



# Machine Learning & Microbiome for Precision Nutrition

Enrique Carrillo de Santa Pau

Head Computational Biology Group

 @esantapau

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MICROBIOME

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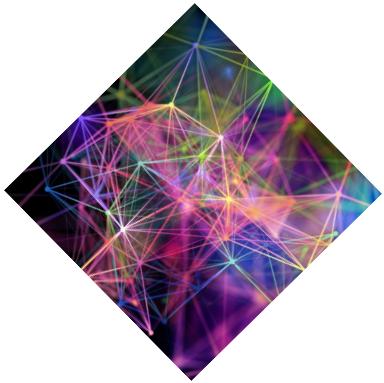
@ImdeaAlimenta





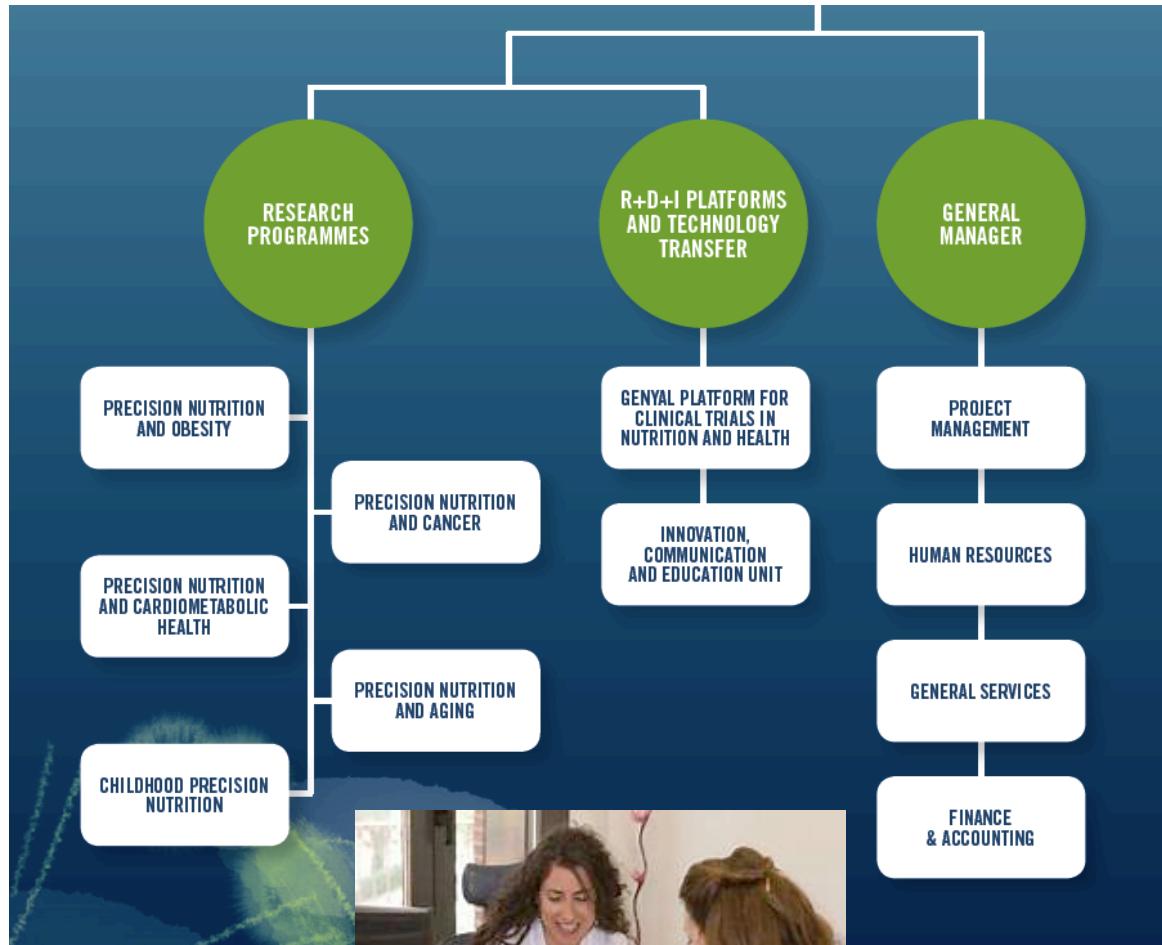
**RESEARCH**

**INNOVATION**

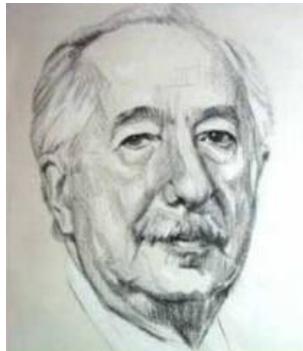


**EDUCATION**

**COMMUNICATION**

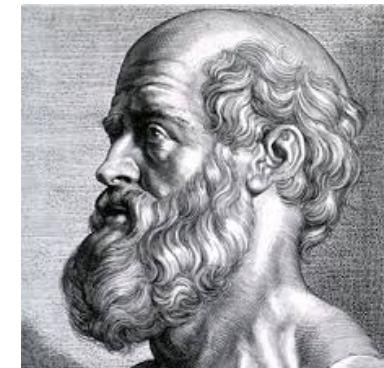


# Food for Health and Medicine



«The man first wanted to eat to survive, then he wanted to eat well and incorporated gastronomy into his cultural world. He now, in addition, he wants to eat health »  
Prof. F. Grande Covian

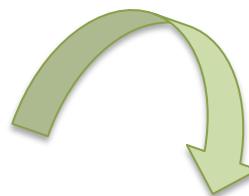
“Let food be the medicine, and let medicine be the food.” (attributed to Hippocrates)



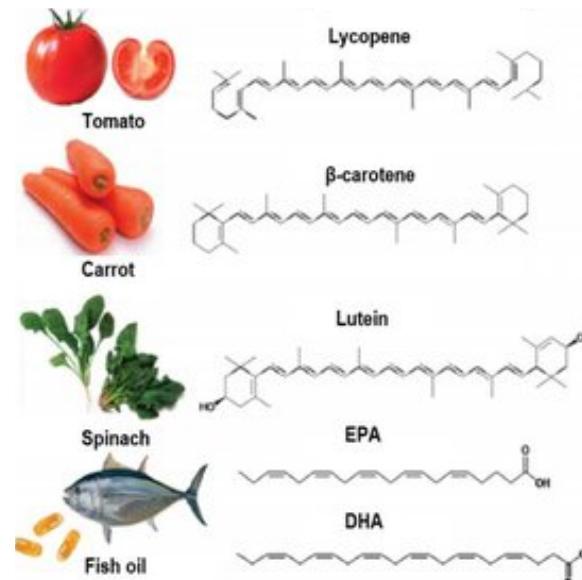
# Food for Health and Medicine



... Have Mechanisms  
of Action to Promote  
Good Health



## Food Chemical Compounds ...



Cardiovascular disease



Cáncer



Diabetes

# Food for Health and Medicine

Randomized Controlled Trial > *Nutrients*. 2019 Aug 24;11(9):2001. doi: 10.3390/nu11092001.

## Tolerability and Safety of a Nutritional Supplement with Potential as Adjuvant in Colorectal Cancer Therapy: A Randomized Trial in Healthy Volunteers

Marta Gómez de Cedrón <sup>1</sup>, José Moises Laparra <sup>2</sup>, Viviana Loria-Kohen <sup>3</sup>, Susana Molina <sup>4</sup>, Juan Moreno-Rubio <sup>4</sup> <sup>5</sup>, Juan Jose Montoya <sup>6</sup>, Carlos Torres <sup>7</sup>, Enrique Casado <sup>5</sup>, Guillermo Reglero <sup>7</sup> <sup>8</sup>, Ana Ramírez de Molina <sup>9</sup>

Affiliations + expand

PMID: 31450563 PMCID: [PMC6769991](#) DOI: [10.3390/nu11092001](https://doi.org/10.3390/nu11092001)

Review > *Int J Mol Sci.* 2016 Nov 10;17(11):1877. doi: 10.3390/ijms17111877.

## Dietary Strategies Implicated in the Prevention and Treatment of Metabolic Syndrome

Rocio de la Iglesia <sup>1</sup>, Viviana Loria-Kohen <sup>2</sup>, Maria Angeles Zulet <sup>3</sup> <sup>4</sup>, Jose Alfredo Martinez <sup>5</sup> <sup>6</sup>, Guillermo Reglero <sup>7</sup>, Ana Ramírez de Molina <sup>8</sup>

Affiliations + expand

PMID: 27834920 PMCID: [PMC5133877](#) DOI: [10.3390/ijms17111877](https://doi.org/10.3390/ijms17111877)

Review > *Nutr Cancer.* 2015;67(8):1221-9. doi: 10.1080/01635581.2015.1082110.

Epub 2015 Oct 9.

## Rosemary (*Rosmarinus officinalis* L.) Extract as a Potential Complementary Agent in Anticancer Therapy

Margarita González-Vallinas <sup>1</sup>, Guillermo Reglero <sup>2</sup>, Ana Ramírez de Molina <sup>1</sup>

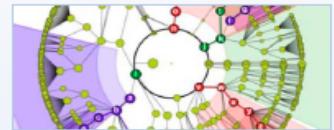
Affiliations + expand

PMID: 26452641 DOI: [10.1080/01635581.2015.1082110](https://doi.org/10.1080/01635581.2015.1082110)



Precision Nutrition and Cancer Programme

Dr. Ana Ramírez de Molina



- Molecular Oncology Research Group  
[Ana Ramírez de Molina](#)

- Clinical Oncology Research Group  
[Enrique Casado and Jaime Fellú](#)

