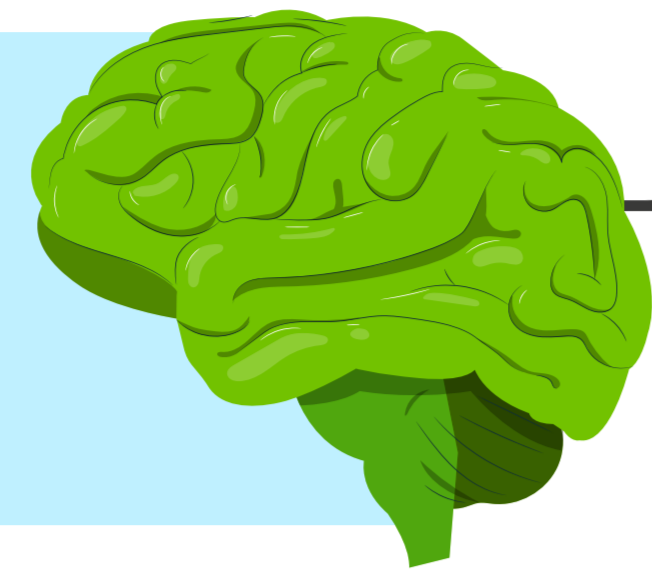


**Butterflies in your stomach and nerve cramps before a job interview suggest that your brain and gut are connected!**

## Evolution of the microbiota-gut-brain axis



### 19th & 20th centuries

Pioneering work from Claude Bernard, Ivan Pavlov, William Beaumont, William James, Carl Lange, Charles Darwin and Walter Cannon recognized the **reciprocal impact of the gut on brain function**<sup>1</sup>.

### 1998

The pediatric neuropsychiatrist Susan Swedo describes a **link between streptococcal infections and psychiatric disorders in children**<sup>2</sup>.

### 2000s

The **microbiota emerges as a new player** in the gut-brain axis, which has led to the term 'microbiota-gut-brain axis'<sup>3</sup>, which can impact both your mental and physical health.

Some disorders where the microbiota-gut-brain connection is altered include<sup>13</sup>:

- Irritable bowel syndrome
- Depression
- Anxiety

### 2013

John Cryan and Ted Dinan defined **psychobiotics** as live microorganisms, specifically bacteria, which, when ingested in adequate amounts, confer a mental health benefit by producing positive changes in the gut-brain axis<sup>4</sup>.

### 2015

Scientists coined the term '**Nutritional Psychiatry**', a field of study that considers the role of diet in mental and brain health<sup>5</sup>.

