

# Stages of change toward meat reduction: associations with motives and longitudinal dietary data on animal-based and plant-based food intakes in French adults

Anouk Reuzé, Caroline Méjean, Lucie Sirieix, Julia Baudry, Emmanuelle Kesse-Guyot, Nathalie Druesne-Pecollo, Joséphine Brunin, Serge Hercberg, Mathilde Touvier, Sandrine Péneau, et al.

# ▶ To cite this version:

Anouk Reuzé, Caroline Méjean, Lucie Sirieix, Julia Baudry, Emmanuelle Kesse-Guyot, et al.. Stages of change toward meat reduction: associations with motives and longitudinal dietary data on animal-based and plant-based food intakes in French adults. Journal of Nutrition, 2023, 153 (11), pp.3295-3307. 10.1016/j.tjnut.2023.09.017. hal-04222209

# HAL Id: hal-04222209 https://hal.inrae.fr/hal-04222209

Submitted on 4 Oct 2023

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1	Stages of change toward meat reduction: Associations with motives and longitudinal
2	dietary data on animal-based and plant-based food intakes in French adults
3	Anouk Reuzé <sup>1</sup> , Caroline Méjean <sup>2</sup> , Lucie Sirieix <sup>2</sup> , Julia Baudry <sup>1</sup> , Emmanuelle Kesse-Guyot <sup>1</sup> ,
4	Nathalie Druesne-Pecollo <sup>1</sup> , Joséphine Brunin <sup>1</sup> , Serge Hercberg <sup>1</sup> , Mathilde Touvier <sup>1</sup> , Sandrine
5	Péneau <sup>1</sup> , Benjamin Allès <sup>1</sup>
6	<sup>1</sup> EREN, Université Sorbonne Paris Nord, CRESS, INSERM, INRAE, Cnam, Bobigny;
0	<sup>2</sup> MOISA, Université de Montpellier, CIRAD, CIHEAM-IAMM, INRAE, IRD, Institut Agro,
7	Montpellier, France
8	
9	Postprint : Reuzé A., Méjean C., Sirieix L., Baudry J., Kesse-Guyot E., Druesne-Pecollo N.,
	Brunin J., Hercberg S., Touvier M., Péneau S., Allès B. (2023). Stages of change toward
10	meat reduction: associations with motives and longitudinal dietary data on animal-based and
11	plant-based food intakes in French adults. Journal of Nutrition:
12	https://doi.org/10.1016/j.tjnut.2023.09.017
13	
14	Sources of support for the work
15	The NutriNet-Santé study is supported by the French Ministry of Solidarity and Health, the
16	National Agency for Public Health (Santé Publique France), the National Institute for Health
10	and Medical Research (INSERM), the National Research Institute for Agriculture, Food and
17	Environment (INRAE), the National Conservatory of Arts and Crafts (CNAM), the Centre for
18	Epidemiological Research and Statistics (CRESS) and Sorbonne Paris Nord University. The
	funders had no role in the design of the study, in the collection, analysis, or interpretation of
19	data, in the writing of the manuscript, or in the decision to publish the results.
20	Conflict of interest
21	Anouk Reuzé, no conflicts of interest
22	Caroline Méjean, no conflicts of interest
23	Lucie Sirieix, no conflicts of interest
24	Julia Baudry, no conflicts of interest
	Emmanuelle Kesse-Guyot, no conflicts of interest

- 25 Nathalie Druesne-Pecollo, no conflicts of interest
- 26 Joséphine Brunin, no conflicts of interest
- 27 Serge Hercberg, no conflicts of interest
- 28 Mathilde Touvier, no conflicts of interest
- 29 Sandrine Péneau, no conflicts of interest
- 30 Benjamin Allès, no conflicts of interest
- 31

## 32 Ethics approval and consent to participate

33 The NutriNet-Santé study complies with the Declaration of Helsinki guidelines and was

34 approved by the Institutional Review Board of the French Institute for Health and Medical

35 Research (IRB Inserm No. 0000388FWA00005831) and the French data protection authority

36 (Commission Nationale de l'Informatique et des Libertés, CNIL No. 908450/ No. 909216).

37 The study protocol is registered at ClinicalTrials.gov under the number NCT03335644. All

38 subjects provided informed consent.

39

# 40 **Consent for publication**

- 41 Not applicable
- 42

#### 43 Availability of data and materials

44 The datasets generated and/or analyzed in this study are secure under health data regulations

45 set by the French data protection authority (Commission Nationale de l'Informatique et des

46 Libertés, CNIL) and are not publicly available. The data are available upon reasonable request

- 47 to the study's operational manager, Nathalie Druesne-Pecollo (n.pecollo@eren.smbh.univ-
- 48 paris13.fr), for review by the NutriNet-Santé study steering committee.

	2
71	ч
-	-

50	Corresponding author
51	Anouk Reuzé
52	Équipe de Recherche en Épidémiologie Nutritionnelle (EREN) – Centre de Recherche en
53	Épidémiologie et Statistiques (CRESS), Université Sorbonne Paris Nord, Inserm U1153,
54	Inrae U1125, Cnam
55	UFR SMBH,
56	74, rue Marcel Cachin,
57	F-93017, Bobigny, France
58	(a.reuze@eren.smbh.univ-paris13.fr)
59	
60	Running title
61	Stages of change and motives toward meat reduction
62	List of abbreviations
63	BMI: body mass index; PDI: plant-based diet index; SEM: standard error of the mean; SD:
64	standard deviation; TEI: total energy intake; TTM: transtheoretical model.
65	
66	
67	
68	
69	
70	

#### 71 Abstract

Background: Reducing meat consumption is advocated for healthier and more sustainable
diets. However, behavioral studies are needed to better understand the mechanisms underlying
meat-reducing dietary changes.

**Objective:** The main aim of this study was to compare the motives associated with stages of change toward meat reduction in French adults, using the transtheoretical model (TTM). A second aim was to investigate the associations between stages of change and adherence to dietary patterns favoring a better balance of animal and plant food consumption over time.

79 Methods: This longitudinal study included 25,143 non-vegetarian participants of the webbased NutriNet-Santé cohort with a mean follow-up of 6.2 (SD = 2.6) years. Dietary data 80 were obtained from 24-hour dietary records over the period 2009–2019. Contribution of meat 81 to total energy intake and scores measuring the contribution of healthy and unhealthy plant-82 based foods to the diet were computed. A questionnaire completed in 2018 allowed us to 83 identify the TTM stages of change related to meat reduction (precontemplation, 84 85 contemplation, preparation, action, maintenance), and recorded motives related to meat consumption. We used multivariate linear mixed models for repeated data to assess 86 associations between food intake changes and stages, and logistic regression for motives, 87 presented as adjusted frequencies. 88

89 **Results:** Participants in late stages were characterized by a significantly higher decrease in 90 meat intake over time, compared to the earliest stage (e.g.,  $\beta_{\text{maintenance}*time} = -0.08$ , p < 0.0001), 91 and a higher increase in the healthy plant-based food consumption score over time 92 (e.g.,  $\beta_{\text{maintenance}*time} = 0.11$ , p < 0.0001). Concerns about health, nutrition, and the environment 93 were the most frequently cited motives for reducing meat consumption at all stages.

94	Conclusions: Individuals who had already initiated meat reduction adhered to healthier and
95	more sustainable diets than meat continuers. Characterizing motives according to readiness to
96	reduce meat consumption could support tailored public health campaigns.
97	Clinical Trial Registry
98	Clinical Trial Registry: NCT03335644
99	https://clinicaltrials.gov/ct2/show/NCT03335644
100	
101	Key words
102	Longitudinal study; Epidemiology; Meat reduction; Transtheoretical model; Motives
103	Highlights
104 105 106 107 108 109 110 111 112	<ul> <li>Participants with higher levels of readiness were more likely to reduce their meat consumption for health, nutritional, and environmental motives than those with lower levels of readiness.</li> <li>Higher level of readiness to reduce meat consumption (i.e., action and maintenance stages of the TTM) was associated with a greater increase in healthy plant-based food consumption over time.</li> <li>Stages of change toward meat reduction were in line with observed changes in meat and meat product intakes measured by repeated 24 h dietary records.</li> </ul>
113	
114	
115	
116	
117	

#### 118 Introduction

119 One pathway for sustainable nutrition transition is a healthier balance of animal-based and plant-based foods. High meat consumption is associated with high environmental 120 121 pressure (1), animal welfare issues (2), and adverse effects on human health (1). Dietary guidelines have been released in several countries to curb the consumption of meat and 122 123 processed meat products (3-6). However, in most countries of the world, current levels of meat and meat product consumption remain above recommended ceilings for both human 124 health and the environment (1,7,8). Even so, consumer intention to reduce meat consumption 125 has recently increased (9,10). For example, in a recent study from the NutriNet-Santé cohort, 126 127 we identified a shift toward more sustainable and healthier diets, in particular reduced meat consumption (11,12). More research is needed to gain a better understanding of how meat 128 129 consumption is changing.