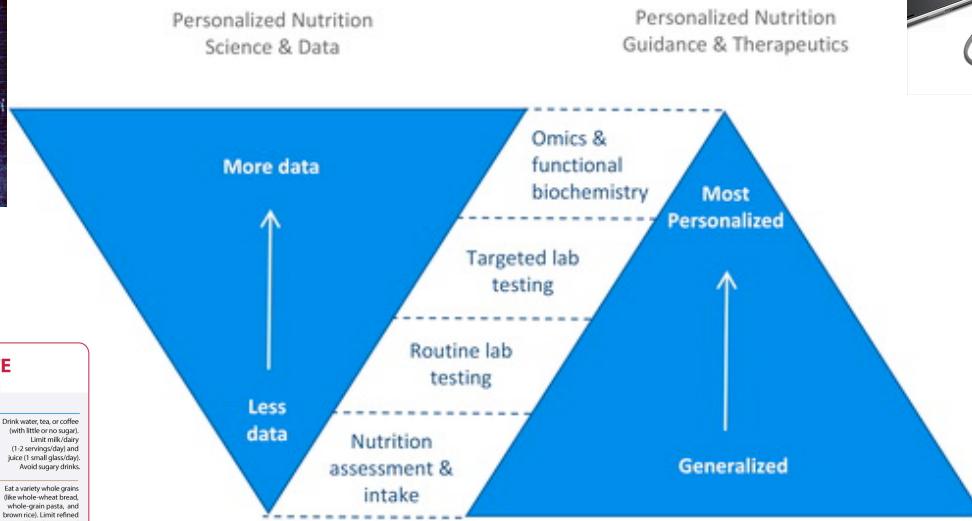
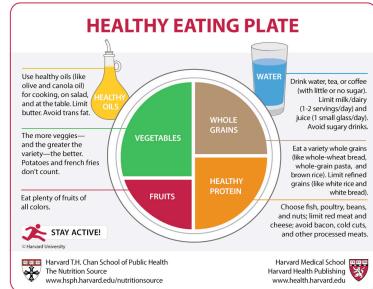
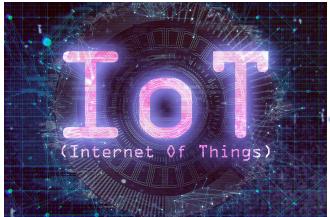
- Molecular Immunonutrition Research Group  
[Moisés LaParra](#)

- Computational Biology Research Group  
[Enrique Carrillo](#)



**Personalized nutrition** is expected to be one of the greatest revolutions for modern **medicine and health**.

This interest mainly due to the great development of omics & digital technologies.



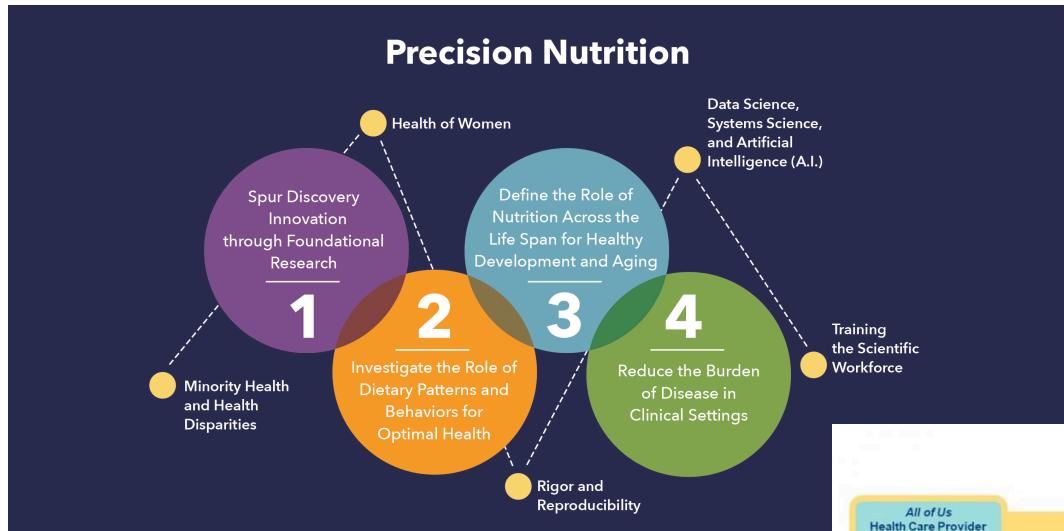
Oxford NANOPORE Technologies



Corinne L. Bush, Jeffrey B. Blumberg, Ahmed El-Sohemy, Deanna M. Minich, Jóse M. Ordovás, Dana G. Reed & Victoria A. Yunez Behm (2020) Toward the Definition of Personalized Nutrition: A Proposal by The American Nutrition Association, Journal of the American College of Nutrition, 39:1, 5-15,

# Personalized Nutrition

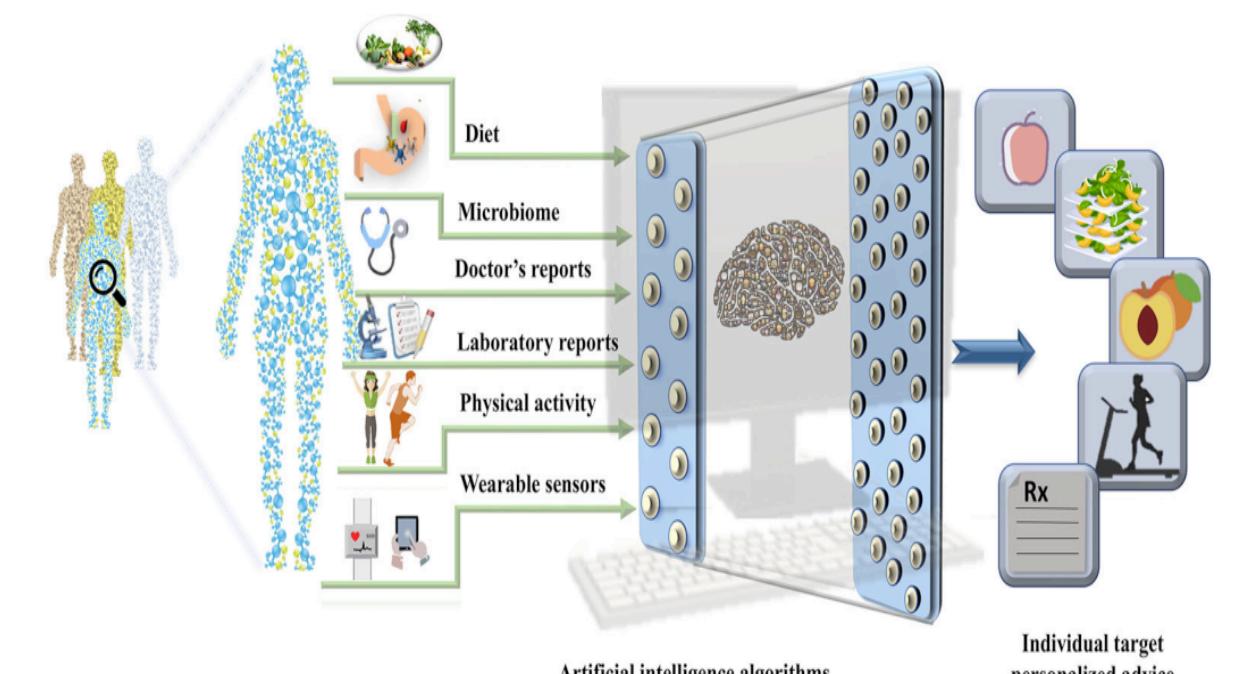
## The Nutrition for Precision Health program 2020-2030 Strategic Plan for NIH Nutrition Research





**Personalized nutrition** is expected to be one of the greatest revolutions for modern **medicine and health**.

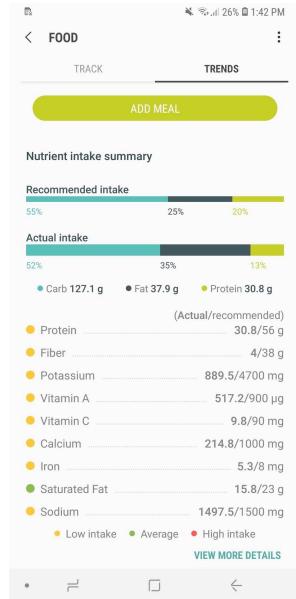
This interest mainly due to the great development of omics & digital technologies.



**FNS - Cloud**  
Food Nutrition Security



Verma, Meghna et al. "Challenges in Personalized Nutrition and Health." Frontiers in Nutrition 5 (2018)



<https://www.samsung.com/au/apps/samsung-health/nutrition/>

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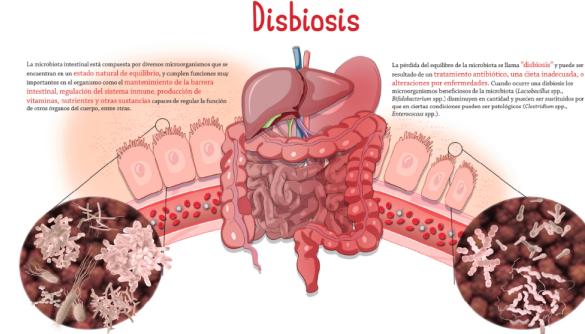
<https://caloriemama.ai/api>



<https://www.fitbit.com>



FreeStyle Libre Flash Glucose Monitoring System (Abbott's)



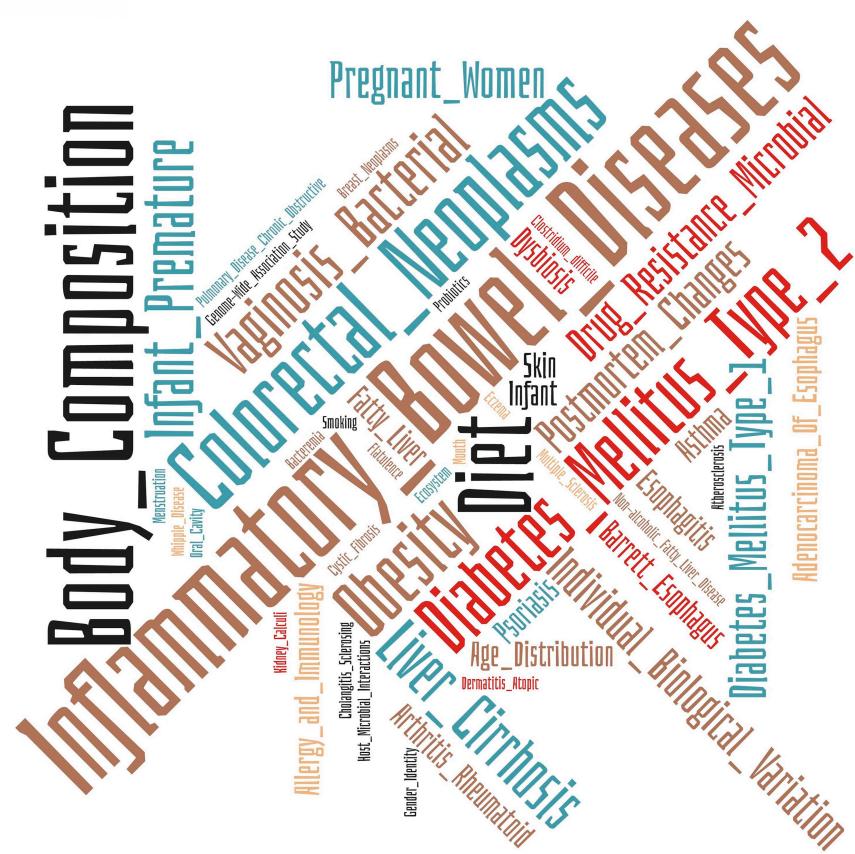
@PictureMicrobes

# Personalized Nutrition

## Applications of Machine Learning in Human Microbiome Studies: A Review on Feature Selection, Biomarker Identification, Disease Prediction and Treatment