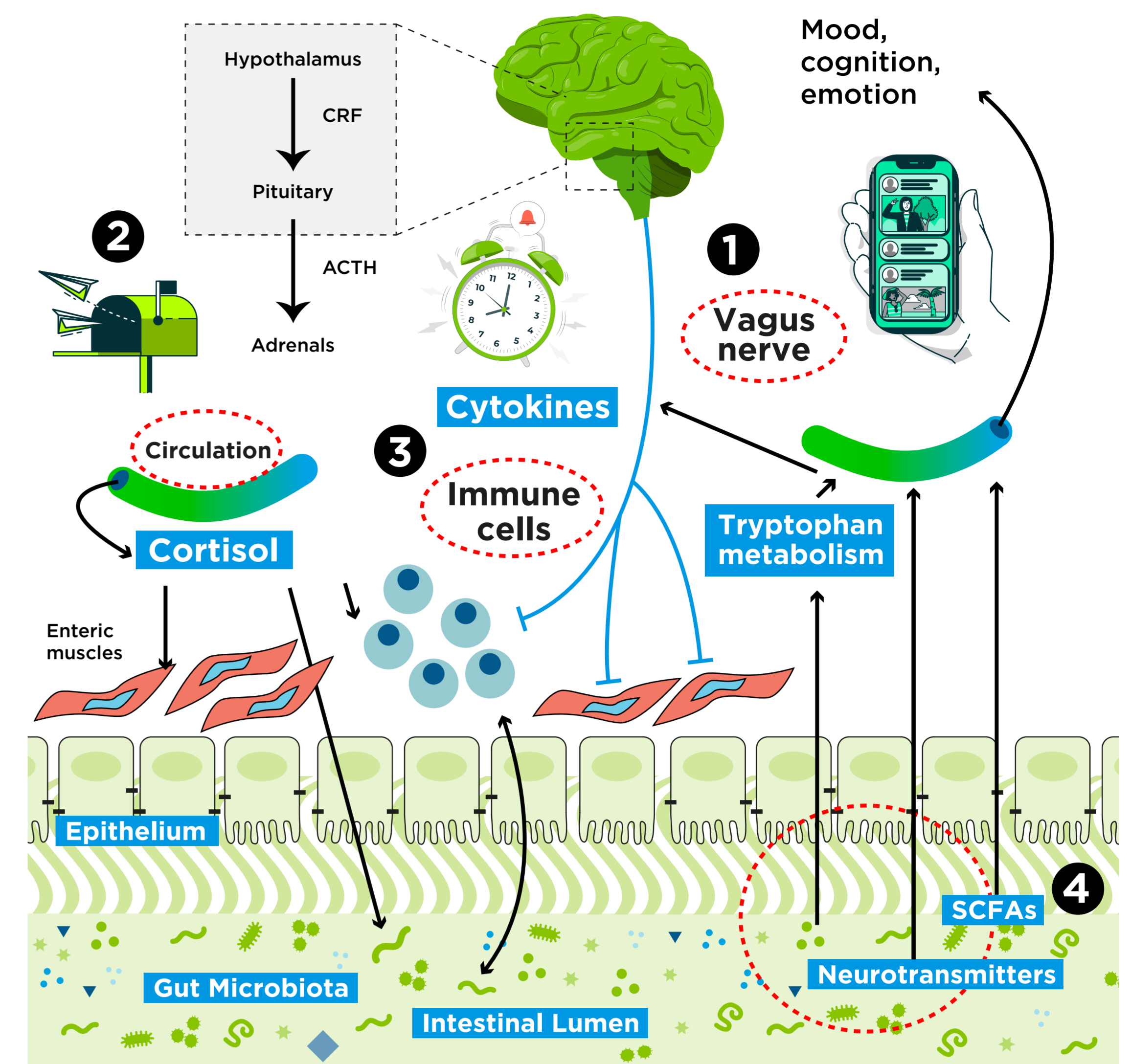
### 2016

The definition of psychobiotic broadens to describe any **exogenous intervention that leads to a bacterially mediated impact on the brain**, including prebiotics, synbiotics, postbiotics, fecal microbiota transplants and some food staples<sup>6</sup>.

## How do the gut and the brain 'talk' to each other?

The gut microbiome can influence the gut-brain axis in many ways<sup>3,7</sup>:

- 1. Neural pathways:** involve the vagus and enteric nervous system and **act like your mobile phone, allowing quick and direct communication** between the gut and the brain.
- 2. Endocrine pathways:** include hormones (e.g., cortisol) and **act like postal mail, allowing a slower communication** between the gut and the brain.
- 3. Immune pathways:** include substances made by immune cells (cytokines) and **act like an alarm signal**.
- 4. Microbial metabolites:** our gut microbes produce many metabolites that are anti-inflammatory (e.g. butyrate) or have a beneficial influence on mental health (e.g. serotonin).



Ref: This image was adapted from the scientific paper: Cryan JF, Dinan TG. 'Mind-altering microorganisms: the impact of the gut microbiota on brain and behaviour.' *Nat Rev Neurosci*. 2012; 13(10):701-12. doi: 10.1038/nrn3346.

## Good food, good mood?

**Nutritional psychiatry is an emerging field of study that considers the role of diet in mental and brain health<sup>8</sup>.**

Considering the role of the gut microbiota in mediating the beneficial effects of diet on the brain, Irish scientists introduced the term "psychobiotic" to describe any external factor that, through bacteria, has a positive impact on mental health<sup>4,6</sup>.

### Potential psychobiotic interventions include:



#### Psychobiotic diet

- ✓ A diet enriched with fiber and fermented foods promoting good bacteria in the gut has beneficial effects on decreasing perceived stress levels in healthy volunteers after just one month<sup>9</sup> and improving depressive mood in adults with obesity<sup>10</sup>.



#### Mediterranean diet

- ✓ A diet rich in vegetables, fruit, whole grains, legumes, nuts and seeds, olive oil, and fish, and with small quantities of red meat and processed foods, would help alleviate depression and provide additional benefits to medication<sup>11</sup> and may improve both gut and psychological symptoms in people with IBS<sup>12,13</sup>.



#### Prebiotics:

- ✓ Supplementation with agalactooligosaccharide prebiotic may reduce stress and anxiety levels in healthy volunteers<sup>17,18</sup>.
- ✓ Polydextrose fiber may improve cognitive flexibility and sustained attention in healthy individuals<sup>19</sup>.
- ✓ Two months supplementation with galactooligosaccharide prebiotic reduced anxiety in people with IBS<sup>20</sup>.



#### Probiotics

- ✓ *Bifidobacterium longum* 1714 is associated with reduced stress and improved memory in healthy individuals<sup>21,22</sup>.
- ✓ *Lactobacillus plantarum* PS128 may reduce perceived stress, anxiety and depression in highly stressed people<sup>23</sup>.
- ✓ *L. helveticus* and *B. longum* may decrease depression severity in patients with major depressive disorder<sup>24</sup>.



#### Other diets

- ✓ The Dietary Approaches to Stop Hypertension (DASH) diet, Norwegian diet, and Japanese diet have been linked to reduced link of common mental diseases and improved cognitive performance<sup>14-16</sup>.



#### Synbiotics

- ✓ Some synbiotics may improve anxiety<sup>25</sup> and mild-to-moderate depression<sup>26</sup>.



#### Postbiotics & microbial metabolites

- ✓ Heat-inactivated microbes have shown some benefits in reducing anxiety as well as improving sleep disturbance in chronically stressed student<sup>30</sup>.
- Human data does not yet support the supplementation of microbial metabolites such as butyrate for improving stress<sup>31</sup>.



#### Fermented foods

- ✓ Small studies have shown the potential benefits of fermented milk drinks in reducing physical symptoms of stress<sup>27</sup> and impact immune cells<sup>28</sup> in students under examination stress and alter brain activity<sup>29</sup>.

## Non-dietary alternatives for improving gut and brain health

**Lifestyle changes and psychological therapies are worth considering for reducing gut symptoms and lessening the psychological sequelae of IBS and IBD<sup>32</sup>:**

### WHICH?

- **Psychological therapies** (cognitive behavioural therapy and gut-directed hypnotherapy).
- **Stress management** (mindfulness-based therapies, yoga).
- **Sleep and rest.**
- **Regular light-to-moderate exercise.**
- **Exposure to nature.**

### WHEN?

- When dietary approaches are difficult to implement.
- As an adjunctive approach.



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