Emerging behaviors and the need to accelerate the sustainable food transition for as 130 many consumers as possible call for a better understanding of how intention becomes 131 132 behavior change. Studies focusing on behavior change have applied theories and models drawn from psychology and sociology to the question of meat reduction (13). Some theories, 133 such as the theory of planned behavior, evaluate behavior change as a continuum process such 134 as the theory of planned behavior (14–16). Others, such as the transtheoretical model (TTM) 135 and the model of self-regulated behavior (16,17) view it as a sequence of discrete stages (18). 136 The TTM is one of the most commonly used behavior change models in health (19) and 137 defines behavior change as a sequence of five temporal stages of change, representing 138 139 different levels of readiness, from a lack of awareness to intention and behavior change, based on past behavior and an action plan. These successive stages are (a) precontemplation (no 140 intention of reducing meat consumption, no awareness of the adverse effects associated with 141 142 eating meat), (b) contemplation (awareness of the adverse effects associated with eating meat,

intention to reduce meat), preparation (intention to reduce meat, action plan), action (recent
modifications to meat consumption), and maintenance (long-term modifications to meat
consumption) (18).

146 Though widely used, the TTM and stage-based models in general have been challenged (20-22). Some studies have criticized the stepwise modeling of the behavior 147 change process, one stage following another, and its unidirectionality, which does not let an 148 individual relapse into an earlier stage (14,23,80). The cut-off points on continuous variables 149 (time and intention) defining stages of change have also been criticized for their arbitrariness 150 (20,21). Even so, the TTM gives insights into the process of intentional behavior change and 151 152 the scope of intervention (13,23). As meat consumption is frequently a norm in Western culture, changing it may require a conscious decision (24). Intention and actual behavior 153 154 could conflict, and individual progress towards those stages that lead to behavior change needs to be studied (13). 155

156 To date, few studies have investigated the process of meat reduction across stages of change (13,25–28) and little is known about the link between the TTM for meat reduction and actual 157 dietary intakes. A few cross-sectional studies have suggested that individuals in later stages of 158 change consume less meat than those in earlier stages (13,26,27). However, these studies did 159 not use validated food questionnaires and large-scale longitudinal studies to assess changes in 160 food consumption across these stages. Also, in the context of sustainable food transition, to 161 the best of our knowledge, no study has examined whether reducing meat consumption 162 among non-vegetarians implies a shift toward a more plant-based diet over time. 163

To gain a better understanding of the process of behavior change, many studies have set out to identify factors influencing the reduction of meat consumption. Among these factors, several food choice motives have frequently been reported as inducing or hindering meat reduction, whether related to health (13,26,29–34), taste preferences (26,34), the

environment (13,26,29,30,34), animal welfare (26,30), or price (29,31–33). Social norms
(13,26,33) and representations (33), and motives related to external factors, such as food
convenience and accessibility (35) have also been described. Although many potential
motives for and against meat reduction have been identified in the literature, few studies have
investigated them in relation to individuals' levels of readiness to reduce their meat
consumption (13,26). A recent Danish study has suggested that motives may vary across the
stages of change toward meat reduction (13).

The main aim of this study was to compare motives for reducing or continuing meat consumption according to individual levels of readiness toward meat reduction in a population of non-vegetarian French adults. A secondary objective of this longitudinal study was to investigate the associations between stages of change and adherence to dietary patterns favoring a more desirable balance of animal-based and plant-based food consumption.

180

#### 181 Methods

## 182 **a. Study population**

The NutriNet-Santé study is a web-based prospective observational French cohort study 183 launched in May 2009 to investigate the relationship between nutrition and health, especially 184 chronic disease risk, and the determinants of dietary behavior and nutritional status. Briefly, 185 186 participants are Internet-using adult volunteers prospectively recruited among the general population. The study design is described elsewhere (36). It complies with the Declaration of 187 Helsinki and was approved by the Institutional Review Board of the French Institute for 188 189 Health and Medical Research and the French data protection authority (Commission Nationale de l'Informatique et des Libertés, CNIL 908,450 and 909,216). All the participants 190

signed an electronic informed consent statement. The ClinicalTrials identifier isNCT03335644.

193

# b. Self-reported reduction or continuation of meat consumption

A questionnaire on the motives and individual readiness for reducing consumption of animal-194 based foods in diet was developed, based on a previous questionnaire on food choice motives 195 196 (37–39). It was built jointly by epidemiology, nutrition, and social marketing researchers. 197 This non-mandatory questionnaire was sent in August 2018 to NutriNet-Santé participants. As meat, particularly ruminant meat, is a major concern for food sustainability and human health 198 199 (1), we focused on changing consumption of meat, defined as beef, minced or roast steak, rib steak, stew, ground beef in a dish such as lasagna or spaghetti Bolognese, veal, lamb, pork, 200 201 offal, breaded meat, game, rabbit or hare and all processed meats or derived products. This definition excludes poultry (turkey, chicken, duck, quail, pigeon). For detailed information 202 about this questionnaire, see a previous study (34). 203

#### 204 Stages of change

205 The questionnaire included a section on individual level of readiness to change meat consumption. Two questions classified participants into five groups corresponding to the five 206 207 stages of change in the TTM (18). First, each participant was asked to pick one answer to the question: "In recent years, have you reduced your meat consumption?" from eight possible 208 209 answers comprising five items related to the stages of change, and two items to include participants' situations outside the stages of change process. Participants who picked one of 210 the five items related to stages of change were classified as follows: precontemplation stage 211 212 ("No, I don't see the point"), contemplation stage ("No, but I plan to do so soon although I don't know exactly how" and "No, but I've already considered doing so although I haven't 213 changed my meat consumption"), preparation stage ("No, but I'm considering doing it soon 214

and I know how"). Participants who gave a favorable response ("Yes") to the question were 215 216 classified in one of the two subsequent stages, namely action and maintenance, and were 217 asked a second question on how long they had been reducing their meat consumption, "Could you please tell us roughly how long you've been reducing your meat consumption?". In the 218 TTM, the boundary between the action and maintenance stages is defined by how long ago 219 220 the behavior change occurred; in the original model it was set at 6 months (18). However, 221 many authors have criticized the arbitrariness with which this value was set (see for example (21)), and its inappropriateness in certain contexts, particularly dietary change (13,40,41). To 222 223 choose the most appropriate boundary value for our context, we conducted sensitivity 224 analyses based on how long ago the change in behavior occurred. We compared three lengths 225 of time (less than 1 year, 1–2 years, more than 2 years) with the daily mean food intakes (in g/day). We observed significant differences between mean food consumptions for participants 226 227 who made a change less than 2 years ago and those who did so more than 2 years ago. We 228 therefore set the boundary at 2 years. Participants who answered that they had reduced their meat consumption for less than 2 years were classified in the action stage and those who had 229 reduced their meat consumption for longer than 2 years were classified in the maintenance 230 231 stage.

Participants whose responses did not correspond to any stage of change ("*No, it's for another reason*" and "*No, because I don't eat much meat anyway*") were categorized in a group
designated "other". Following the aim of this study, data for this group are not presented.

235

#### 236 Change-inducing and change-hindering motives toward meat reduction

237 Participants were asked to respond to the following two statements by "Yes" or "No": "I've

238 reduced, or already thought about reducing my meat consumption" (meat reduction) and "I've

always kept my meat consumption, I've never felt like reducing it" (meat continuation).

For either reduction or continuation of meat consumption, a set of motives was proposed,
including taste, health, environment, animal protection, and sociocultural influences (see all
items in **Supplemental Table 1**). We used the literature to select motives in the questionnaire
(30,42).

Motives: For each motive, participants who declared a change/continuation in their meat
consumption were asked to rate their corresponding motives on a 5-point Likert scale, from
"*Strongly disagree*" to "*Strongly agree*", including "*Neither agree nor disagree*", plus an "*I don't know*" answer. For example, participants who declared a reduction of their meat
consumption, were asked to rate statements such as "*I care about animal welfare and the lives of animals*" or "*I think it's healthier not to eat too much meat*".

