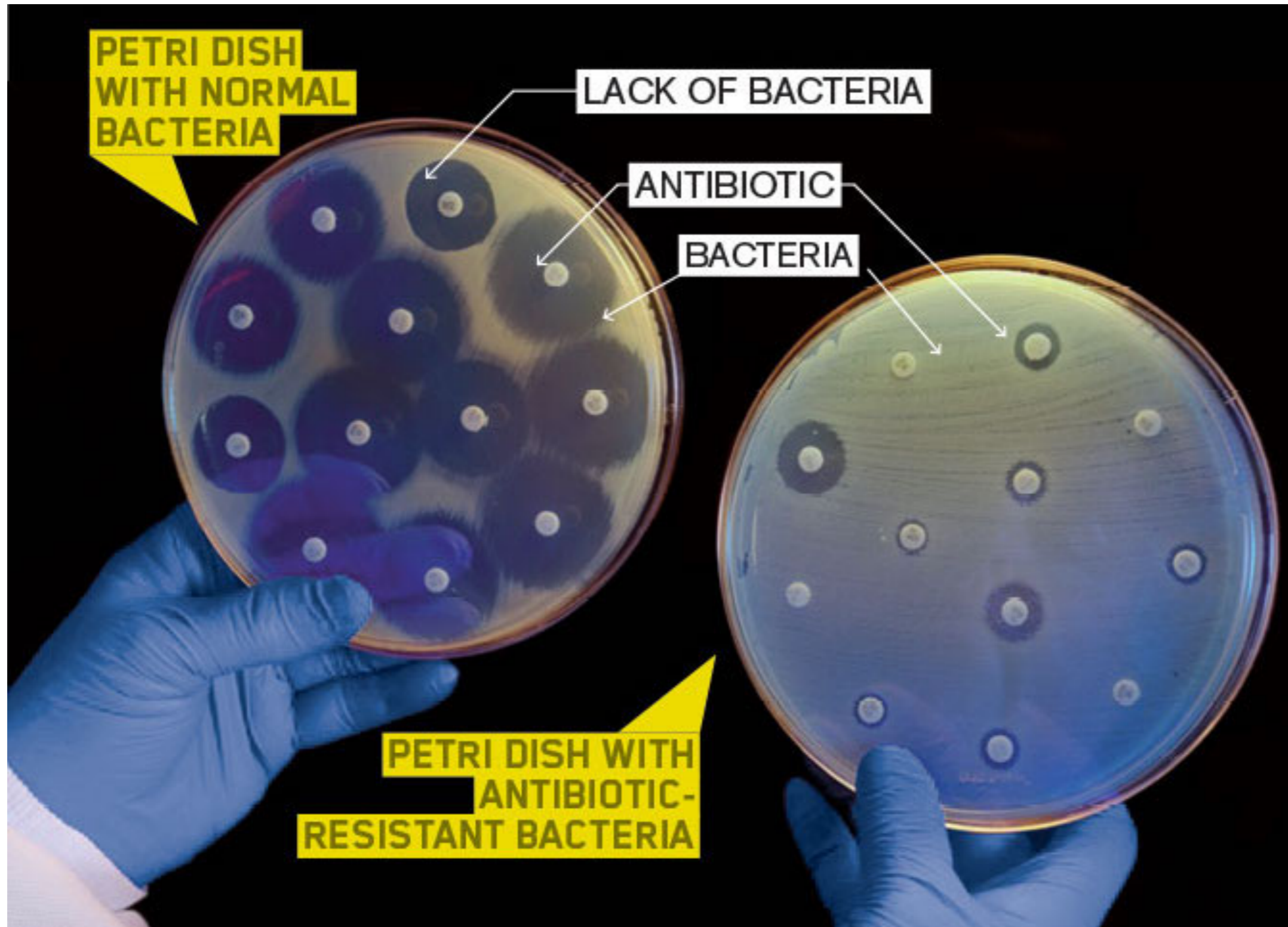
Environment

### Negatives of antibiotics:

- Taking Antibiotics too often can contribute to creating resistant bacteria in the body as bacteria adapt to avoid being sensitive to the antibiotics that cause their death
- All bacteria that are sensitive to the antibiotics will be killed: including both good and bad bacteria