Laura Judith Marcos-Zambrano<sup>1\*</sup>, Kanita Karadzovic-Hadziabdic<sup>2</sup>, Tatjana Loncar Turukalo<sup>3</sup>, Piotr Przymus<sup>4</sup>, Vladimir Trajkovik<sup>5</sup>, Oliver Aasmets<sup>6,7</sup>, Magali Berland<sup>8</sup>, Aleksandra Gruba<sup>9</sup>, Jasminka Hasic<sup>10</sup>, Karel Hron<sup>11</sup>, Thomas Klammersteiner<sup>12</sup>, Mikhail Kolev<sup>13</sup>, Leo Lahti<sup>14</sup>, Marta B. Lopes<sup>15,16</sup>, Victor Moreno<sup>17,18,19,20</sup>, Irina Naskinova<sup>13</sup>, Elin Org<sup>6</sup>, Inês Paciência<sup>21</sup>, Georgios Papoutsoglou<sup>22</sup>, Rajesh Shigdel<sup>23</sup>, Blaz Stres<sup>24</sup>, Baiba Vilne<sup>25</sup>, Malik Yousef<sup>26,27</sup>, Eftim Zdravevski<sup>15</sup>, Ioannis Tsamardinos<sup>22</sup>, Enrique Carrillo de Santa Pau<sup>1</sup>, Marcus J. Claesson<sup>28</sup>, Isabel Moreno-Indias<sup>29,30</sup> and Jaak Truu<sup>31\*</sup> on behalf of ML4Microbiome

- ◆ Complex follow-up or interventional studies
- ◆ Small Sample Size
- ◆ Low adherence to studies
- ◆ Sort intervention times
- ◆ Small cumulative effects



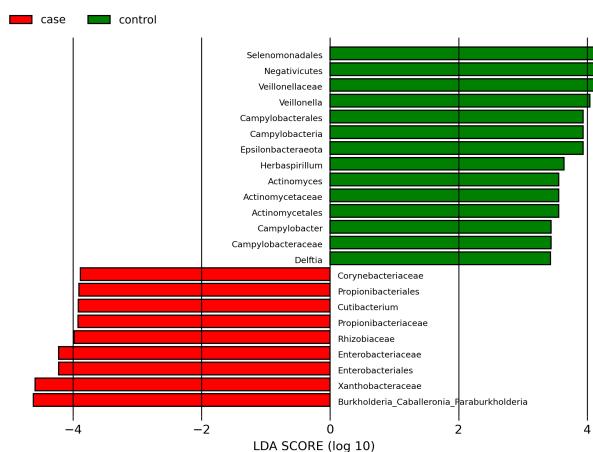
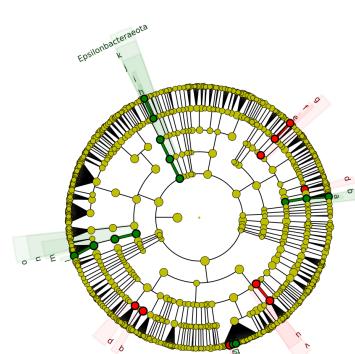
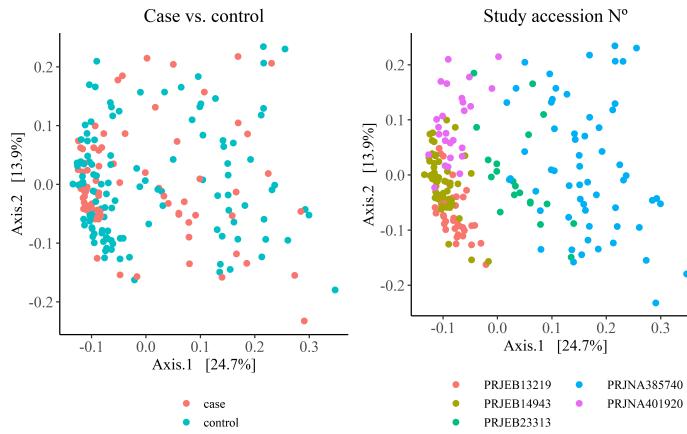
# Personalized Nutrition

## Metataxonomic review to elucidate the role of the microbiome in Celiac disease across the gastrointestinal tract

Juliana Arcila, Viviana Loria-Kohen, Ana Ramírez de Molina, Enrique Carrillo de Santa Pau, Laura Judith Marcos-Zambrano



**bioRxiv**  
THE PREPRINT SERVER FOR BIOLOGY



Body site	Diversity	Main Microbial Changes	SCFA	Genes and Pathways
Saliva	CeD	<i>Oceanivirga</i>	N/A	Peptidoglycan biosynthesis
Pharynx	CeD	<i>Rothia</i> <i>Peptostreptococcus</i> <i>Alloprevotella</i>	N/A	Alternative routes for energy obtention
Duodenum	CeD GFD	<i>Rhizobiales</i> <i>Xanthobacteriaceae</i> <i>Enterobacteriaceae</i> <i>Betaproteobacteriales</i> <i>Burkholderia</i> <i>Cutibacterium</i> <i>Haemophilus</i> <i>Neisseria</i> <i>Campylobacter</i> <i>Deltia</i> <i>Alloprevotella</i> <i>Pseudomonadales</i> <i>Veillonella</i> <i>Actinomycetes</i>	Production: -Acetate -Lactate -Butyrate	Alternative routes for energy obtention. Inflammation pathways
	CeD			
Stool	CeD GFD	<i>Akkermansia</i> <i>Pseudomonas</i> <i>Anaerostipes</i> <i>Dorea</i> <i>Bacteroides</i> <i>Alteromonadales</i> <i>Faecalitalea</i> <i>Betaproteobacteriales</i> <i>Lactobacillus</i> <i>Clostridiales</i> <i>Roseburia</i> <i>Bifidobacterium</i> <i>Prevotella</i> <i>Ruminococcaceae</i> <i>Haemophilus</i>	Production: -Acetate -Lactate  Degradation: - Acetate	LPS biosynthesis Vitamin B production
	CeD			

- Equal to
- Increased
- Decreased
- Not applicable
- Greater than
- Lower than
- Gluten-free diet (GFD)
- GFD and unrestricted diet

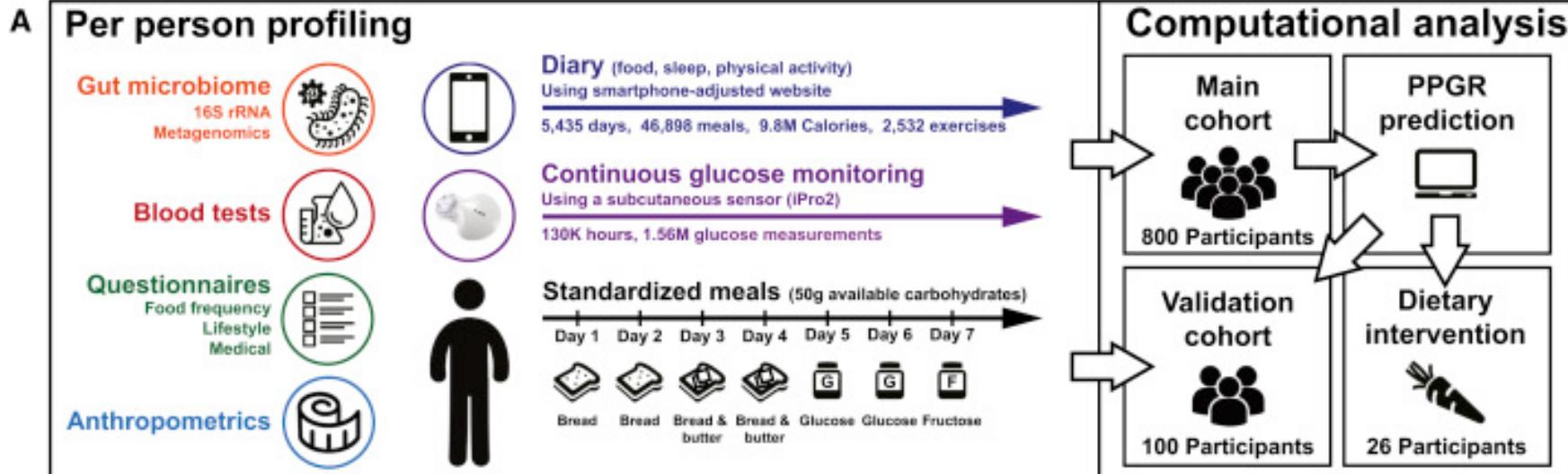
- Epsilonbacteraeota
- Verrucomicrobia
- Bacteroidetes
- Proteobacteria
- Actinobacteria
- Fusobacteria
- Firmicutes

# Personalized Nutrition

## Cell

### Personalized Nutrition by Prediction of Glycemic Responses

David Zeevi <sup>8</sup> • Tal Korem <sup>8</sup> • Niv Zmora <sup>8</sup> • ... Zamir Halpern • Eran Elinav <sup>8</sup>   • Eran Segal <sup>8</sup>  

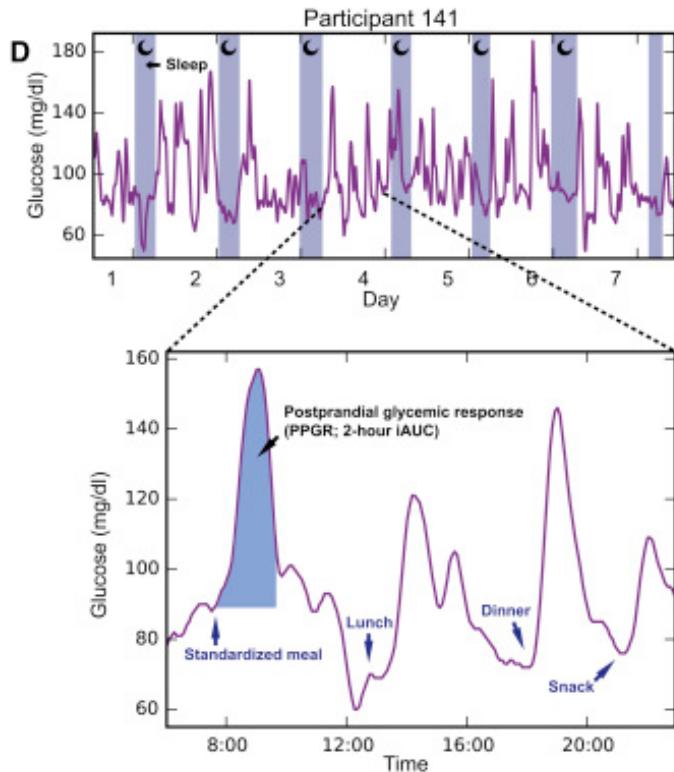


# Personalized Nutrition

## Cell

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David Zeevi <sup>8</sup> • Tal Korem <sup>8</sup> • Niv Zmora <sup>8</sup> • ... Zamir Halpern • Eran Elinav <sup>8</sup>   • Eran Segal <sup>8</sup>  



Glucose monitor (CGM), which measures interstitial fluid glucose every 5 min for 7 full days (the “connection week”), using subcutaneous sensors

we recorded over 1.5 million glucose measurements from 5,435 days.