250 Change-inducing and change-hindering motives: If participants gave a favorable response to one motive ("Somewhat agree" or "Strongly agree"), a second statement "and it encourages 251 me to reduce my meat consumption" was proposed to assess whether this motive induced a 252 253 change in consumption, on a separate 5-point Likert scale. Similarly, for meat continuation motives, a second statement "and this is one reason why I'm not reducing my meat 254 consumption" was proposed to assess whether this motive hindered a change in consumption. 255 256 Both Likert scales, for the motive and for the change-inducing or change-hindering motive, were then recoded to compute agreement scores ranging from 0 to 5 and from 1 to 5, 257 respectively. 258 Using the same method as described previously (34), participants were then classified into 259 three groups representing different types of motive, based on their answers to each motive: 260 "No motive": Participants were considered to have "no motive" if they gave an 261 unfavorable response ("Strongly disagree", "Somewhat disagree", "Neither agree nor 262

263 *disagree*" and "*I don't know*") for the motive.

For participants in this group, the motive related to animal welfare was thus not felt to be important.

- 266 "Motive, not change-inducing": Participants with a "motive, not change-inducing"
- 267 were those who gave a favorable response ("*Strongly agree*" and "*Somewhat agree*")
- to the motive but an unfavorable one ("Strongly disagree", "Somewhat disagree",
- 269 *"Neither agree nor disagree")* to the statement that the motive had induced a change

in consumption.

- For participants in this group, the motive related to animal welfare was thus felt to be important but was not declared as change-inducing.
- 273 "Change-inducing motive": Participants who gave favorable responses to both sets of
   274 statements were considered as having a "change-inducing motive".
- For participants in this this group, the motive related to animal-welfare was thus felt tobe important and did lead to a change.
- Similarly, for each motive related to meat continuation, participants were classified into three
  groups representing different types of motive: "no motive", "motive, not change-hindering",
  "change-hindering motive".
- 280 c. Dietary data

# 281 Dietary intake assessment

Dietary data were collected through web-based, self-administered 24 h dietary records using validated tools (43,44). At baseline and every 6 months, participants were asked to provide three non-consecutive-day 24 h dietary records (here, the term "follow-up" refers to each time that the three dietary records were completed). These three records were randomly assigned over a two-week period (two weekdays and one weekend day) to take into account the intravariability of the daily intake. The dietary assessment method took a meal-based approach, reporting all foods and beverages consumed at any eating occasion. After filling in names of all food items, portion size for each item was estimated using standard measurements or photographs from a validated picture manual (45). Mean daily quantities of food groups (in g/d for solid and mL/d for liquid) were calculated from 24 h dietary records, weighted according to the day (week or weekend) for each follow-up. Energy, macronutrient and micronutrient values from the dietary questionnaire were estimated by the NutriNet-Santé food composition table listing more than 3500 different foods (46).

Food and beverages were classified into 12 plant-based and 6 animal-based food groups 295 296 considering nutrients and culinary similarities, as developed by Satija et al. (47), and was 297 adapted for the NutriNet Santé database to match French consumption habits more closely 298 (48) (Supplemental Table 2). Owing to the increased diversity of plant foods consumed, we also estimated intakes of the following food groups: "Plant-based drinks" (e.g., soy, almond, 299 300 or rice), "Miscellaneous plant-based food" including subgroups such as "Meat and processed meat substitutes" (abbreviated "meat substitutes"), "Dairy dessert and cheese substitutes" 301 (abbreviated "dairy substitutes") and "Fermented or coagulated foods" (e.g., tempeh, tofu), 302 and "Uncooked cereals and seeds" (e.g., oatmeal, sesame seeds). Three indices including the 303 304 contribution of meat, processed meat, and meat products to total energy intake were also 305 computed.

#### 306 Plant-based diet indices

The three plant-based diet indices developed by Satija et al. were used to assess the contribution of plant-based foods to the diet (47). These indices measure the impact of plantbased foods on health: the plant-based diet index (PDI), the healthy plant-based diet index (healthy PDI) and the unhealthy plant-based diet index (unhealthy PDI). These indices were computed based on the consumption of the 18 food groups (12 plant-based foods and 6 animal-based food groups) mentioned above. For each food group, the participants' intakes

were classified into quintiles. The 18 food groups were classified into three categories 313 314 according to their source (animal or plant) and nutritional quality: healthy plant-based foods, 315 unhealthy plant-based foods, and animal-based foods. For a given individual, a sub-score for each of the food groups was assigned based on the category of the food group and the quintile 316 317 of consumption of the food group. The sub-scores for the 18 food groups were then summed to obtain the final scores (range 18–90). To compute PDIs, positive scores were given to the 318 319 healthy and unhealthy plant-based food categories (score of 1 for the first quintile and score of 5 for the fifth quintile) and reverse scores to animal-based food category (score of 1 for the 320 fifth quintile and score of 5 for the first quintile). The same method was used for healthy 321 322 PDIs, with positive scores for healthy plant-based food groups and reverse scores for 323 unhealthy plant-based food and animal-based food groups, and for unhealthy PDIs, with positive scores for unhealthy plant-based food and reverse scores for healthy plant-based food 324 325 and animal-based food groups. A higher PDI thus reflected higher consumption of plant-based 326 foods and lower consumption of animal-based foods compared to the sample. A higher healthy PDI reflected higher consumption of healthy plant-based foods. A higher unhealthy 327 PDI reflected higher consumption of unhealthy plant-based foods. 328

329

# d. Sociodemographic, anthropometric, and lifestyle data

330 At baseline and once a year thereafter, participants were invited to fill out a set of self-

administered questionnaires on sociodemographic, anthropometric, and lifestyle

332 characteristics. For this study, characteristics collected closest to the questionnaire on changes

- in meat consumption were used. Data collected included sex, age, occupational category
- 334 (unemployed/self-employed, farmer, employee, manual worker/intermediate
- 335 profession/managerial staff, intellectual profession/no occupation) corresponding to their last
- 336 occupational category before retirement, educational level (none or
- 337 primary/secondary/undergraduate and others/postgraduate), household composition (alone

without children/alone with at least one child/two adults living as a couple without children/ 338 339 two adults living as a couple with at least one child/two or more adults without children), size 340 of urban residence unit (rural/<20,000 inhabitants/20,000-200,000 inhabitants/>200,000 inhabitants). Monthly income per household unit was obtained per household consumer unit 341 (c.u.). One c.u. was assigned to the first adult in the household, 0.5 c.u. for other persons aged 342 14 or older and 0.3 c.u. for children under 14. Five categories were defined and were assigned 343 344 to participants: <1200 € per c.u./1200–1800 € per c.u./1800–2700 € per c.u./>2700 € per c.u./refused to declare). The date of the most recent weight-loss diet followed was collected, 345 and individuals were classified into three groups: no weight-loss diet, <5 years, >5 years. 346 347 Self-reported height and weight measurements were collected. Body mass index (BMI) was calculated as weight (kg) per height squared (m<sup>2</sup>), and participants were classified into three 348 categories, according to World Health Organization (WHO) criteria: underweight 349 350 (<18.5 kg/m<sup>2</sup>), normal (18.5–25 kg/m<sup>2</sup>), overweight (excluding obesity) (25–30 kg/m<sup>2</sup>), obese  $(\geq 30 \text{ kg/m}^2)$  (49). Self-reported height and weight measurements were validated against 351 clinical measurements (50). Level of physical activity was assessed using the International 352 Physical Activity Questionnaire (IPAQ) (51), and three categories were defined. 353

354

### e. Statistical analysis

We included participants who had dietary data at least at two different follow-up times, from their inclusion in the cohort study until 6 months after the questionnaire on changes in meat consumption (included between 2009 and 2019). In addition, only follow-ups with two or three 24-hour dietary records were considered. Self-reported vegetarians and vegans together with those declaring they had eaten no meat in recent years were excluded from the study (n = 3162), giving a final sample of 25,143 participants. More details of selection criteria can be found in the flowchart (**Supplemental Figure 1**).

362 Sociodemographic, anthropometric, and lifestyle characteristics

Sociodemographic, anthropometric, and lifestyle characteristics were described in the
total sample and compared across groups of individuals corresponding to stages of change
using chi2 and ANOVA tests.