# Bacteria

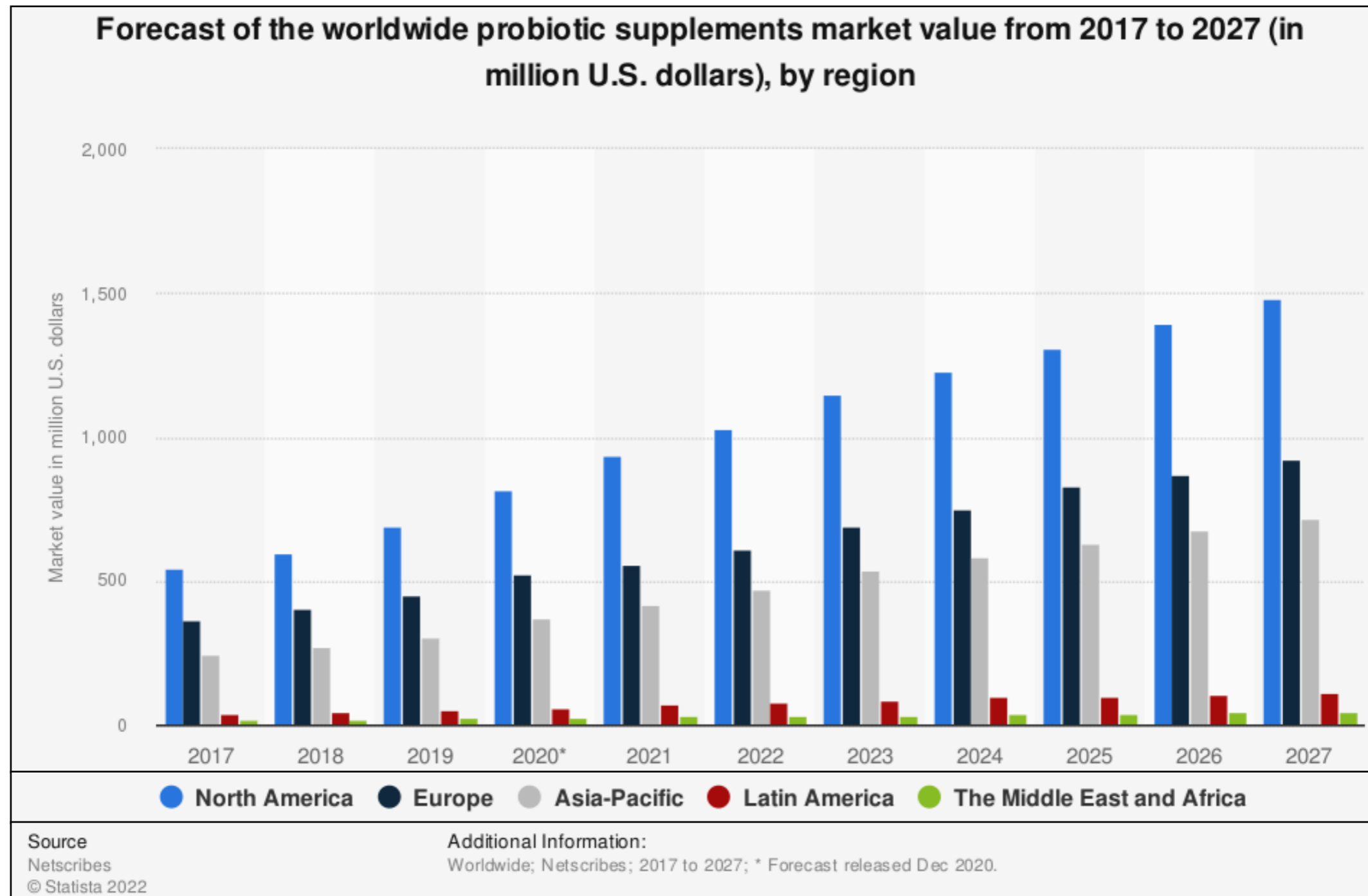
## Resistance



# Bacteria

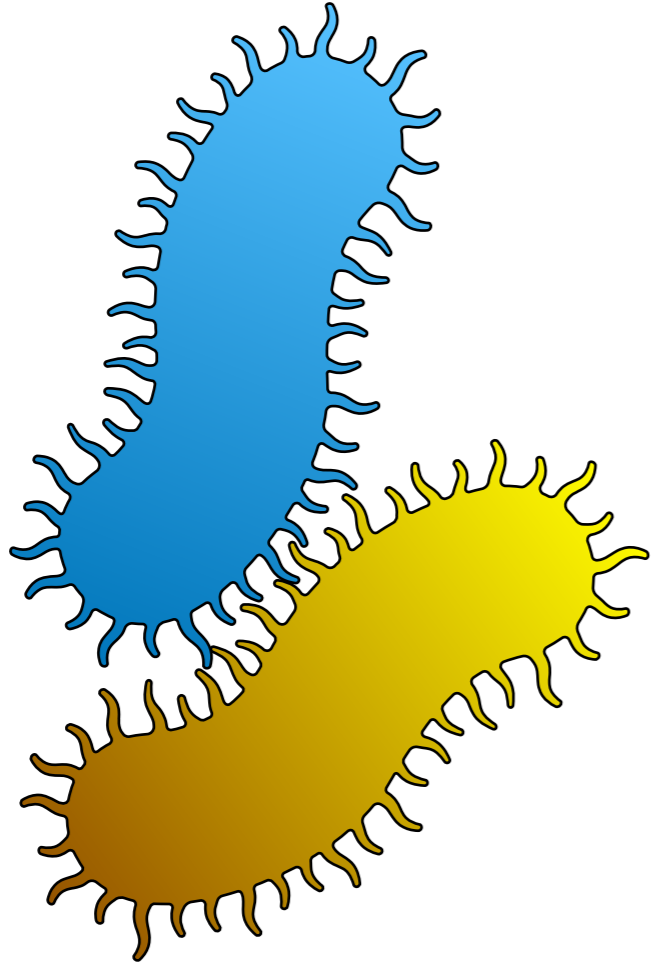
## Probiotics market

*Taking probiotics may contribute to balancing out the negative impact antibiotics have on good bacteria in the microbiota (Valdes et al., 2018)*