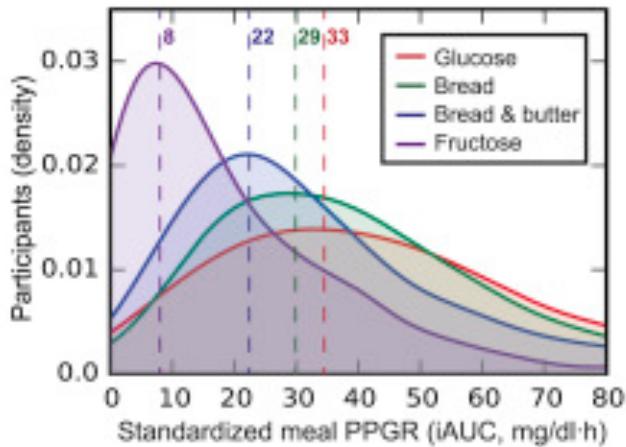
# Personalized Nutrition

## Cell

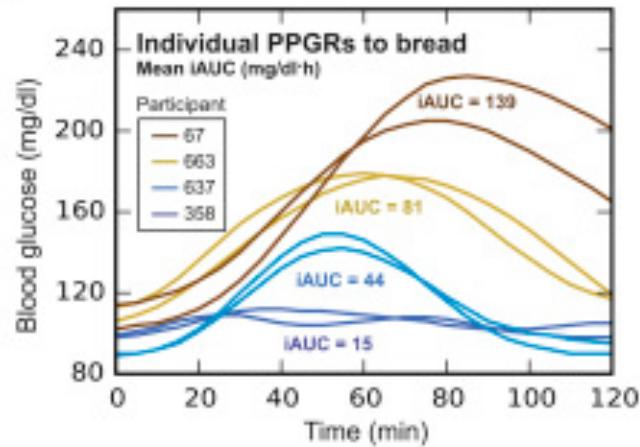
### Personalized Nutrition by Prediction of Glycemic Responses

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B



C

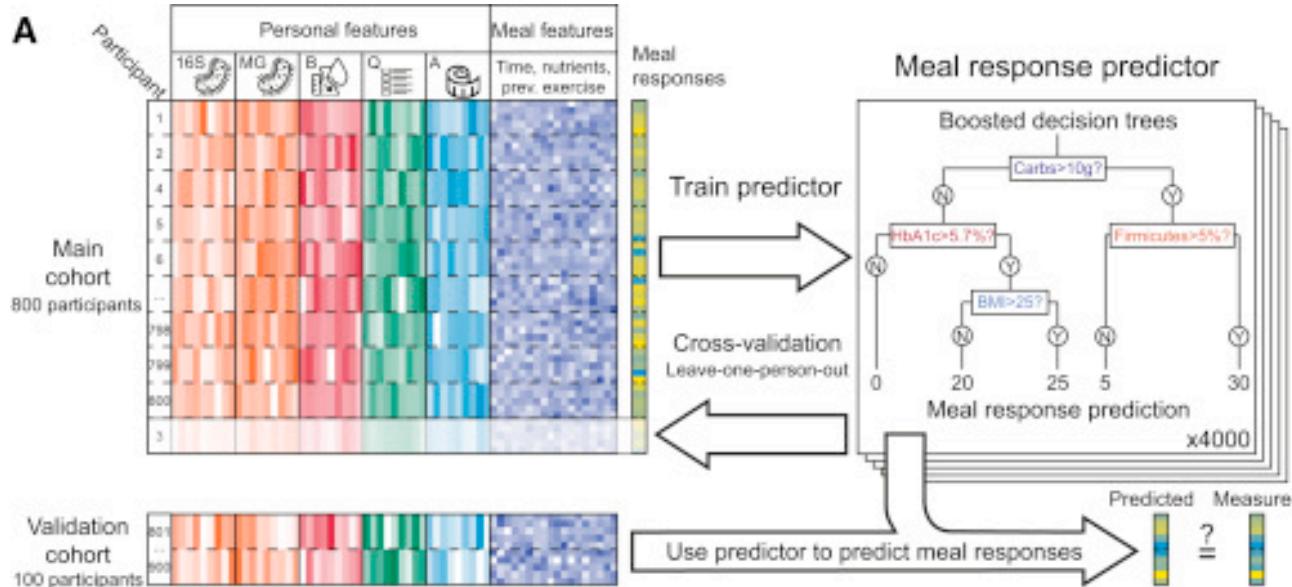


# Personalized Nutrition

## Cell

### Personalized Nutrition by Prediction of Glycemic Responses

David Zeevi <sup>8</sup> • Tal Korem <sup>8</sup> • Niv Zmora <sup>8</sup> • ... Zamir Halpern • Eran Elinav <sup>8, 9</sup> • Eran Segal <sup>8, 9</sup> •



### Gradient Boosting Regression

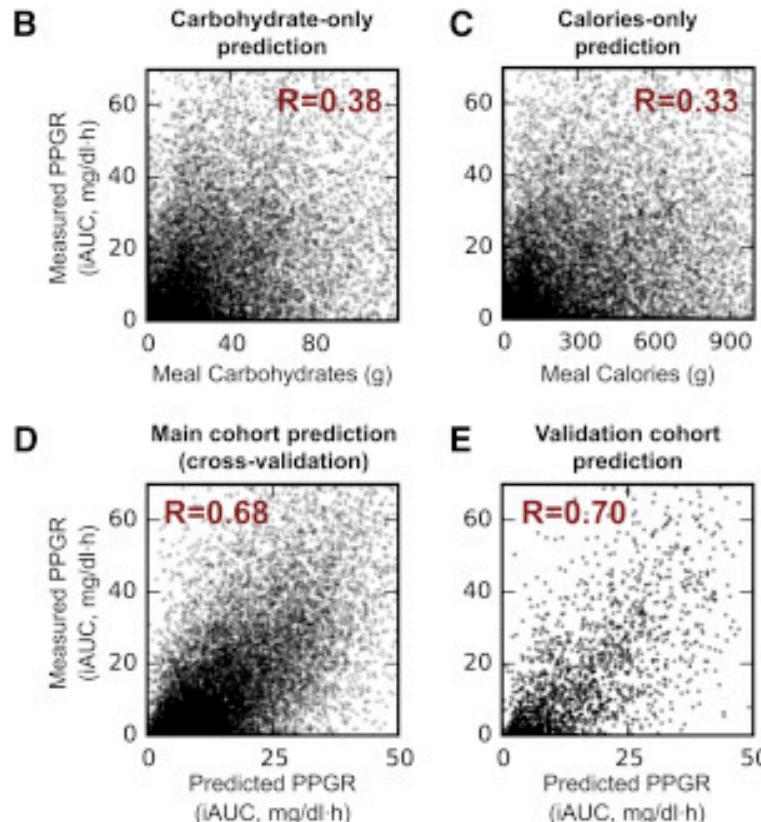
Trees are inferred sequentially, with each tree trained on the residual of all previous trees and making a small contribution to the overall prediction

# Personalized Nutrition

Cell

## Personalized Nutrition by Prediction of Glycemic Responses

David Zeevi <sup>8</sup> • Tal Korem <sup>8</sup> • Niv Zmora <sup>8</sup> • ... Zamir Halpern • Eran Elinav   • Eran Segal   •