366 *Food consumption* 

We collected all dietary data from each complete follow-up over the period from 367 inclusion in the cohort study until 6 months after the questionnaire on changes in meat 368 369 consumption. For each follow-up, we computed mean daily food consumptions based on available 24 h dietary records, together with the six dietary indices in relation to animal-based 370 and plant-based food consumptions: daily mean contributions of meat, processed meat, and 371 372 meat products to total energy intake, PDIs, healthy PDIs, and unhealthy PDIs. For each follow-up, PDIs, healthy PDIs, and unhealthy PDIs were calculated according to the 373 consumption guintiles of the dietary data collected in 2009 and 2010. 374

First, we compared the mean daily consumption of meat, processed meat and meat products at inclusion and at the latest follow-up available for each participant, for the five stages of change.

Secondly, we assessed the mean daily food consumption over the period 2009–2019 by computing the average of the mean daily food consumptions of each follow-up. These means were adjusted for sex, age, and total energy intake for the mean daily food consumptions and mean PDIs, healthy PDIs, and unhealthy PDIs, and for sex and age for the mean daily contributions of meat, processed meat, and meat products to total energy intake using linear regression models.

The above two analyses included adjustments to correct potential estimation bias but did not include comparison tests. Accordingly, we conducted additional analyses using multivariate linear mixed models. These models were run to assess the association between the six dietary indices related to animal-based and plant-based food consumptions in the diet

over time (as outcomes) and stages of change (as the main explanatory variable, with the 388 389 precontemplation stage as reference). This approach provides a more robust assessment of potential changes in dietary behaviors over time. Mixed models for repeated measures were 390 used (PROC MIXED in the statistical software SAS®), with dietary indices as fixed effects, 391 and intercept and time as random effects. In our analysis, the variable "time" refers to the 392 length of time between the completion of the baseline dietary questionnaire and the 393 394 completion of another questionnaire during the follow-up. The value of "time" corresponds to 395 the date on which the baseline dietary questionnaire was completed. Given the non-normal distribution of the contributions of meat, processed meat, and meat products to the total 396 397 energy intake, logarithmic transformations (Napierian) were computed and used as 398 normalized dependent variables in the three corresponding models. The beta coefficient for stages of change represents the difference between the dietary index of a given stage and the 399 400 precontemplation stage of change (reference) at baseline. The beta coefficient for stages of change  $\times$  time interaction represents the difference in slope between the curve representing 401 the dietary index over time for a given stage of change and the curve for the reference stage of 402 change. Models were adjusted for sex and for characteristics collected closest to the 403 404 questionnaire on changes in meat consumption, including age (continuous), educational level, 405 number of follow-up times at which dietary data were recorded, monthly household income 406 classes, occupational category, household composition, size of urban residence unit, BMI category, date of most recent weight-loss diet and physical activity level. Models for PDI, 407 408 healthy PDI, and unhealthy PDI were also adjusted on the total energy intake, collected at the latest available follow-up. Models for contribution of meat, processed meat, and meat 409 products to the total energy intake were run on the total sample, excluding participants who 410 did not consume the food product measured by the index. 411

412 Motives related to meat reduction and meat continuation according to stage of change

In contrast to an earlier study conducted by our group (11), we used new variables of motives for meat reduction or continuation using the dedicated questionnaire previously described in the methods, and also described elsewhere (34). In this study, motives for reducing meat were described in the contemplation, preparation, action, and maintenance stages, and motives for continuing meat consumption were assessed for the precontemplation and contemplation stages.

419 For each motive, we ran multivariable logistic regression models between the groups representing different types of motive (no motive; motive, not change-inducing/hindering; 420 change-inducing/hindering motive) and the stages of change. These models were adjusted for 421 422 sex, age, educational level, monthly household income classes, occupational category, 423 household composition, size of urban residence unit, BMI, date of most recent weight-loss diet and level of physical activity. We then computed the adjusted percentages from these 424 425 regression models and for either meat reduction or meat continuation, adjusted frequencies of 426 the three groups representing different types of motive were described according to stage of change. 427

All tests were two-sided, and a *p*-value of <0.05 was considered significant. Statistical</li>
analyses were conducted with SAS® (version 9.4, SAS Institute, Inc.) and some of the figures
were made with R Studio® (version 3.6.2, RStudio, Inc).

431

#### 432 **Results**

433

#### a. Sample selection and description

A total of 25,143 participants were included in this analysis. Characteristics of the sample are
given in **Table 1**. Women made up 74.8% of the sample. Mean age at date of completion of
the meat consumption questionnaire was 56.4 years (Standard Deviation (SD) = 13.8). More
than 70% of the participants were at least undergraduate level, two-thirds belonged to an

occupational category corresponding to a higher socioeconomic position (e.g., managerial
staff), and a third reported a monthly income per household above 2700 € (Table 1). More
than 60% of participants were in one of the two last stages (action and maintenance)
(Table 1).

442 Sociodemographic, anthropometric, and lifestyle characteristics were compared according to the five stages of change. Participants in the precontemplation stage included the highest 443 444 proportion of men, whereas we observed the highest proportion of women in the action stage group. We also observed a higher proportion of older individuals in the precontemplation 445 stage, whereas the contemplation stage group included a higher proportion of younger 446 447 individuals. Participants in the maintenance stages included the highest proportion of 448 individuals with high educational level. Participants in the preparation stage included the highest proportion of individuals with lower physical activity whereas the maintenance stage 449 450 included the highest proportion of participants with high level of physical activity (see Supplemental Table 3 for detailed results). 451

# 452 b. Dietary intakes and indices of healthy and unhealthy plant-based diets according 453 to stage of change

454 Over the period 2009–2019, the median number of follow-up times at which dietary data were 455 recorded was 7 and the mean follow-up period was 6.2 (SD = 2.6) years.

Regardless of the stage of change, participants consumed less meat, processed meat, and meat products, comparing consumptions at baseline and at the latest available follow-up (except for processed meat in the preparation stage) (**Figure 1, A**). Mean consumption of meat, processed meat, and meat products gradually decreased between groups from the precontemplation to the maintenance stage, at both inclusion (e.g., for meat, 57.5 (SD = 47.0) g/day for precontemplation stage vs. 41.3 (SD = 40.1) g/day, for maintenance stage) and at the latest available follow-up (e.g. for meat, 51.4 (SD = 46.4) vs. 33.2 (SD=37.0) g/day,

463 respectively). For more detailed results for dietary intakes among consumers, see

# 464 **Supplemental Table 4**.

Over the follow-up period, the adjusted mean daily contributions of meat products, 465 meat, and processed meat to total energy intake gradually decreased between the groups, from 466 467 precontemplation stage to maintenance stage. Adjusted mean PDI and healthy PDI gradually increased between the groups (for PDI, 47.6, for precontemplation stage, and 51, for 468 469 maintenance stage; for healthy PDI, 52.7 and 56.3, respectively), while unhealthy PDI was progressively slightly lower (respectively, 58.5 and 56.8) (Supplemental Figure 2). We also 470 observed higher consumptions of meat and dairy plant-based analogues (e.g., soy or almond 471 472 milk, plant-based patties, tofu, etc.) in later stages of meat reduction (see Supplemental Figure 473 2).

# 474 c. Evolution of meat intakes and of the contribution of healthy and unhealthy plant475 based foods to the diet, according to stage of change

476 At baseline, there was a significant association between the action and maintenance 477 stages and a smaller contribution of meat products to the diet, compared to the 478 precontemplation stage (Supplemental Table 5). Only later stages were significantly associated with the slope of meat, processed meat, and meat product consumptions over time, 479 480 meaning that only these participants showed a higher decrease in their consumption of meat products over time, compared to those in the precontemplation stage (Figure 1, B). 481 Stages of change toward meat reduction were all statistically associated with higher scores of 482 PDI and healthy PDI at baseline, compared to the precontemplation stage (Supplemental 483 Table 6). Only the last two stages were significantly associated with the slope of PDI and 484 485 healthy PDI over time, compared to the precontemplation stage (Figure 1, B). The action stage was statistically associated with a higher contribution of plant-based foods over time 486 and a higher contribution of healthy plant-based food over time, compared to the 487

precontemplation stage. For the maintenance stage, we also observed a statistically higher
contribution of overall plant-based food and healthy plant-based food over time. At baseline,
the contribution of unhealthy plant-based food to the diet was statistically lower for
participants in the contemplation, preparation, action, and maintenance stages, compared to
those in the precontemplation stage.