# Bacteria

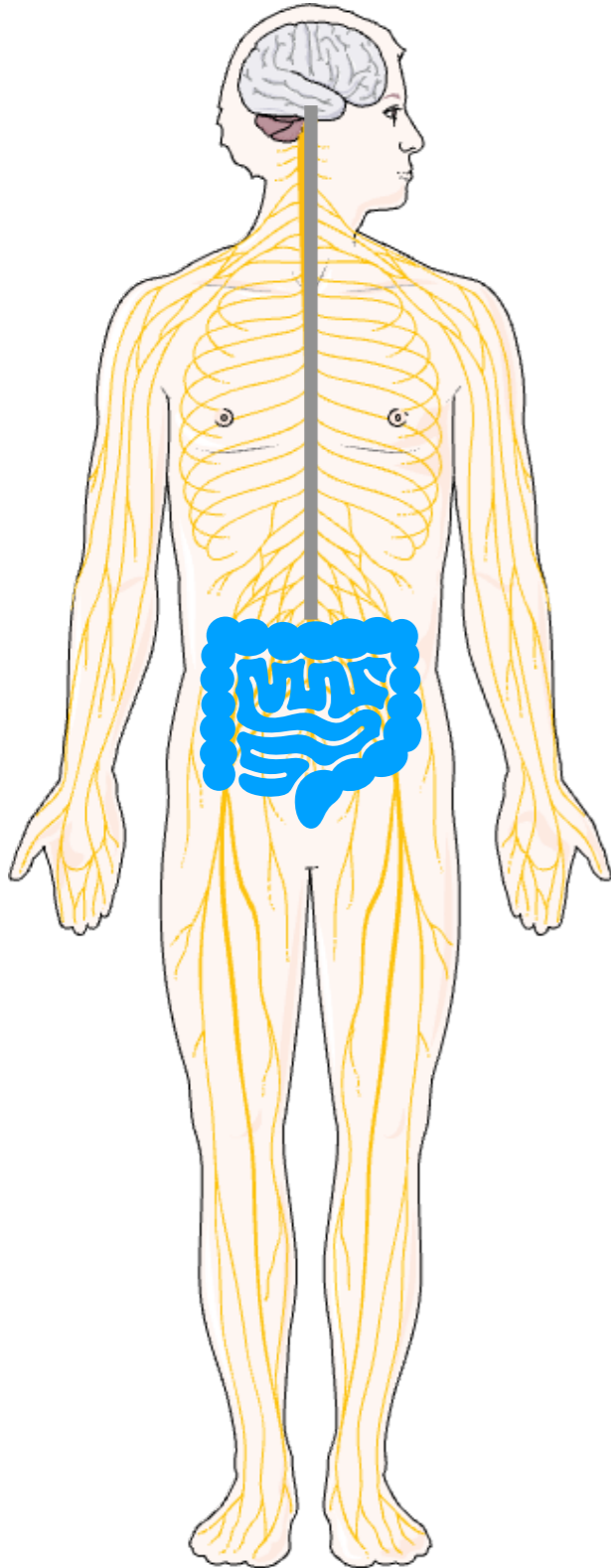
## Identification



Bacteria can be:

- harmful or useful
- identified
- isolated, with precision

# GBA: Gut-brain axis



## Central Nervous System

Brain + spinal cord

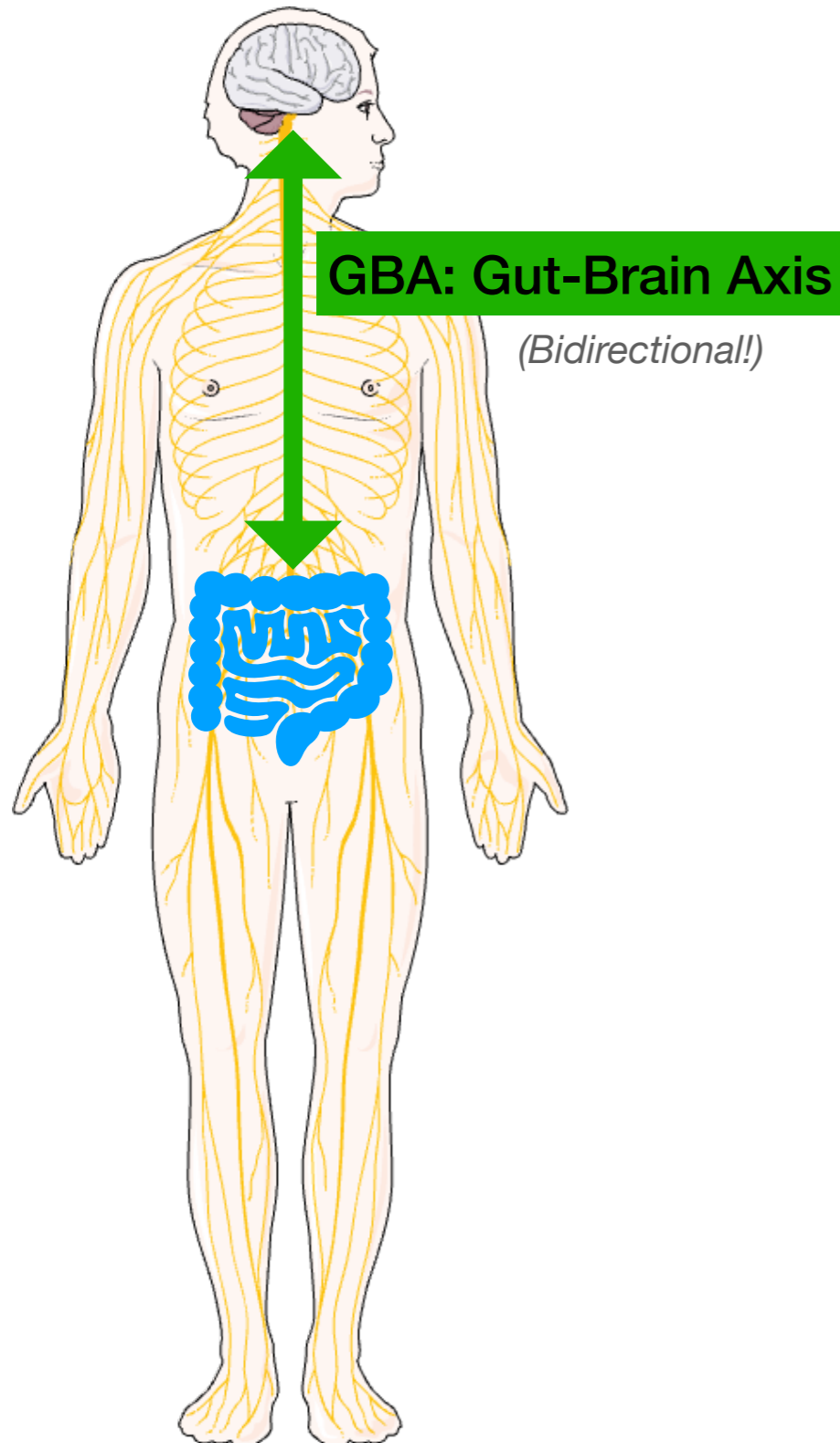
## Peripheral Nervous System

Nerves reaching from spinal cord to body areas

## Enteric Nervous System

Mesh of nerves entirely within the gut

# GBA: Gut-brain axis



## GBA and behaviour

- The microbiome-gut-brain axis: from bowel to behavior (Cryan and O'Mahony, 2011)...