<https://doi.org/10.1016/j.cell.2015.11.001>

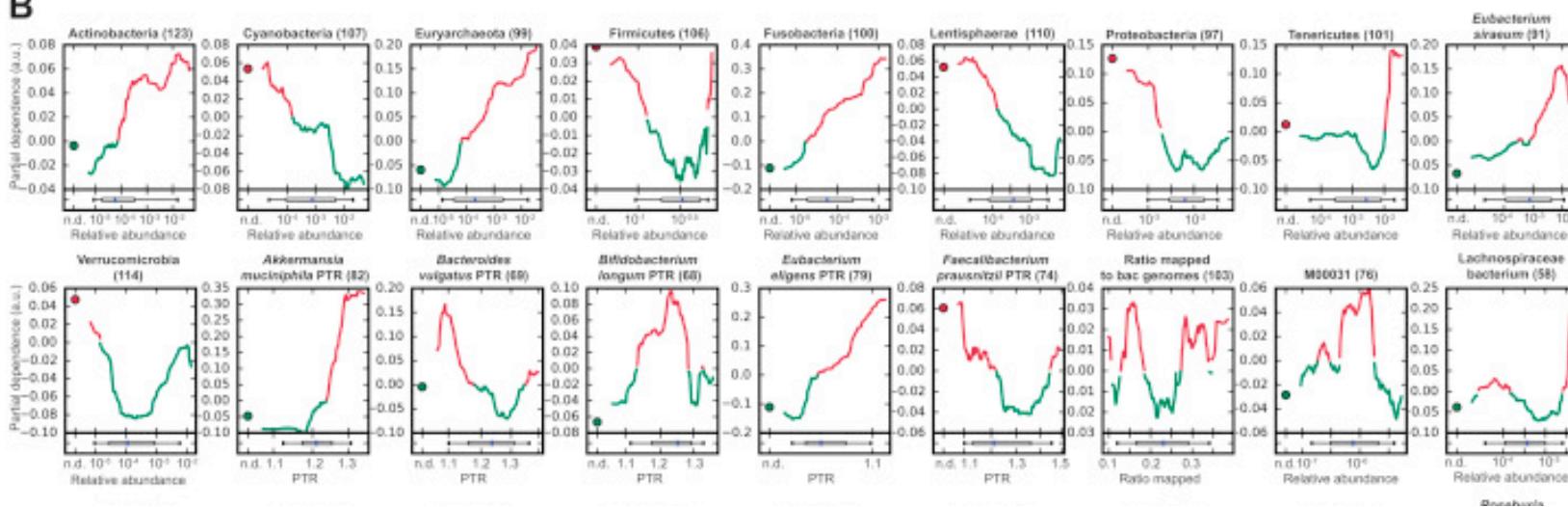
# Personalized Nutrition

## Cell

### Personalized Nutrition by Prediction of Glycemic Responses

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B



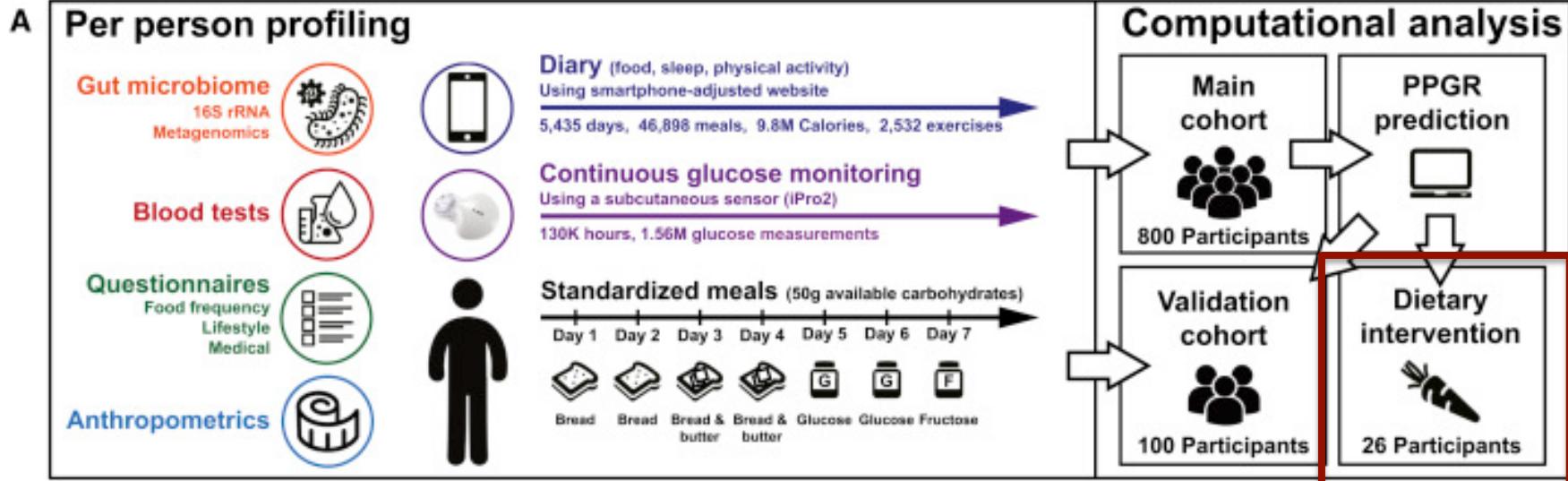
72 PDPs of the microbiome-based features used in our predictor were either beneficial (21 factors), non-beneficial (28), or non-decisive (23)

# Personalized Nutrition

## Cell

### Personalized Nutrition by Prediction of Glycemic Responses

David Zeevi <sup>8</sup> • Tal Korem <sup>8</sup> • Niv Zmora <sup>8</sup> • ... Zamir Halpern • Eran Elinav <sup>8</sup>   • Eran Segal <sup>8</sup>  

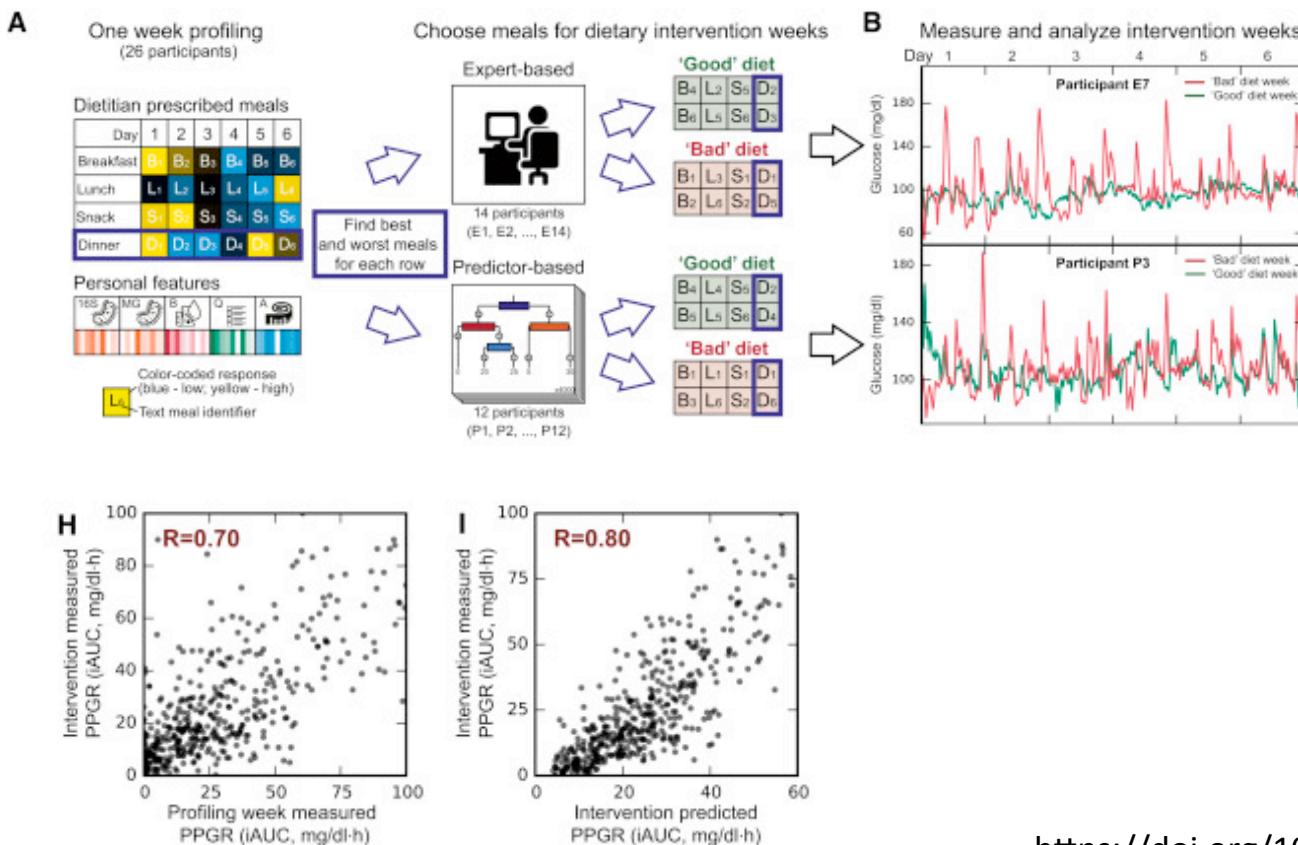


# Personalized Nutrition

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### Personalized Nutrition by Prediction of Glycemic Responses

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# Personalized Nutrition



<https://www.daytwo.com/>



**Eric Topol**  
(American Cardiologist)

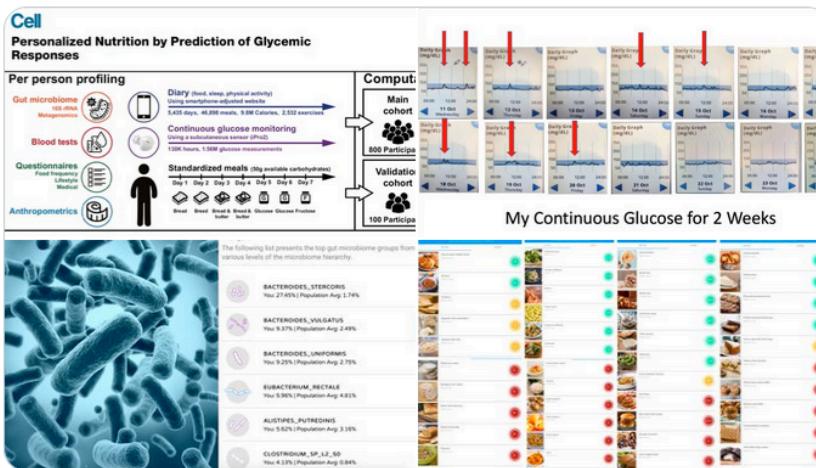
← Hilo



Eric Topol ✅  
@EricTopol

I followed @CellCellPress @WeizmannScience protocol: glucose X 2 wks, gut #microbiome, lots of other tracking data-> #AI -> my diet recommendations (sample) [@daytwohealth cell.com /cell/fulltext/...](http://daytwohealth.cell.com) v interesting stuff!