493 Finally, no significant association was observed between the four stages of change and the494 slope of unhealthy PDI over time.

495 d. Motives for meat reduction and meat continuation according to stage of change

# 496 Motives for meat reduction

Concerns about health, nutrition, and preservation of the environment were the motives most 497 frequently declared for reducing meat consumption by participants in the contemplation, 498 preparation, action, and maintenance stages (Table 2). Frequencies of participants declaring 499 these motives as change-inducing were even higher between the early and the later stage of 500 501 change (e.g., for the health motive, 51% for contemplation vs. 75.3% for maintenance in the 502 "change-inducing motive" group). In addition, some motives were felt to be important, but were less frequently declared as encouraging meat reduction in every stage of change. For 503 example, up to 65% of participants in each stage declared they had concerns about animal 504 505 welfare (participants in "motive, not change-inducing" and "change-inducing motive" groups). However, this motive was declared to have induced meat reduction in fewer than half 506 of participants in all stages (33.1% for contemplation and 47.4% for maintenance, in the 507 508 "change-inducing motive" group). Also, fewer than 10% of the participants declared motives such as aversion to the taste of meat or doctor's advice as change-inducing. 509

# 510 *Motives for meat continuation*

In both the precontemplation and contemplation stages, the pleasure of eating meat was 511 512 frequently reported as a motive to continue meat consumption (73.9% and 67.1% for the precontemplation and contemplation stages, respectively, corresponding to the "change-513 hindering motive" group) (Table 3). Other motives such as thinking that meat is a good 514 source of protein (64% and 53.4%), and that meat is part of personal culture (49.7% and 53%) 515 516 were also fairly frequently declared as motives for not reducing meat consumption. 517 Participants in the precontemplation stage frequently declared that they continued their meat consumption because they thought meat had health benefits (63.6%). Participants in the 518 contemplation stage frequently declared that they continued their meat consumption owing to 519 520 difficulty changing their meat-eating habits (51.5%). 521

522 **Discussion** 

Concerns about health, nutrition, and the preservation of the environment motivated 523 524 individuals to reduce their meat consumption. Liking meat seemed to be one of the main barriers to change. Being in later stages of change toward meat reduction was associated with 525 a higher decrease in the consumption of meat products and a higher increase in the 526 527 consumption of healthy plant-based foods over time. To the best of our knowledge, this study is the first to examine the association between quantitative measures, which represent an 528 evolution of food intakes, and the TTM, and to investigate a phase model of behavior change 529 related to meat reduction in the French population. 530

531

According to the principles of the TTM applied to meat reduction, individuals in thetwo last stages of change (action and maintenance) had already started to reduce their meat

consumption. Observed meat intakes over time were consistent with self-reported intentionsand behavior change, supporting the use of this TTM construct.

We observed that individuals who had already started to reduce their meat consumption
consumed more plant-based foods, and especially healthy plant-based foods, than animalbased foods over time, compared to those who had no intention of changing their
consumption (i.e., the precontemplation stage). Previous data in the same cohort study, using
food frequency questionnaires and general food choice motives highlighted a slight trend
towards healthier and plant-based diets over time in some parts of the population (12), notably
in individuals with sustainability food concerns (11).

543

In our study, we found that concerns for health and nutrition were the main effective 544 motives for reducing meat consumption for participants in contemplation through to 545 maintenance stages. These two motives have been widely cited by meat reducers in previous 546 547 studies (52), and even more among individuals in later stages (53). Yet the same two motives were also declared by participants who continued their meat consumption at the earlier stages 548 of change, especially in the precontemplation stage. This in line with other studies which 549 550 found that these motives were strongly expressed by meat eaters (31, 53-55), for example those in the precontemplation stage (26,30). This paradox or ambivalent role of health and 551 nutrition-related motives has been described previously (31,56,57) and may be partly 552 explained by the evolution of messages derived from dietary guidelines over the last 20 years. 553 These messages have evolved from encouraging meat intake in the early 2000s, to 554 555 discouraging red meat and processed meat in the late 2010s and setting recommended ceilings 556 (4).

557 Among change-inducing motives, preserving the environment was also frequently 558 declared as a reason for reducing meat consumption, particularly in the later stages. This 559 finding is in line with the recent Danish study (13), although previous studies have reported 560 heterogeneous results (9,29,31,58). Public health campaigns combining health and 561 environmental impacts of meat in their messages could thus be an effective strategy for 562 encouraging meat reduction compared to a message focusing on a single motive, as suggested 563 by a previous British study (59).

Concern for the preservation of animal life and for animal welfare was declared with 564 moderate frequency as having induced meat reduction, compared to the previously cited 565 566 motives. Animal welfare may be a stronger lever in other cultural settings (60) and especially for vegetarians or vegans (61), but we lack results on the effectiveness of this motive in 567 reducing meat consumption in non-vegetarian populations. An intervention study highlighted 568 569 that information about animal welfare had a strong effect on reducing meat consumption in 570 Germany (55). To provide information about animal welfare, front-of-pack labels were 571 developed (62), but are seldom available on food products in many countries including 572 France. Few results are available on the effectiveness of such labels in influencing food choices (63), but further studies could investigate whether such information can incentivize 573 574 meat reduction.

Among change-hindering motives, enjoying meat was the main motive reported by participants for continuing their meat consumption. This motive was even more often stated by consumers who had no intention of changing their consumption (precontemplation stage). Many previous studies have shown that the sensory attributes of meat, and in particular its taste, were a main lever of meat consumption (54,64), and so formed an important disincentive to meat reduction (61,65). Furthermore, in our study, food habits and culinary traditions seemed to hinder change in meat consumption, especially among individuals who

declared their intention to reduce meat (contemplation stage), as previously described (53). As 582 583 the pleasure of eating is a core value of French food culture, public health authorities could also promote messages following the "less but better" principle (66), that is to say eating less 584 animal-based foods both in quantity and frequency, but choosing those with better overall 585 586 quality: fair trade, organic, or short circuit supply. To reduce their meat consumption, individuals could replace animal-based dishes by plant-based dishes in their meals, assuming 587 588 they have the cooking skills and ideas for plant-based food recipes (67). Public health 589 authorities could provide practical advice such as shopping tips, weekly meal planning, and recipes to help consumers add plant-based meals to their food habits such as the "La Fabrique 590 591 à menus" in France (68)). Tasty plant-based products such as legumes could also be 592 promoted, in line with previous findings (34).

Our study has some limitations. The study population consisted of volunteers, 593 registered to answer questionnaires related to health and nutrition. This population might 594 595 therefore have been more aware of health and nutrition issues. Although over 60% of the 596 participants declared they had initiated a reduction in meat consumption, the mean intake of 597 meat remained similar to national representative surveys (69). Another limit is the overrepresentation of women in our study sample compared to the general population (70), as 598 599 commonly observed in various epidemiological studies (70), possibly producing selection bias. This over-representation could mean an over-representation of individuals reducing or 600 willing to reduce their meat consumption, as it is well-established that sex is associated with 601 changes in meat consumption (52,71). Nevertheless, our study offers the advantage of a large 602 sample size, with over 25,000 participants, enabling us to identify a diverse range of meat 603 604 consumption behaviors. Besides those who reduced their meat consumption, we identified 605 more than 6,000 participants who reported continuing their meat consumption, of whom

51.8% reported no interest in reducing meat. Our analysis was controlled for

607 sociodemographic characteristics, including sex, which helps limit this bias.

Secondly, some limitations regarding the use of the TTM can be highlighted, such as the 608 609 arbitrary boundary between the action and maintenance stages, set at 2 years in this study. These stages are distinguished by the length of time since the behavior change occurred, 610 which can be difficult to define in specific contexts, especially for food behavior (13,40,41). 611 In addition, the definitions of contemplation and preparation stages is heterogeneous in the 612 literature (13). For this study, we defined these stages in line with both the original definition 613 of the TTM and the study of Tobler et al. (30). We note that the use of different thresholds 614 615 and the variability of definitions in different studies make comparison between findings difficult and so might limit the external validity of our results. 616

617 Our study design did not enable us to study the characteristics of individuals who had reduced 618 their meat consumption, but no longer do so, compared to those who were still reducing their 619 consumption. Further research could address this topic.

Some authors have questioned the validity of the stages of change, suggesting that finer distinctions within stages may be relevant (72). For example, some authors have suggested subcategories for the precontemplation stage, such as "aware" and "unaware" (73). However, as claimed by one of the original authors of the TTM, the purpose of this model is not to identify a rigidly defined set of stages and prove their existence, but rather to improve our understanding of the process of behavior change and the scope to influence this process (23). Future longitudinal studies could explore diverse decision-making paths.