## GBA and neurobiology

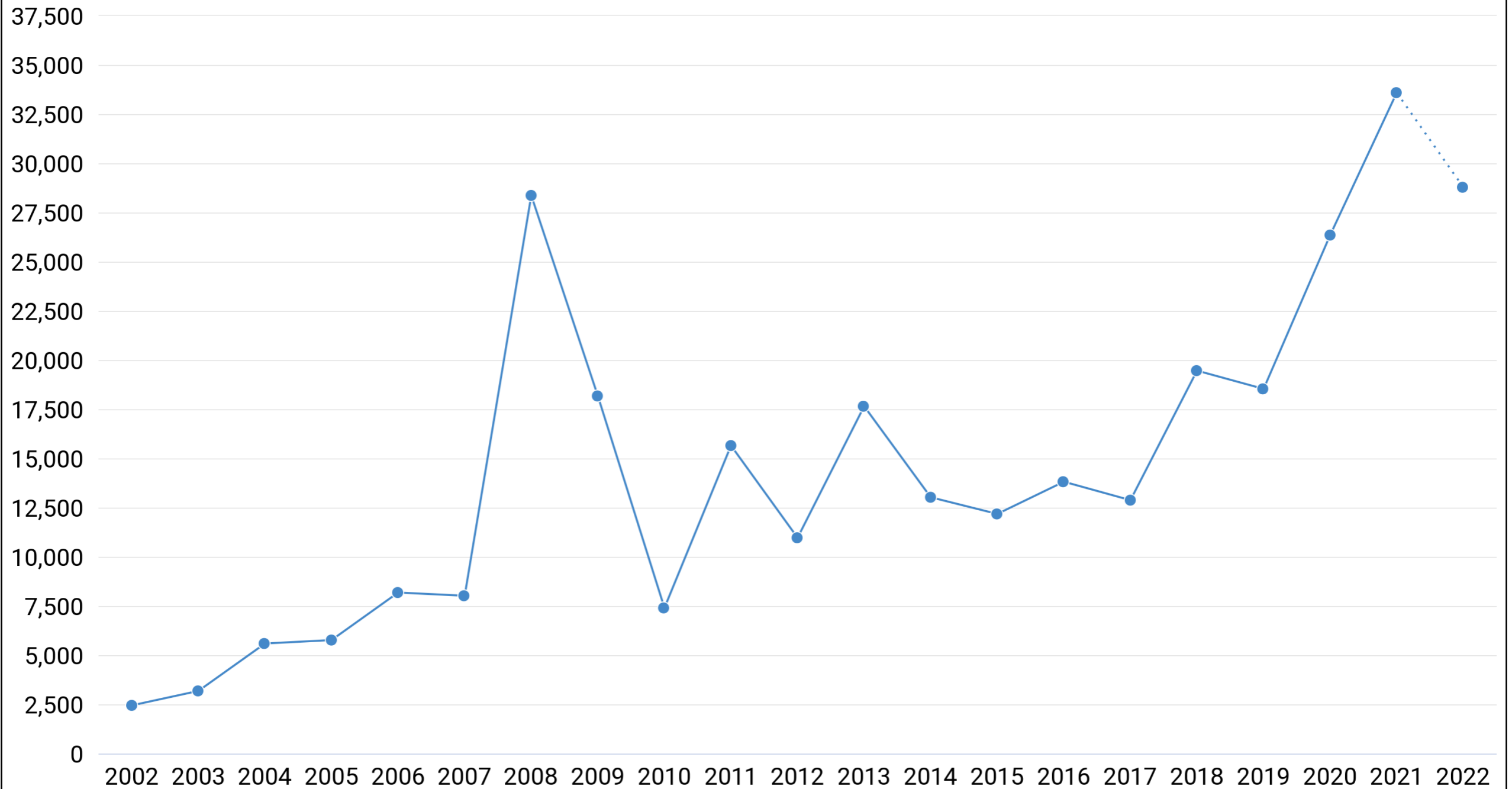
- Effects of probiotics on gut microbiota: mechanisms of intestinal immunomodulation and neuromodulation (Hemarajata and Versalovic, 2013)...

## GBA and pathology

- The microbiome-gut-brain axis in Parkinson disease — from basic research to the clinic (Tan et al., 2022)...
- The Microbiota-Gut-Brain Axis and Alzheimer's Disease: Neuroinflammation Is to Blame? (Megan et al., 2020)...

# GBA: Gut-brain axis

Publications in each year. (Criteria: see below)



● Publications (total)

# **The effects of probiotics on risk and time preferences**

# Demographics and groups

- Recruitment = 72 individuals  
via on-campus posters and social media
- Attrition = 15 (3 breach of protocol, 12 COVID-lockdown-related withdrawals)
- 57 healthy participants
  - *29 Female, 28 Male; split into gender-balanced treatment groups*  
*Average age = 23.4, sd = 4*
  - 29 participants = Probiotics
  - 28 participants = Placebo (Control)