Traducir Tweet



7:16 p. m. · 26 nov. 2017 · Twitter Web Client

70 Retweets 13 Tweets citados 131 Me gusta

# Personalized Nutrition

Bread, Cereal, Rice and Pasta		Vegetables		Legumes, Tofu and Nuts		Snacks and Sweets	
Your maximum daily allowance is: 2350 Cal		Your maximum daily allowance is: 2350 Cal		Your maximum daily allowance is: 2350 Cal		Your maximum daily allowance is: 2350 Cal	
BETTER	WORSE	BETTER	WORSE	BETTER	WORSE	BETTER	WORSE
	French toast challah bread 319 Cal   5.2 oz		Cooked broccoli 53 Cal   6.3 oz		Almond butter 98 Cal   0.5 oz		Cheese danish 393 Cal   3.2 oz
	Granola 137 Cal   0.9 oz		Cooked cauliflower 20 Cal   2.1 oz		Brazil nuts 184 Cal   0.9 oz		Cheesecake 357 Cal   2.8 oz
	Crackers 80 Cal   0.5 oz		Kimchi 17 Cal   4 oz		Mixed nuts 170 Cal   0.9 oz		Fiber almond brownie bar 200 Cal   1.7 oz
	Baguette with camembert 244 Cal   3 oz		Yellow beans 44 Cal   4.4 oz		Sunflower seeds 164 Cal   0.9 oz		Protein almond brownie bar 200 Cal   1.7 oz
	Oatmeal with milk 345 Cal   6.1 oz		Prepared cauliflower 64 Cal   2.3 oz		Tahini spread 98 Cal   0.3 oz		Carrot cake with extra icing 380 Cal   2.5 oz
	Salted rice cakes 70 Cal   0.8 oz		Artichokes 64 Cal   4.2 oz		Edamame 100 Cal   2.6 oz		Whole wheat fig bars 60 Cal   0.6 oz
	Multigrain rice cakes 35 Cal   0.3 oz		Pickled daikon radish 17 Cal   1.8 oz		Home prepared hummus 27 Cal   0.5 oz		Wheat bran raisin muffin 183 Cal   2.1 oz
	Italian-herb focaccia 150 Cal   2 oz		Celeriac 66 Cal   0.5 oz		Soy burger 314 Cal   7.7 oz		Banana nut muffin 220 Cal   2.9 oz
	Gluten-free bread 217 Cal   3.5 oz		Baked potatoes 201 Cal   10.8 oz		Spicy black bean burger 324 Cal   7.6 oz		Honey graham crackers 118 Cal   0.9 oz
	Cheerios 113 Cal   1 oz		Yellow peppers 90 Cal   6.4 oz		Roasted chestnuts 96 Cal   0.9 oz		Chocolate cake cookie 50 Cal   0.5 oz
			Baked squash 76 Cal   7.2 oz		Lentil veggie burger 342 Cal   7.4 oz		
			Yams 216 Cal   7.2 oz				

<https://twitter.com/EricTopol/status/934848245162901504/photo/4>

# Personalized Nutrition



Eric Topol   
@EricTopol

En respuesta a @EricTopol

A partial list of the algorithmic recommendations.  
Bratwurst A+ and other ratings were not what I had in mind ;)

And this is based on avoidance of glucose spikes  
They're associated w/ leaky gut, infection & cancer in mouse models

[ncbi.nlm.nih.gov/pmc/articles/PMC30022161/](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC30022161/)

[science.sciencemag.org/content/359/63.../eaar3033](https://science.sciencemag.org/content/359/6373/eaar3033)

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DEEP MEDICINE

Bread, Cereal, Rice, and Pasta			Legumes, Tofu, and Nuts			Dairy and Dairy Substitutes		
Item	Grade	Item	Grade	Item	Grade	Item	Grade	
French toast challah bread	A	Almond butter	A+	Nuts, seeds & raisins trail mix	A-	Almond milk	A+	
Granola	A-	Brazil nuts	A+	Roasted & salted pumpkin seeds	B+	Blue cheese	A+	
Crackers	B+	Mixed nuts	A+	Berry blend trail mix	B+	Goat's milk	A+	
Baguette with Camembert	B	Sunflower seeds	A+	Home prepared hummus	B	Gouda cheese	A+	
Oatmeal with milk	B	Tahini spread	A+	Soy burger	C+	Soy cheddar cheese	A+	
Whole wheat bread with butter	B	Edamame	A	Spicy black bean burger	C+	Plain whole yogurt	A	
Quinoa	B-	Unsalted trail mix	A	Roasted chestnuts	C	Whole milk	A	
Bran flakes with soy milk	B-			Lentil veggie burger	C	Greek yogurt	B+	
Gluten free whole grain bread w/olive oil	B-			Veggie burger	C	Soy milk	B+	
Corn tortilla	C+					Berry soy yogurt	B-	
Multigrain crackers	C+					Skim milk	B-	
Oatmeal	C+					Soy yogurt	B-	
Cooked buckwheat	C					Berry yogurt 0% fat	C	
Banana nut crunch cereal with milk	C					Chocolate soy milk	C-	
Ciabatta bread with avocado	C					Yogurt 0% fat	C-	
Cheetos	C-							
Gluten-free bread	C-							
Italian-herb focaccia	C-							
Multigrain rice cakes	C-							
Salted rice cakes	C-							
Vegetables			Fruits			Snacks and Sweets		
Item	Grade	Item	Grade	Item	Grade	Item	Grade	
Cooked broccoli	A+	Star fruit	A+	Cheese danish	A	Cheese danish	A	
Cooked cauliflower	A+	Strawberries	A+	Cheesecake	A	Fiber almond brownie bar	A-	
Kimchi	A+	Unsweetened coconut	A+	Protein almond brownie bar	A-	Carrot cake with extra icing	B+	
Yellow beans	A+	Blackberries	A	Raspberry white chocolate muffin	B+	Raspberry danish	B	
Prepared cauliflower	A+	Asian pear	A-	Chocolate cream sandwich cookie	B+	White chocolate macadamia cookies	B	
Artichokes	A	Guava	A-	Almond raisin cinnamon danish	B	Mini chocolate chip muffin	B-	
Beets	B+	Raspberries	A-	Apple, cinnamon, raisin & strawberry danish	B	Peach pie	B-	
Winter squash	B	Nectarine	B-	Coffee cake	B	Pecan pie	B-	
Cooked brussel sprouts	B-	Pear	B-	Raspberry danish	B	Fruit & hazelnut bar	C+	
Baked sweet potatoes	B-	Plum	B-	White chocolate macadamia cookies	B	Ice cream sandwich	C+	
Lima beans	B-	Pomegranate	B-	Mini chocolate chip muffin	B-	Strawberry frozen yogurt	C+	
Yams	C+	Tangerine	B-	Peach pie	B-	Apple cinnamon muffin	C	
Baked squash	C	Banana	C+	Fruit & hazelnut bar	C+	Chocolate cake cookie	C	
Yellow peppers	C	Cherries	C+	Ice cream sandwich	C+	Honey graham crackers	C	
Baked potatoes	C-	Dried cherries	C+	Strawberry frozen yogurt	C+	Banana nut muffin	C-	
Celeriac	C-	Goji berries	C+	Apple cinnamon muffin	C	Wheat bran raisin muffin	C-	
Pickled daikon radish	C-	Orange	C+	Chocolate cake cookie	C	Whole wheat fig bars	C-	
		Melon	C	Honey graham crackers	C			
		Raisins	C	Banana nut muffin	C			
		White grapefruit	C	Wheat bran raisin muffin	C			
		Dried papaya	C-	Whole wheat fig bars	C-			
		Pomelo	C-					
Beverages			Meat, Fish, and Eggs					
Item	Grade	Item	Grade	Item	Grade			
Decaf instant coffee	A+	Bratwurst veal cooked	A+					
Light beer	A+	Hard-boiled egg	A+					
Martini	A+	Smoked salmon	A+					
Cappuccino	A	Breaded veal cutlet	A+					
Pina colada	A	Fried muller	A+					
American-style pale lager	A-	Grilled chicken breast	A					
Sweetened vanilla coffee	A-	Spicy shrimp ceviche	A					
Cola	B-	Cod cakes	A					
Cranberry juice	B-	Pickled Atlantic herring	A-					
Orange juice	B-	Salmon sashimi	A-					
Fruit punch	C+	Fried squid	B+					
Guava passion fruit juice	C+	Fish sticks	C-					
Spicy apple cider	C+							

<https://twitter.com/erictopol/status/1102234234582781952>

# Personalized Nutrition

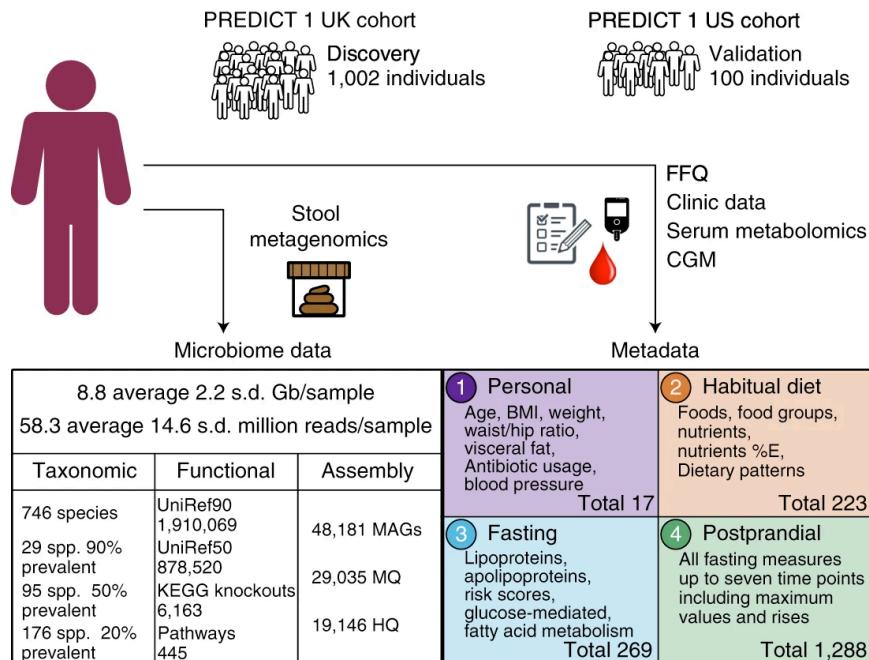
## Microbiome connections with host metabolism and habitual diet from 1,098 deeply phenotyped individuals

Francesco Asnicar, Sarah E. Berry [✉](#), [...] Nicola Segata [✉](#)

*Nature Medicine* 27, 321–332(2021) | [Cite this article](#)

### Random forest regression and classification

a



A cross-validation approach was implemented, which was based on 100 bootstrap iterations and an 80/20 random split of training and testing folds

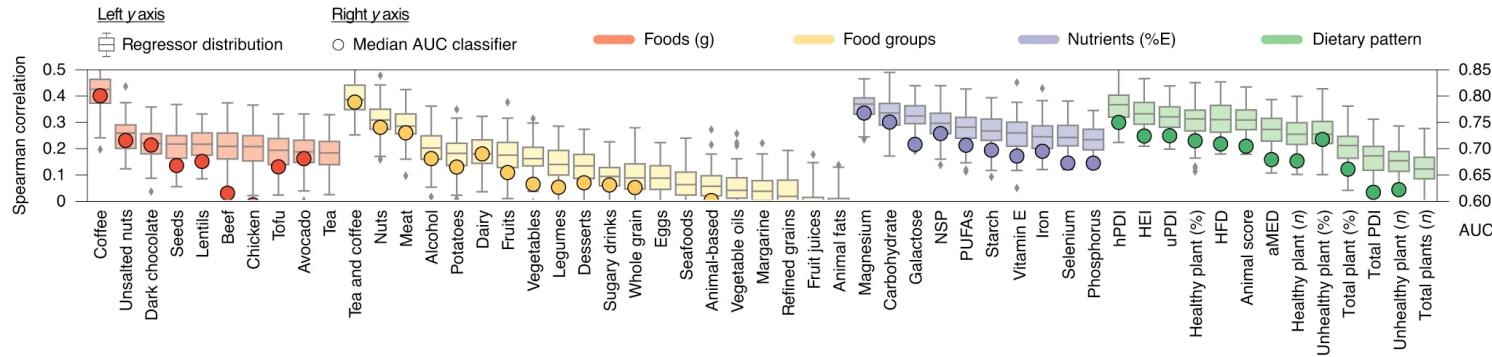
shown to be particularly suitable and robust to the statistical challenges inherent to microbiome abundance data