627 Thirdly, as suggested by the TTM, the process of change involves an individual going through628 successive stages toward behavioral change. However, this model might not fully capture the

629 complexity of behavior change, as some individuals may skip a stage or stay in one (23,74),

630 or regress to an earlier stage (75). Further studies assessing stages at different time points

could specifically explore relapse and other dynamics of the process. However, we observed
that stages of change were in line with longitudinal dietary data. Our results support the use of
such a model, although we acknowledge that this approach can be completed by other models
of food behavior change.

Our study has several strengths. First, only a few studies in the literature have used the TTM to explore the process of meat reduction in a large population (13,26–28) or to explore the motives for meat reduction or continuation in the general population (13), although our sample may not be fully representative of the French population.

639 The longitudinal design of our study to explore the evolution of food consumption is another 640 strength. It enabled us to observe changes in meat and meat product consumption over time using validated dietary questionnaires, and to evaluate the nutritional quality of diets across 641 different stages of meat reduction. Further studies on the trajectory of other types of meat, 642 such as poultry, could provide more information on the sustainable food transition. In the 643 literature, certain studies suggest that meat reduction starts with increased poultry 644 consumption (76–78), but other studies, in line with our cross-sectional findings, indicate a 645 646 steady poultry consumption (31,76,78).

Another key strength of our study is that it examines the reduction in meat consumption in the specific context of France, where meat is central in the food culture (79). Meat reduction is thus highly relevant to a sustainable food transition in France. Transitions toward meat reduction may vary across different countries with different cultural and culinary backgrounds (28,80), which limits the comparison of the results. Our study may provide knowledge about Europeans who are less reluctant to reduce meat consumption, as more than 60% declared they were reducing their consumption, whereas in other studies, such as Denmark, only 27,6%

of participants did so (13). Country-specific studies are thus essential to ensure the relevanceand robustness of results for sustainable food transition.

### 656 *Conclusion*

In this study, longitudinal dietary data were in line with theoretical assumptions of the 657 TTM, individuals who had already initiated a meat reduction adhering to healthier and more 658 sustainable diets, as defined by the stages of change. Health, nutrition and environmental 659 concerns were associated with reduced meat consumption. Enjoying meat hindered meat 660 reduction, indicating an opportunity to provide advice and practical tools to enhance the 661 662 attractiveness of plant-based foods, particularly in specific populations who do not yet feel concerned by meat reduction. Further studies quantifying the environmental impacts of diets 663 could evaluate their contributions to enhance the current nutritionally sustainable transition. 664

665

#### 666 Acknowledgments

667 The authors thank all the volunteers of the NutriNet-Santé cohort.

668 We thank Cédric Agaesse, Alexandre De Sa, Rebecca Lutchia (dietitians); Thi Hong Van

669 Duong, Younes Esseddik (IT manager), Régis Gatibelza, Jagatjit Mohinder and Aladi Timera

670 (computer scientists); Julien Allegre, Nathalie Arnault, Laurent Bourhis and Fabien Szabo de

671 Edelenyi, PhD (supervisor) (data-manager/statisticians) for their technical contribution to the

672 NutriNet-Santé study and Nathalie Druesne-Pecollo, PhD (operational coordination).

## 673 Statement of authors' contributions to the manuscript

674 SH, CM, MT, SP, BA, EKG and NDP designed and implement the cohort study; BA, CM, LS

and AR designed research and provided essential materials; AR and BA analyzed data or

676 performed statistical analysis; AR drafted the paper; BA had primary responsibility for final

677 content. All the authors have read and approved the final manuscript.

678

# 679 **References**

- Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, Garnett T, Tilman D,
   DeClerck F, Wood A, et al. Food in the Anthropocene: the EAT–Lancet Commission on healthy
   diets from sustainable food systems. The Lancet 2019;393:447–92.
- Bonnet C, Bouamra-Mechemache Z, Réquillart V, Treich N. Viewpoint: Regulating meat
   consumption to improve health, the environment and animal welfare. Food Policy
   2020;97:101847.
- WHO. IARC Monographs evaluate consumption of red meat and processed meat [Internet].
  World Health Organization International Agency for Research on Cancer (IARC); 2015.
  Available from: https://www.iarc.fr/wp-content/uploads/2018/07/pr240\_E.pdf
- 4. HCSP. Révision des repères alimentaires pour les adultes du futur Programme national nutrition
  santé 2017-2021 [Internet]. Rapport de l'HCSP. Paris: Haut Conseil de la Santé Publique; 2017
  Feb. Available from: https://www.hcsp.fr/explore.cgi/avisrapportsdomaine?clefr=600
- 692 5. Anses. Actualisation des repères du PNNS : Révision des repères de consommations
  693 alimentaires [Internet]. Paris: ANSES; 2016 Dec. Available from:
  694 https://www.anses.fr/fr/system/files/NUT2012SA0103Ra-1.pdf
- 6. Continuous Update Project Report. Food, nutrition, physical activity, and the prevention of
   colorectal cancer. Colorectal cancer 2011 report [Internet]. London: WCRF; 2011. Available
   from: https://www.wkof.nl/sites/default/files/Colorectal-Cancer-2011-Report.pdf
- Miller V, Reedy J, Cudhea F, Zhang J, Shi P, Erndt-Marino J, Coates J, Micha R, Webb P,
  Mozaffarian D, et al. Global, regional, and national consumption of animal-source foods
  between 1990 and 2018: findings from the Global Dietary Database. The Lancet Planetary
  Health Elsevier; 2022;6:e243–56.
- Cocking C, Walton J, Kehoe L, Cashman KD, Flynn A. The role of meat in the European diet:
   current state of knowledge on dietary recommendations, intakes and contribution to energy
   and nutrient intakes and status. Nutrition Research Reviews Cambridge University Press;
   2020;33:181–9.
- Sanchez-Sabate R, Sabaté J. Consumer Attitudes Towards Environmental Concerns of Meat
   Consumption: A Systematic Review. International Journal of Environmental Research and Public
   Health Multidisciplinary Digital Publishing Institute; 2019;16:1220.
- Siegrist M, Visschers VHM, Hartmann C. Factors influencing changes in sustainability perception of various food behaviors: Results of a longitudinal study. Food Quality and Preference 2015;46:33–9.
- Brunin J, Allès B, Péneau S, Reuzé A, Pointereau P, Touvier M, Hercberg S, Lairon D, Baudry J,
   Kesse-Guyot E. Do individual sustainable food purchase motives translate into an individual
   shift towards a more sustainable diet? A longitudinal analysis in the NutriNet-Santé cohort.
   Cleaner and Responsible Consumption 2022;5:100062.

- Brunin J, Pointereau P, Allès B, Touvier M, Hercberg S, Lairon D, Baudry J, Kesse-Guyot E. Are
   recent dietary changes observed in the NutriNet-Santé participants healthier and more
   sustainable? Eur J Nutr 2022;61:141–55.
- Hielkema MH, Lund TB. Reducing meat consumption in meat-loving Denmark: Exploring
   willingness, behavior, barriers and drivers. Food Quality and Preference 2021;93:104257.
- Ajzen I. The theory of planned behavior. Organizational Behavior and Human Decision
   Processes 1991;50:179–211.
- de Gavelle E, Davidenko O, Fouillet H, Delarue J, Darcel N, Huneau J-F, Mariotti F. Self-declared
   attitudes and beliefs regarding protein sources are a good prediction of the degree of transition
   to a low-meat diet in France. Appetite 2019;142:104345.
- Weibel C, Ohnmacht T, Schaffner D, Kossmann K. Reducing individual meat consumption: An
   integrated phase model approach. Food Quality and Preference 2019;73:8–18.
- Bamberg S. Changing environmentally harmful behaviors: A stage model of self-regulated
   behavioral change. Journal of Environmental Psychology 2013;34:151–9.
- Prochaska JO, DiClemente CC, Norcross JC. In search of how people change. Applications to
   addictive behaviors. Am Psychol 1992;47:1102–14.
- Michie S, Johnston M, Abraham C, Lawton R, Parker D, Walker A, on b. Making psychological
   theory useful for implementing evidence based practice: a consensus approach. Qual Saf Health
   Care 2005;14:26–33.
- 20. Etter J-F. Theoretical tools for the industrial era in smoking cessation counselling: a comment
  on West (2005). Addiction 2005;100:1041–2; author reply 1048-1050.
- 737 21. West R. Time for a change: putting the Transtheoretical (Stages of Change) Model to rest.
  738 Addiction 2005;100:1036–9.
- 22. Littell JH, Girvin H. Stages of Change: A Critique. Behav Modif SAGE Publications Inc;
  2002;26:223–73.
- 741 23. Diclemente CC. A Premature Obituary for the Transtheoretical Model: A Response to West
  742 (2005). Addiction 2005;100:1046–8.
- Strässner A-M, Hartmann C. Gradual behaviour change towards meat reduction: Development
   and validation of a novel decisional balance scale. Appetite 2023;186:106537.
- 745 25. Klöckner CA. A stage model as an analysis framework for studying voluntary change in food
   746 choices The case of beef consumption reduction in Norway. Appetite 2017;108:434–49.
- Arnaudova M, Brunner TA, Götze F. Examination of students' willingness to change behaviour
   regarding meat consumption. Meat Science 2022;184:108695.
- Barbieri P, Palma RFM, Nishimura RY, Damião R, Bevilacqua M, Massimino F, Chain R, Gimeno
   SGA, Ferreira SRG, Sartorelli DS. Factors associated with stages of change for red meat and
   vegetable intake by Japanese-Brazilians. Cadernos de Saúde Pública 2009;25:1466–74.