# Experimental Approach

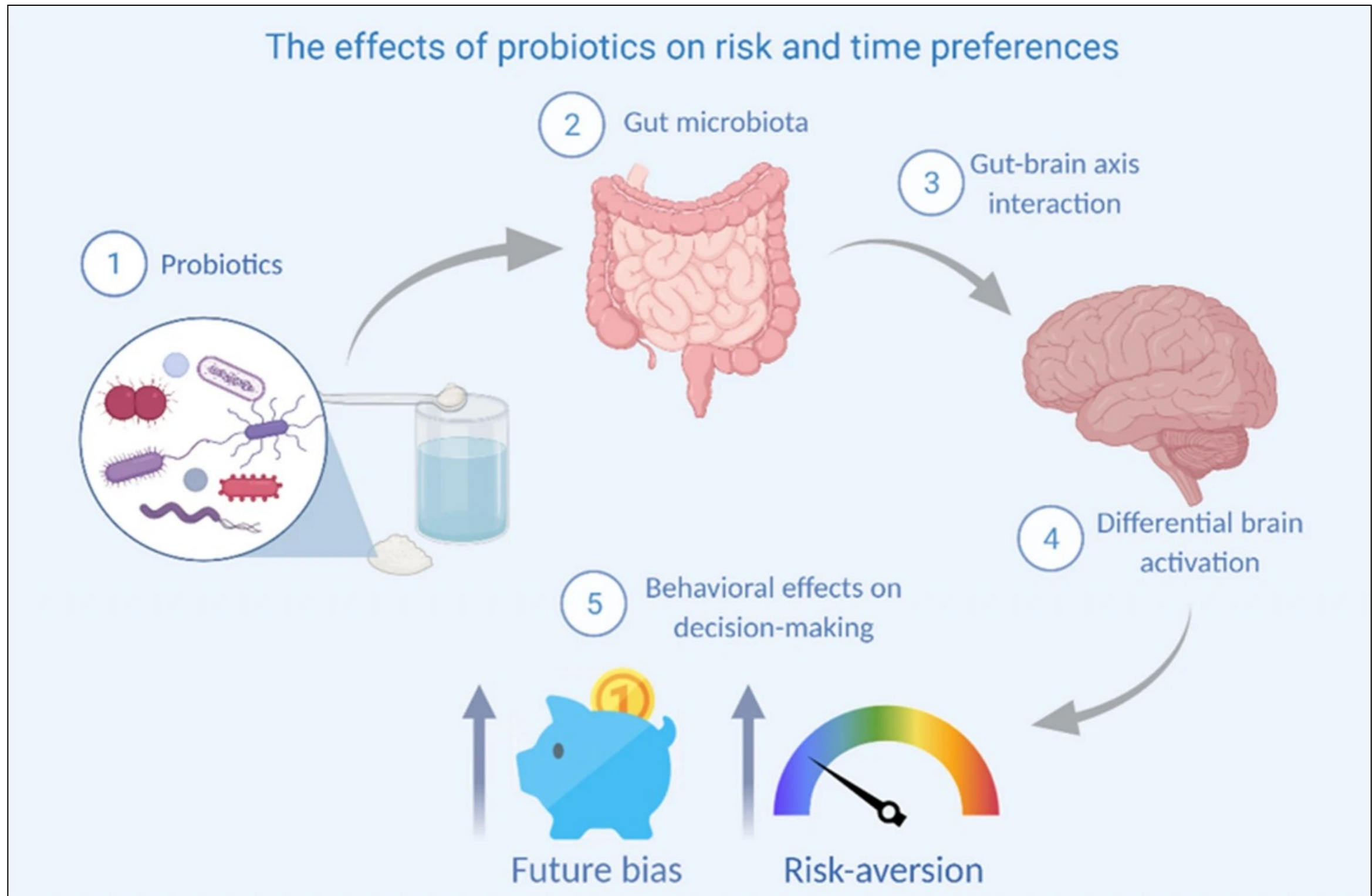


Fig.1 Dantas et al., 2022

# Experimental Approach

- Double-blinded treatments: Placebo or Probiotics
- Two sessions including:
  - One task to measure changes in risk-taking behaviour (MGT)
  - One task to measure changes in intertemporal choices (MCG)
  - Questionnaires to control for:
    - Diet, arousal, self-control, mood effects
    - Risk-taking behaviour and intertemporal choices (GPS)

# Experimental Design

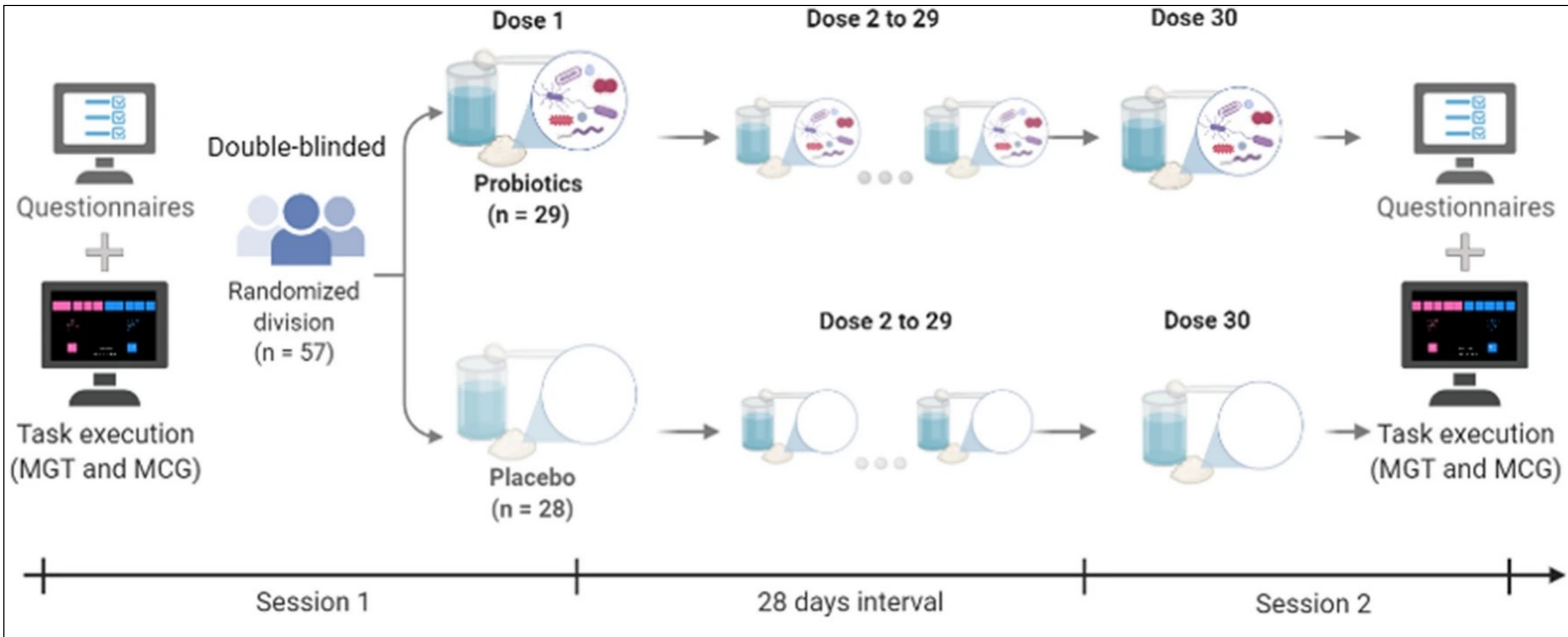


Fig.2 Dantas et al., 2022

*Questionnaires to check for:*

1. Mood, diet, arousal, self-control (Sessions 1 and 2)
2. Time and risk preferences (Session 1 only)

# Experimental Design

## Treatment



Placebo

Bacteria-free

Based on corn starch

Identical to probiotic in taste and look

30 days



Probiotics

*Bifidobacterium bifidum W23*

*Bifidobacterium lactis W52*

*Lactobacillus acidophilus W37*

*Lactobacillus brevis W63*

*Lactobacillus casei W56*

*Lactobacillus salivarius W24*

*Lactococcus lactis (W19 and W58)*

*Individually wrapped daily doses (2g)*

*Manufactured by Winlove Probiotics (NL)*

*Daily, automated email reminders to take pills*

# Experimental Design

## MGT: Maastricht Gambling Task

- Number of pink boxes is randomised 1-5 (rest = blue)
- “Guess the colour of the box that hides the yellow token”
- Gains or zero outcome. No negative outcome controls for loss aversion. Independent trials controls for memory.
- Bet values randomly selected from: 5, 25, 50, 75, 100
- 250 trials (rounds unknown)