*Nat. Med.* 25, 667–678 (2019)

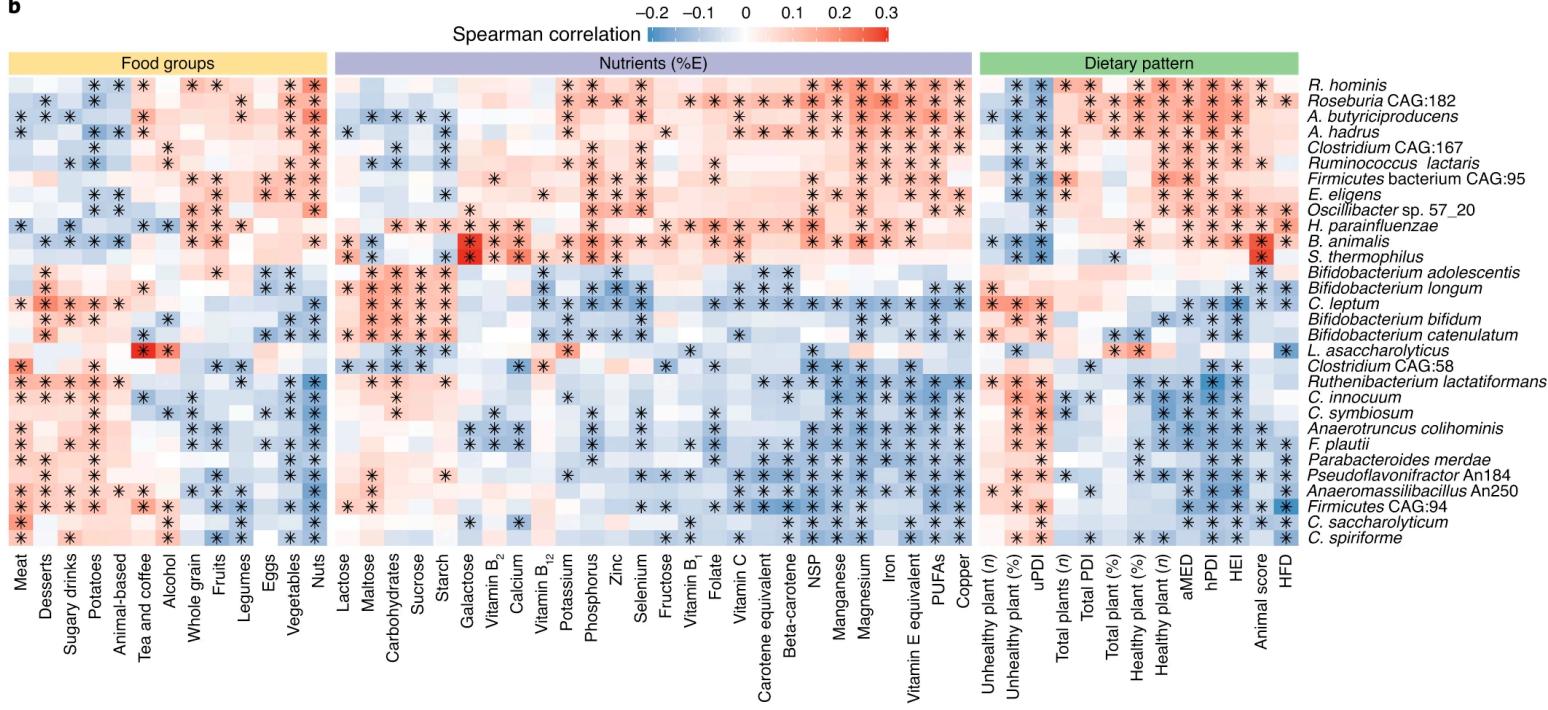
*PLoS Comput. Biol.* 12, e1004977 (2016).

# Personalized Nutrition

a

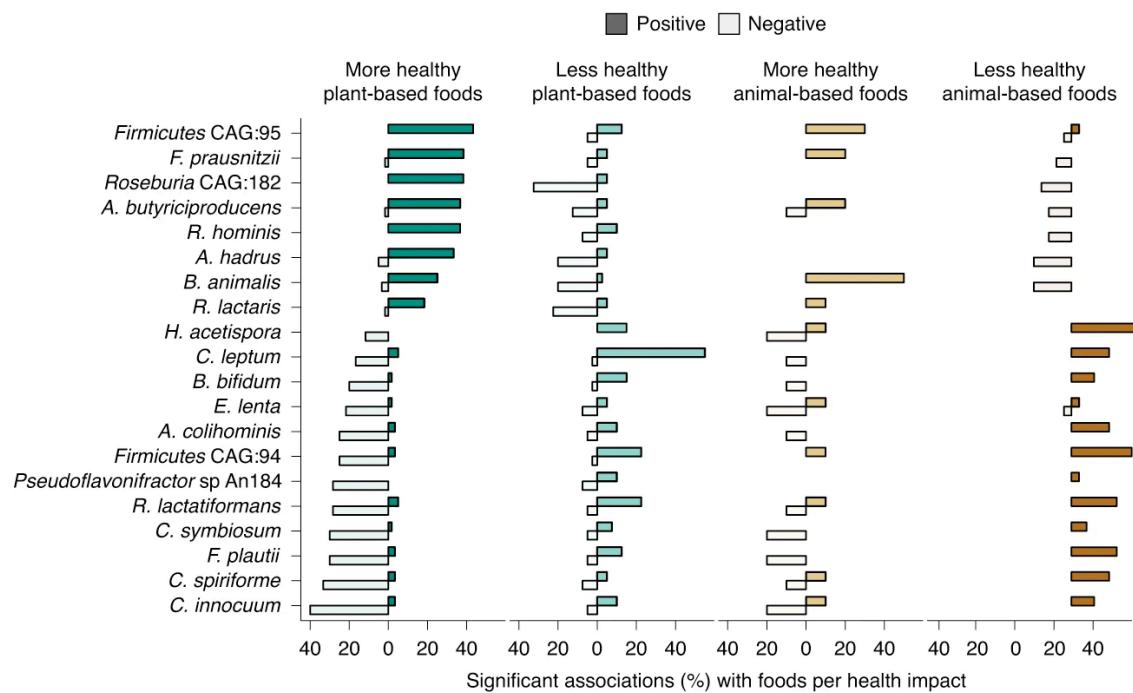


b

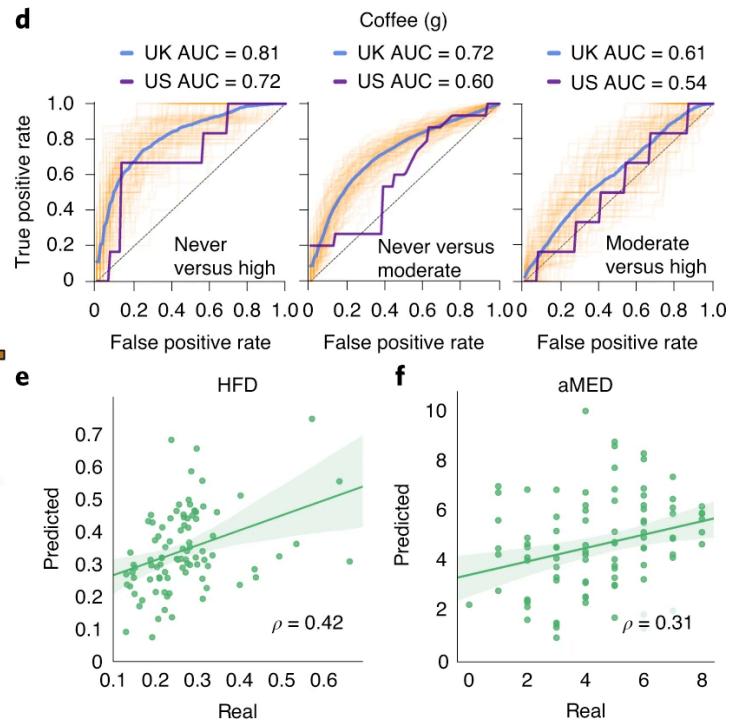


# Personalized Nutrition

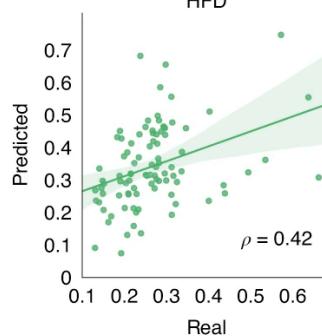
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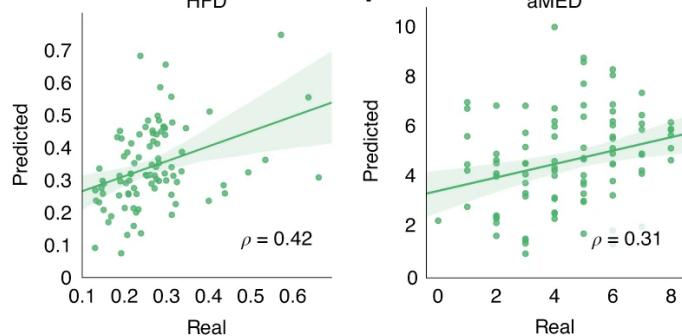
d



e



f



# Future Challenges

## Statistical and Machine Learning Techniques in Human Microbiome Studies: Contemporary Challenges and Solutions

*Isabel Moreno-Indias<sup>1,2\*</sup>, Leo Lahti<sup>3</sup>, Miroslava Nedyalkova<sup>4</sup>, Ilze Elbore<sup>5</sup>, Gennady Roshchupkin<sup>6</sup>, Muhamed Adilovic<sup>7</sup>, Onder Aydemir<sup>8</sup>, Burcu Bakır-Gungor<sup>9</sup>, Enrique Carrillo-de Santa Pau<sup>10</sup>, Domenica D'Ella<sup>11</sup>, Mahesh S. Desai<sup>12,13</sup>, Laurent Falquet<sup>14,15</sup>, Aycan Gundogdu<sup>16,17</sup>, Karel Hron<sup>18</sup>, Thomas Klammsteiner<sup>19</sup>, Marta B. Lopes<sup>20,21</sup>, Laura Judith Marcos-Zambrano<sup>10</sup>, Cláudia Marques<sup>22</sup>, Michael Mason<sup>23</sup>, Patrick May<sup>24</sup>, Lejla Pašić<sup>25</sup>, Gianvito Pio<sup>26</sup>, Sándor Pongor<sup>27</sup>, Vasilis J. Promponas<sup>28</sup>, Piotr Przymus<sup>29</sup>, Julio Saez-Rodriguez<sup>30</sup>, Alexia Samprí<sup>31</sup>, Rajesh Shigdel<sup>32</sup>, Blaz Stres<sup>33,34,35</sup>, Ramona Suharoschi<sup>36</sup>, Jaak Truu<sup>37</sup>, Ciprian-Octavian Truică<sup>38</sup>, Baiba Vilne<sup>39</sup>, Dimitrios Viachakis<sup>40</sup>, Ercument Yilmaz<sup>41</sup>, Georg Zeller<sup>42</sup>, Aldert L. Zomer<sup>43</sup>, David Gómez-Cabrero<sup>44</sup> and Marcus J. Claesson<sup>45</sup> on Behalf of ML4Microbiome*