- Wolstenholme E, Carfora V, Catellani P, Poortinga W, Whitmarsh L. Explaining intention to
  reduce red and processed meat in the UK and Italy using the theory of planned behaviour,
  meat-eater identity, and the Transtheoretical model. Appetite 2021;166:105467.
- 29. Lacroix K. Comparing the relative mitigation potential of individual pro-environmental
   behaviors. Journal of Cleaner Production 2018;195:1398–407.
- Tobler C, Visschers VHM, Siegrist M. Eating green. Consumers' willingness to adopt ecological
   food consumption behaviors. Appetite 2011;57:674–82.
- Neff RA, Edwards D, Palmer A, Ramsing R, Righter A, Wolfson J. Reducing meat consumption in
   the USA: a nationally representative survey of attitudes and behaviours. Public Health Nutrition
   2018;21:1835–44.
- 32. Lentz G, Connelly S, Mirosa M, Jowett T. Gauging attitudes and behaviours: Meat consumption
   and potential reduction. Appetite 2018;127:230–41.
- Vainio A, Niva M, Jallinoja P, Latvala T. From beef to beans: Eating motives and the replacement
   of animal proteins with plant proteins among Finnish consumers. Appetite 2016;106:92–100.
- Reuzé A, Méjean C, Carrère M, Sirieix L, Druesne-Pecollo N, Péneau S, Touvier M, Hercberg S,
  Kesse-Guyot E, Allès B. Rebalancing meat and legume consumption: change-inducing food
  choice motives and associated individual characteristics in non-vegetarian adults. International
  Journal of Behavioral Nutrition and Physical Activity 2022;19:112.
- Harguess JM, Crespo NC, Hong MY. Strategies to reduce meat consumption: A systematic
   literature review of experimental studies. Appetite 2020;144:104478.
- 36. Hercberg S, Castetbon K, Czernichow S, Malon A, Mejean C, Kesse E, Touvier M, Galan P. The
  Nutrinet-Santé Study: a web-based prospective study on the relationship between nutrition
  and health and determinants of dietary patterns and nutritional status. BMC Public Health
  2010;10:242.
- 37. Sautron V, Péneau S, Camilleri GM, Muller L, Ruffieux B, Hercberg S, Méjean C. Validity of a
   questionnaire measuring motives for choosing foods including sustainable concerns. Appetite
   2015;87:90–7.
- Péneau S, Fassier P, Allès B, Kesse-Guyot E, Hercberg S, Méjean C. Dilemma between health and
  environmental motives when purchasing animal food products: sociodemographic and
  nutritional characteristics of consumers. BMC Public Health [Internet] 2017 [cited 2019 May
  24];17. Available from: https://bmcpublichealth.biomedcentral.com/articles/10.1186/s12889017-4875-6
- Allès B, Péneau S, Kesse-Guyot E, Baudry J, Hercberg S, Méjean C. Food choice motives
  including sustainability during purchasing are associated with a healthy dietary pattern in
  French adults. Nutrition Journal [Internet] 2017 [cited 2019 May 16];16. Available from:
  http://nutritionj.biomedcentral.com/articles/10.1186/s12937-017-0279-9
- Povey R, Conner M, Sparks P, James R, Shepherd R. A critical examination of the application of the Transtheoretical Model's stages of change to dietary behaviours. Health Education Research 1999;14:641–51.
- 41. Bandura A. The anatomy of stages of change. Am J Health Promot 1997;12:8–10.

- 42. de Boer J, Hoogland CT, Boersema JJ. Towards more sustainable food choices: Value priorities
   and motivational orientations. Food Quality and Preference 2007;18:985–96.
- 794 43. Touvier M, Kesse-Guyot E, Méjean C, Pollet C, Malon A, Castetbon K, Hercberg S. Comparison
  795 between an interactive web-based self-administered 24 h dietary record and an interview by a
  796 dietitian for large-scale epidemiological studies. British Journal of Nutrition 2011;105:1055–64.
- 44. Lassale C, Castetbon K, Laporte F, Camilleri GM, Deschamps V, Vernay M, Faure P, Hercberg S,
  Galan P, Kesse-Guyot E. Validation of a Web-based, self-administered, non-consecutive-day
  dietary record tool against urinary biomarkers. Br J Nutr 2015;113:953–62.
- 45. Le Moullec N, Deheeger M, Hercberg S, Preziosi P, Monteiro P, Valeix P, Rolland=Cachera M-F,
  Potier de Courcy G, Christides J-P, Cherouvrier F, et al. Validation du manuel-photos utilisé pour
  l'enquête alimentaire de l'étude SU.VI.MAX. Cah nutr diét 1996;31:158–64.
- 46. Unité de recherche en épidémiologie nutritionnelle. Table de composition des aliments, Etude
  NutriNet-Santé (Food Composition Database, NutriNet-Santé study). Les éditions
  INSERM/Economica. Bobigny, France; 2013.
- Satija A, Bhupathiraju SN, Rimm EB, Spiegelman D, Chiuve SE, Borgi L, Willett WC, Manson JE,
  Sun Q, Hu FB. Plant-Based Dietary Patterns and Incidence of Type 2 Diabetes in US Men and
  Women: Results from Three Prospective Cohort Studies. PLoS Med 2016;13:e1002039.
- 48. Gehring J, Touvier M, Baudry J, Julia C, Buscail C, Srour B, Hercberg S, Péneau S, Kesse-Guyot E,
  Allès B. Consumption of Ultra-Processed Foods by Pesco-Vegetarians, Vegetarians, and Vegans:
  Associations with Duration and Age at Diet Initiation. The Journal of Nutrition 2021;151:120–
  31.
- 49. Obesity: preventing and managing the global epidemic. Report of a WHO consultation. Geneva,
  814 Switzerland: World Health Organization; 2000 p. 9. Report No.: 894.
- Lassale C, Péneau S, Touvier M, Julia C, Galan P, Hercberg S, Kesse-Guyot E. Validity of WebBased Self-Reported Weight and Height: Results of the Nutrinet-Santé Study. J Med Internet
  Res 2013;15:e152.
- 818 51. Hagströmer M, Oja P, Sjöström M. The International Physical Activity Questionnaire (IPAQ): a
   819 study of concurrent and construct validity. Public Health Nutr 2006;9:755–62.
- S2. Graça J, Godinho CA, Truninger M. Reducing meat consumption and following plant-based
   diets: Current evidence and future directions to inform integrated transitions. Trends in Food
   Science & Technology 2019;91:380–90.
- Sollier ES, Oberrauter L-M, Normann A, Norman C, Svensson M, Niimi J, Bergman P. Identifying
  barriers to decreasing meat consumption and increasing acceptance of meat substitutes among
  Swedish consumers. Appetite 2021;167:105643.
- Piazza J, Ruby MB, Loughnan S, Luong M, Kulik J, Watkins HM, Seigerman M. Rationalizing meat
   consumption. The 4Ns. Appetite 2015;91:114–28.
- S5. Cordts A, Nitzki S, Spiller A. Consumer Response to Negative Information on Meat Consumption
   in Germany. IFAMR 2014;17:83–106.