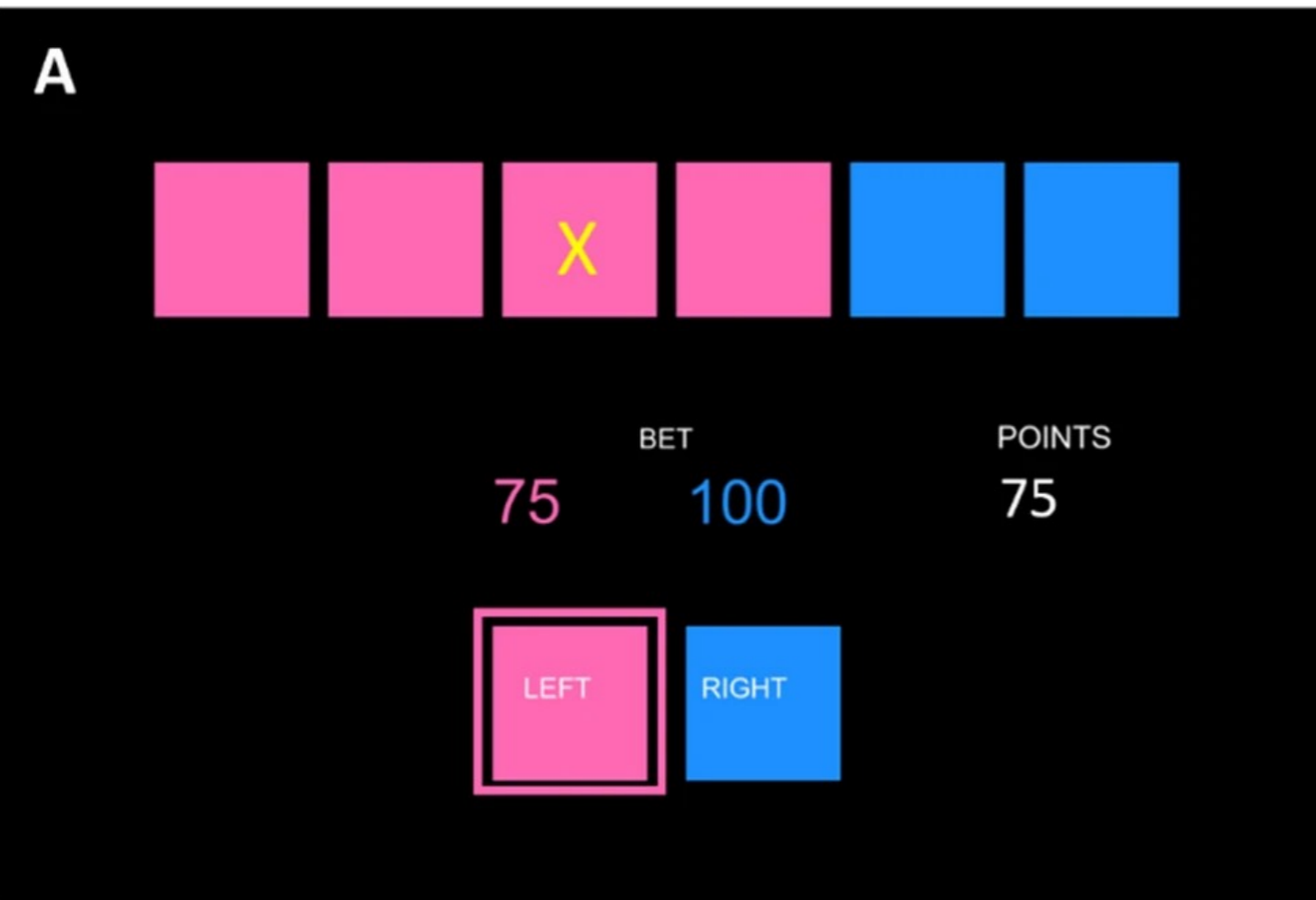


Fig.3 Dantas et al., 2022

# Experimental Design

## MCG: Maastricht Choice Game



- Endowment/trial = 100 tokens  
One box = 10 tokens
- Sooner reward vs. Later reward; with sooner reward always receiving a discount rate of [0.50;0.99] in 0.025 increments
- 120 combinations of discount rates and dates; each combo displayed twice = 240 trials
- Five blocks of 48 trials