- (1) create standards (incl. data pre-processing) for the development and deployment of ML techniques with an easy, transparent, and trustable interpretability for non-experts taking in account the peculiarities of microbiome data
- (2) increase the number and quality of human microbiome studies
- (3) create efficient data structures and ML repositories following Findable, Accessible, Interoperable and Reusable (FAIR) principles
- (4) chose appropriate distributional assumptions including sparsity and compositionality, appropriate feature selection

# Future Challenges

## Statistical and Machine Learning Techniques in Human Microbiome Studies: Contemporary Challenges and Solutions

*Isabel Moreno-Indias<sup>1,2\*</sup>, Leo Lahti<sup>3</sup>, Miroslava Nedyalkova<sup>4</sup>, Ilze Elbore<sup>5</sup>, Gennady Roshchupkin<sup>6</sup>, Muhamed Adilovic<sup>7</sup>, Onder Aydemir<sup>8</sup>, Burcu Bakır-Gungor<sup>9</sup>, Enrique Carrillo-de Santa Pau<sup>10</sup>, Domenica D'Ella<sup>11</sup>, Mahesh S. Desai<sup>12,13</sup>, Laurent Falquet<sup>14,15</sup>, Aycan Gundogdu<sup>16,17</sup>, Karel Hron<sup>18</sup>, Thomas Klammsteiner<sup>19</sup>, Marta B. Lopes<sup>20,21</sup>, Laura Judith Marcos-Zambrano<sup>10</sup>, Cláudia Marques<sup>22</sup>, Michael Mason<sup>23</sup>, Patrick May<sup>24</sup>, Lejla Pašić<sup>25</sup>, Gianvito Pio<sup>26</sup>, Sándor Pongor<sup>27</sup>, Vasilis J. Promponas<sup>28</sup>, Piotr Przymus<sup>29</sup>, Julio Saez-Rodríguez<sup>30</sup>, Alexia Samprí<sup>31</sup>, Rajesh Shigdel<sup>32</sup>, Blaz Stres<sup>33,34,35</sup>, Ramona Suharoschi<sup>36</sup>, Jaak Truu<sup>37</sup>, Ciprian-Octavian Truică<sup>38</sup>, Baiba Vilne<sup>39</sup>, Dimitrios Vlachakis<sup>40</sup>, Ercument Yilmaz<sup>41</sup>, Georg Zeller<sup>42</sup>, Aldert L. Zomer<sup>43</sup>, David Gómez-Cabrero<sup>44</sup> and Marcus J. Claesson<sup>45</sup> on Behalf of ML4Microbiome*



- (5) control for technical biases such as read count variations, the potential confounding effects, and multiple testing
- (6) Improve interpretability ML methods
- (7) build bridges between different disciplines, microbiology, biology, statistics, bioinformatics, engineering and others to increase interdisciplinary for innovative solutions

# Future Challenges

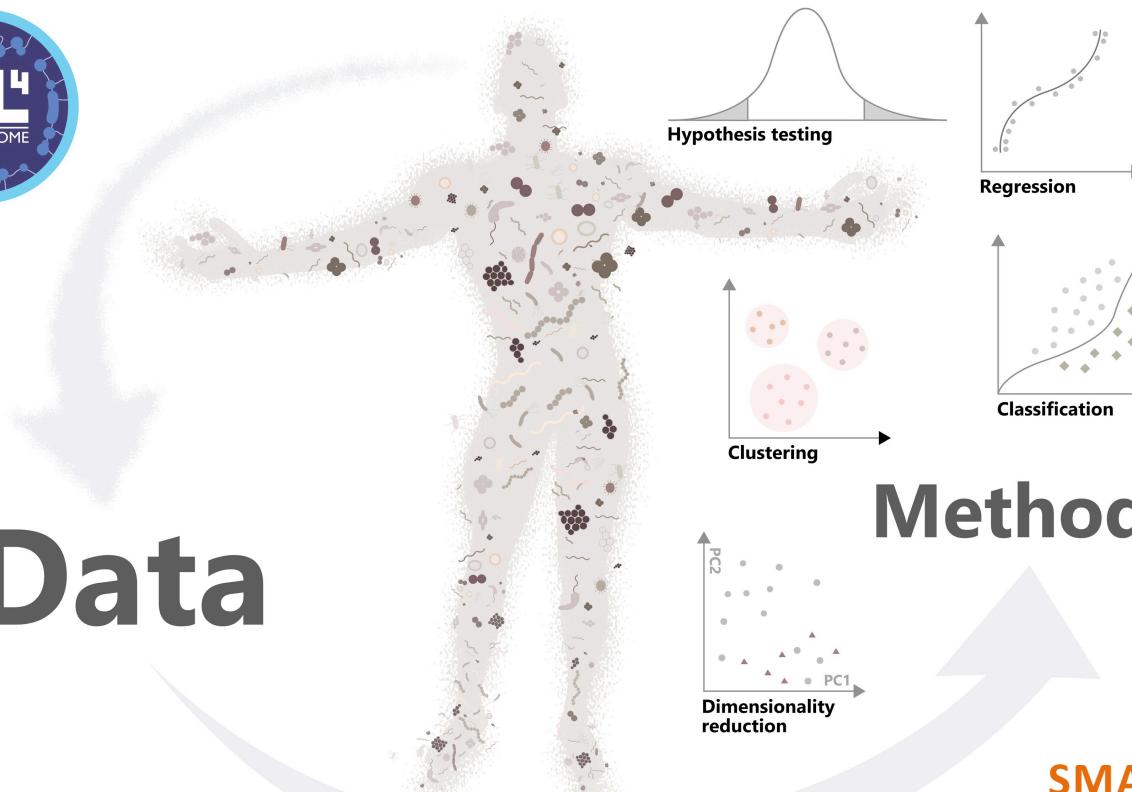
which motivate and enable each person to make appropriate changes to his or her eating pattern



## Data

<https://doi.org/10.3389/fmicb.2021.634511>

behaviours, beliefs, preferences, barriers



## Methods

**SMART goals** (Specific, Measurable, Achievable, Relevant, and Time-bound)

# The Human Talent



Enrique Carrillo  
de Santa Pau  
(April 2018)



Laura J Marcos  
(October 2018)



Teresa Laguna  
(January 2019)



Marco Garranzo  
(May 2020)



Carlos Madariaga  
(December 2020-  
June 2021)



Sheyla Ordoñez  
(April 2021 –  
September 2021)



Silvia García  
(April 2021 -  
September 2021)

## Funding



Comunidad de Madrid



FUNDACIÓN  
RAMÓN ARECES

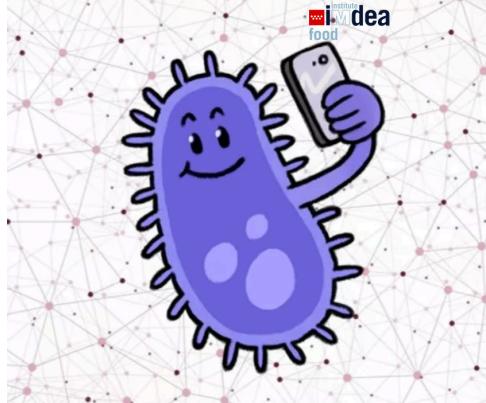


# WELCOME TO "PICTURE YOUR MICROBES"

The project that connects science with photography,  
raising awareness of the importance of caring for our  
bacterial communities and motivating citizens to  
improve their nutritional health decisions.



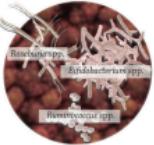
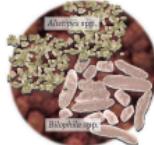
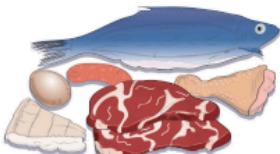
Funded by  
the European Union



## #PictureYourMicrobes

### Diet rich in protein and fats of animal origin

A diet rich in protein and fats of animal origin will stimulate the growth of bacteria able to tolerate bile such as *Bilophila* spp. and *Allobacillus* spp., which increase the production of trimethylamine N-oxide (TMAO), a compound that plays an important role in the development of cardiovascular diseases.



### High-fibre diet

Plant fibre stimulates the growth of bacteria capable of fermenting it, such as *Ruminococcus* spp., *Roseburia* spp., and *Bifidobacterium* spp., which in turn produce short-chain fatty acids that play an important role in the regulation of the immune system.

### Diet rich in protein of plant origin

On the other hand, a diet rich in protein of plant origin will be enriched in bacteria of the genus *Prevotella* spp., which produce beneficial fatty acids that are associated with low serum cholesterol levels.



## Nutrition - Microbiota



### Diet rich in fermented foods

Currently, there is no conclusive scientific evidence on the effect of fermented foods on the composition of the microbiome. However, since most of them contain lactic acid bacteria (mainly *Lactobacillus* spp.), yeasts *Saccharomyces* spp., and *Bifidobacterium* spp., it is estimated that the consumption of food containing these fermentations can stimulate the colonization of the same in the gut and enhance their beneficial effects over health.





# Machine Learning & Microbiome for Precision Nutrition

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MICROBIOME

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