Fig.3 Dantas et al., 2022

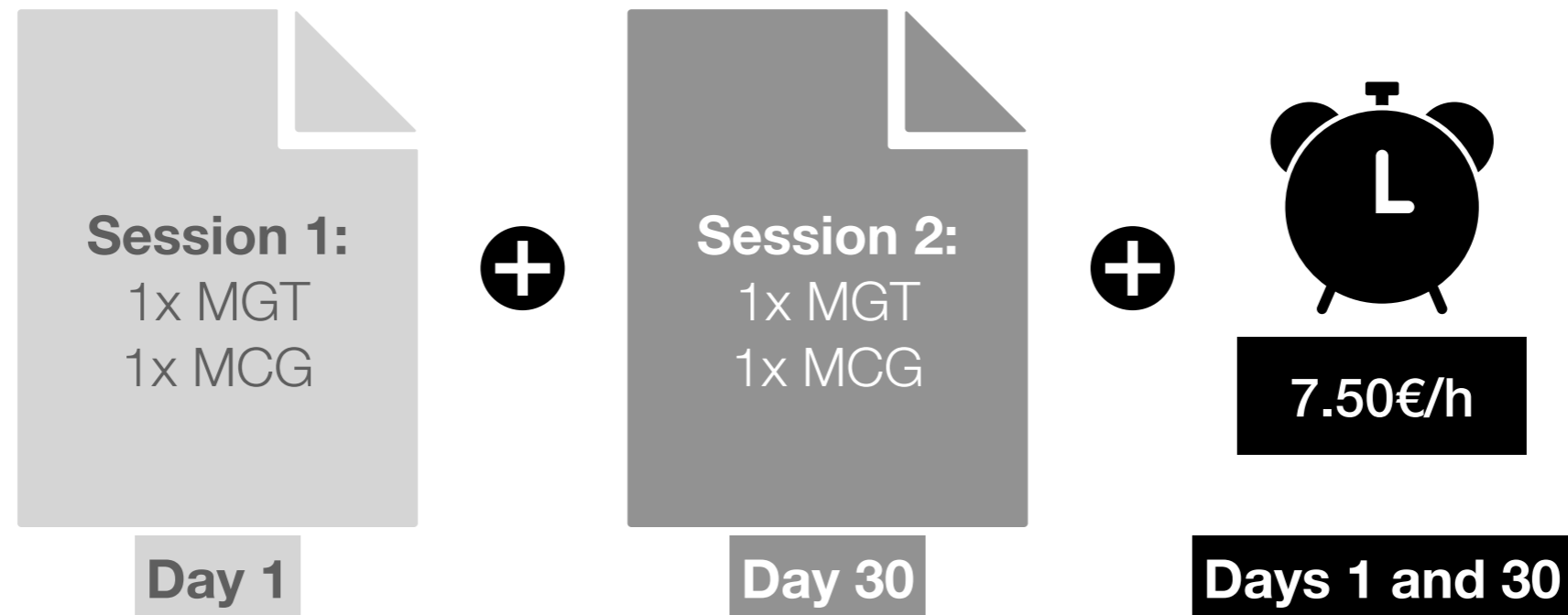
### Sooner options

$t$  in 0 days  
in 35 days

### Later options

in  $t + 35$  days  
 $k$  in  $t + 72$  days  
in  $t + 90$  days

# Incentive structure



- Payout of MGT and Hourly rate, for both sessions, via vouchers of equivalent monetary value after Session 2
- Payout of MCG at each unique, specified date of the in-game gamble via bank transfer in euros

# Results

## Questionnaires

- Mood, diet, arousal, self-control were controlled for via questionnaires
- No significant effects were observed:
  - Mood  $p = 0.17$
  - Diet  $p = 0.48$
  - Arousal  $p = 0.72$
  - Self-control  $p = 0.49$
- Risk and time preferences from questionnaires were correlated with corresponding experimentation results


# Results

## Risk-taking (MGT)

Restricted Maximum Likelihood, 2 models:

$formula_1 = risk \sim group + time + group \times time$

$formula_2 = risk \sim group + time + \text{payment} + group \times time$



Avoid house-money effect of the payments made in between the two sessions for the participants that did receive a payment

# Results

## Risk-taking (MGT)

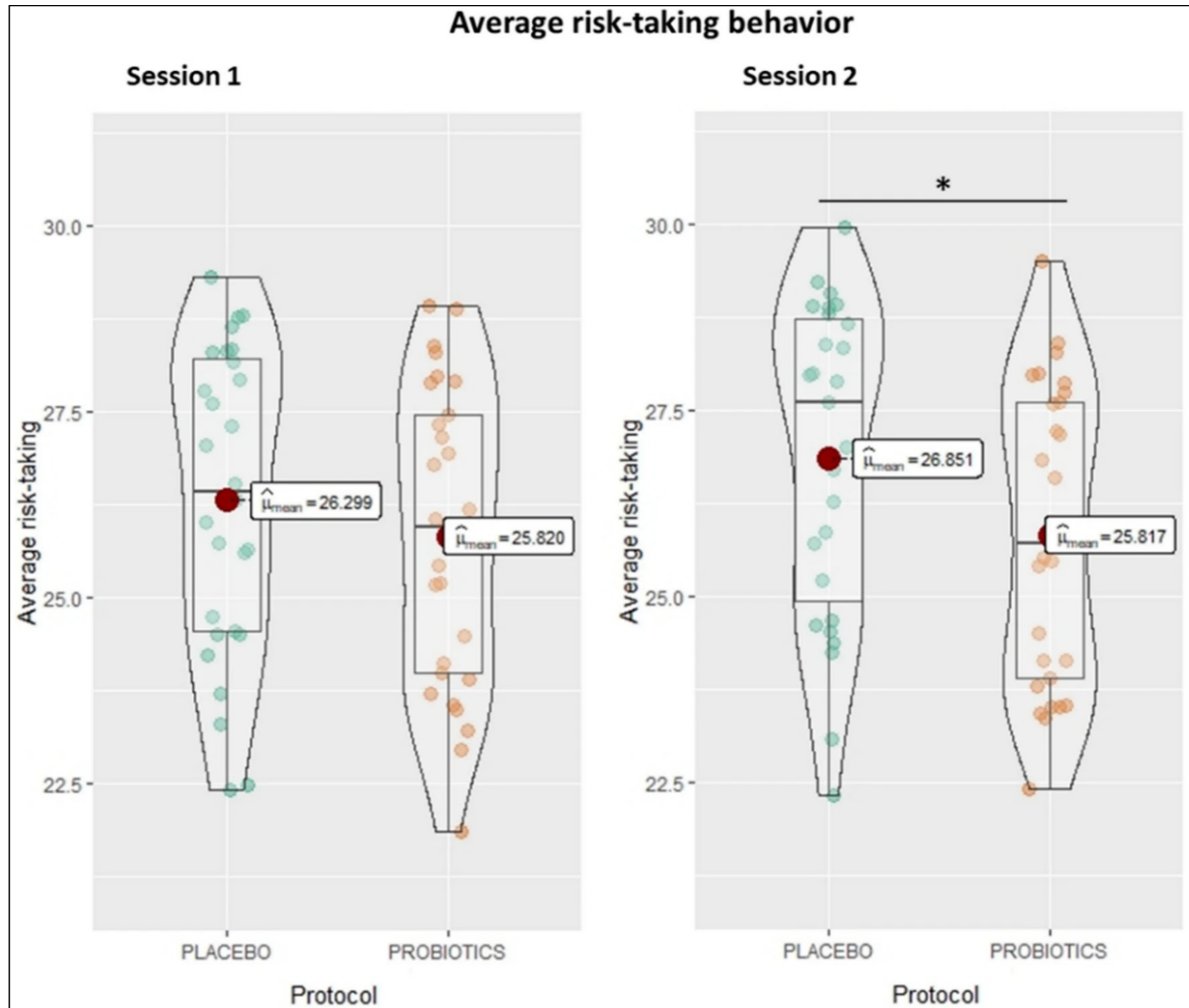


Fig.4 Dantas et al., 2022

# Results

## Intertemporal Choice (MCG)

Model used to evaluate time preferences:

$$Max_{x_t} U(x_t) = x_t^\alpha + \beta \delta^k (x_{t+k})^\alpha$$

$\alpha$  risk attitude

$\beta$  present-bias

$\delta$  time discounting

$t$  duration for sooner reward

$k$  duration for later reward

$\beta < 1$  Present biased

$\beta > 1$  Future biased

# Results

## Intertemporal Choice (MCG)

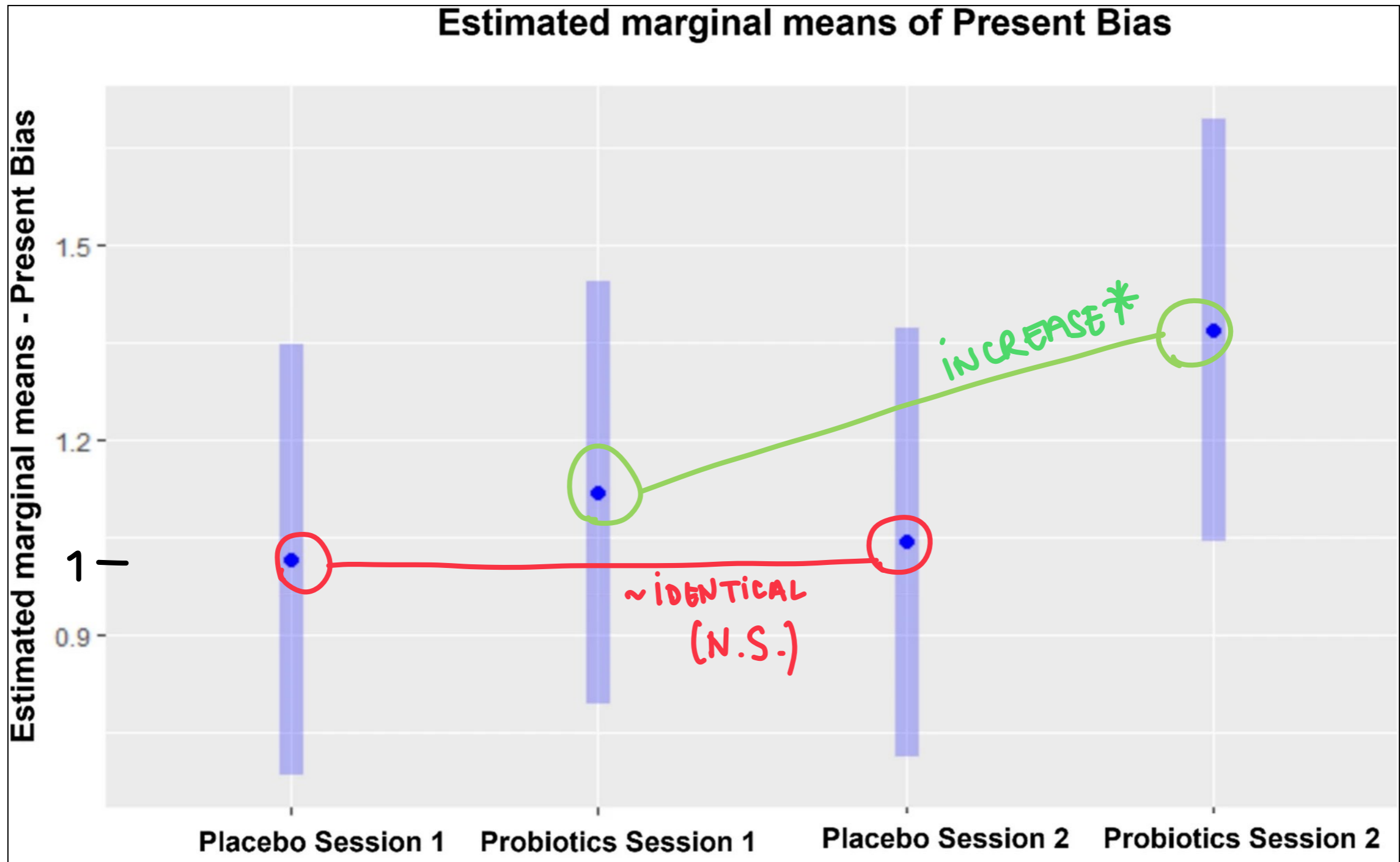



Fig.5 Dantas et al., 2022

# Discussion

- Reproducibility? (Open Data, Open Code )
- Stool samples to see how long the probiotics would last in the gut (*Prilassnig et al., 2007, suggests that probiotic-supplemented bacteria should be found in stools of most participants*)
- Neuroimaging mentioned in the paper but not used, only referenced to support their reasoning regarding functional connectivity and probiotics benefits  
*“Bifidobacterium concentration is positively correlated with the increasing connectivity of the frontal nodes of the default mode network, while the prevalence of Prevotella\_9 and Bacteroides is negatively correlated” (Kohn et al., 2020)*

# Conclusion

- Participants in the probiotics protocol were **significantly less likely to choose risky options** as compared to participants in the placebo group in Session 2, indicating a significant decrease in risk-taking behaviour.
- After the prolonged use of probiotics, these same participants were **significantly more likely to make future-oriented choices,** investing more in delayed options than participants who received a placebo for the same period

# Thank you.

Dantas, A. M., Sack, A. T., Bruggen, E., Jiao, P., & Schuhmann, T. (2022). The effects of probiotics on risk and time preferences. *Scientific Reports*, 12(1). <https://doi.org/10.1038/s41598-022-16251-x>