- de Boer J, Schösler H, Aiking H. Towards a reduced meat diet: Mindset and motivation of young
   vegetarians, low, medium and high meat-eaters. Appetite 2017;113:387–97.
- 57. Graves C, Roelich K. Psychological Barriers to Pro-Environmental Behaviour Change: A Review
  of Meat Consumption Behaviours. Sustainability Multidisciplinary Digital Publishing Institute;
  2021;13:11582.
- 58. De Backer CJS, Hudders L. From meatless Mondays to meatless Sundays: motivations for meat
  reduction among vegetarians and semi-vegetarians who mildly or significantly reduce their
  meat intake. Ecol Food Nutr 2014;53:639–57.
- 838 59. Wolstenholme E, Poortinga W, Whitmarsh L. Two Birds, One Stone: The Effectiveness of Health
  839 and Environmental Messages to Reduce Meat Consumption and Encourage Pro-environmental
  840 Behavioral Spillover. Front Psychol 2020;11:577111.
- 841 60. Zander K, Feucht Y. Consumers' Willingness to Pay for Sustainable Seafood Made in Europe.
  842 Journal of International Food & Agribusiness Marketing Routledge; 2018;30:251–75.
- Rosenfeld DL, Tomiyama AJ. Taste and health concerns trump anticipated stigma as barriers to
   vegetarianism. Appetite 2020;144:104469.
- 845 62. Vanhonacker F, Verbeke W. Public and Consumer Policies for Higher Welfare Food Products:
  846 Challenges and Opportunities. J Agric Environ Ethics 2014;27:153–71.
- 63. Hyland JJ, Regan Á, Sweeney S, McKernan C, Benson T, Dean M. Consumers attitudes toward
  animal welfare friendly produce: An island of Ireland study. Frontiers in Animal Science
  [Internet] 2022 [cited 2022 Sep 19];3. Available from:
  bttps://www.frontiersip.org/articles/10.3389/fapim 2022 930930
- 850 https://www.frontiersin.org/articles/10.3389/fanim.2022.930930
- 64. Mullee A, Vermeire L, Vanaelst B, Mullie P, Deriemaeker P, Leenaert T, De Henauw S, Dunne A,
  Gunter MJ, Clarys P, et al. Vegetarianism and meat consumption: A comparison of attitudes and
  beliefs between vegetarian, semi-vegetarian, and omnivorous subjects in Belgium. Appetite
  2017;114:299–305.
- 855 65. He J, Evans NM, Liu H, Shao S. A review of research on plant-based meat alternatives: Driving
  856 forces, history, manufacturing, and consumer attitudes. Comprehensive Reviews in Food
  857 Science and Food Safety 2020;19:2639–56.
- de Boer J, Schösler H, Aiking H. "Meatless days" or "less but better"? Exploring strategies to
  adapt Western meat consumption to health and sustainability challenges. Appetite
  2014;76:120–8.
- 67. Corrin T, Papadopoulos A. Understanding the attitudes and perceptions of vegetarian and
   plant-based diets to shape future health promotion programs. Appetite 2016;
- Fabrique à menus | Manger Bouger [Internet]. 2022 [cited 2021 May 17]. Available from:
   https://www.mangerbouger.fr/Manger-mieux/Vos-outils/Fabrique-a-menus
- Anses. Étude individuelle nationale des consommations alimentaires 3 (INCA3). France: Agence
  nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (ANSES); 2017
  Jun.

- Andreeva VA, Salanave B, Castetbon K, Deschamps V, Vernay M, Kesse-Guyot E, Hercberg S.
  Comparison of the sociodemographic characteristics of the large NutriNet-Santé e-cohort with
  French Census data: the issue of volunteer bias revisited. J Epidemiol Community Health BMJ
  Publishing Group Ltd; 2015;69:893–8.
- Stoll-Kleemann S, Schmidt UJ. Reducing meat consumption in developed and transition
  countries to counter climate change and biodiversity loss: a review of influence factors.
  Regional Environmental Change 2017;17:1261–77.
- 875 72. Brug J, Conner M, Harré N, Kremers S, McKellar S, Whitelaw S. The Transtheoretical Model and 876 stages of change: a critique: observations by five commentators on the paper by Adams, J. and 877 White, M. (2004) why don't stage-based activity promotion interventions work? Health Educ 878 Res 2005;20:244–58.
- Kechner L, Brug J, De Vries H, van Assema P, Mudde A. Stages of change for fruit, vegetable and
   fat intake: consequences of misconception. Health Education Research 1998;13:1–11.
- 74. Lenio JA. Analysis of the transtheoretical model of behavior change. 2006 [cited 2023 Sep 1];
  882 Available from: https://minds.wisconsin.edu/handle/1793/52717
- Prochaska JO, Velicer WF. The Transtheoretical Model of Health Behavior Change. Am J Health
  Promot SAGE Publications Inc; 1997;12:38–48.
- 76. Nevalainen E, Niva M, Vainio A. A transition towards plant-based diets on its way? Consumers'
   substitutions of meat in their diets in Finland. Food Quality and Preference 2023;104:104754.
- 887 77. Erkkola M, Kinnunen SM, Vepsäläinen HR, Meinilä JM, Uusitalo L, Konttinen H, Saarijärvi H,
  888 Fogelholm M, Nevalainen J. A slow road from meat dominance to more sustainable diets: An
  889 analysis of purchase preferences among Finnish loyalty-card holders. PLOS Sustainability and
  890 Transformation Public Library of Science; 2022;1:e0000015.
- Kotro J, Forsman-Hugg S. Diversifying meat
  consumption patterns: Consumers' self-reported past behaviour and intentions for change.
  Meat Science 2012;92:71–7.
- Poquet D, Chambaron-Ginhac S, Issanchou S, Monnery-Patris S. Interroger les représentations
  sociales afin d'identifier des leviers en faveur d'un rééquilibrage entre protéines animales et
  végétales : approche psychosociale. Cahiers de Nutrition et de Diététique 2017;sous presse:np.
- 897 80. de Boer J, Aiking H. Prospects for pro-environmental protein consumption in Europe: Cultural, 898 culinary, economic and psychological factors. Appetite 2018;121:29–40.

Table 1. Sociodemographic, anthropometric,	and lifestyle characteristics of	included participants and s	tages of change, NutriNet-
Santé, 2009–2018, <i>n</i> = 25,143			

	Total sample (n = 25,143)	
	n	% or mean (SD)
Sex		
Men	6326	25.2
Women	18817	74.8
Age (y)		56.4 (13.8)
Age (y, category)		
[18-30]	683	2.7
[30-50]	7127	28.4
[50-65] [65+[	8743 8590	34.8 34.2
Monthly household income class (ner u.c.)		
< 1200 €	3203	13.1
1200-1800€	5044	20.1
1800–2700 €	5966	23.7
> 2700 €	8478	33.7
Refused to declare	2362	9.4
Occupational category		
Self-employed, farmer, employee, manual worker	6510	25.9
Intermediate profession	6254	24.9
Managerial staff, intellectual profession	10388	41.3
Unemployed	1830	7.3
No occupation	161	0.6
Educational level		
None or primary	428	1.7
Secondary	6696	26.6
Undergraduate and others	8044	32.0
Postgraduate	9975	39.7
Household composition		
Alone without children	4612	18.3
Alone with at least one child	1621	6.5
Two adults living as a couple without children	10800	43.0
Two or more adult without children	//14 396	30.7
	570	1.0
Size of urban residence unit	5700	22.2
< 20,000 inhabitants	5602 2877	22.3
20,000-200,000 inhabitants	3877 4707	13.4
> 200,000 inhabitants	10957	43.6
Last weight-loss diet followed		
Not declaring a weight-loss diet	9615	38.2
< 5 years	1700	6.8
> 5 years	13828	55.0
BMI		
Underweight	1040	4.1
Normal	15426	61.4
Overweight	6229	24.8
Obesity	2448	9.7
Physical activity		
Low physical activity	4311	17.2

Moderate physical activity	9840	39.1
High physical activity	10992	43.7
Stages of change		
Precontemplation	3141	12.5
Contemplation <sup>1</sup>	1454	5.8
Participants who declared meat reduction (%)	916	63.0
Participants who declared meat continuation (%)	538	37.0
Preparation	184	0.7
Action	5052	20.1
Maintenance	10509	41.8

<sup>1</sup>Participants identified in the contemplation stage could either respond that they were thinking of reducing their meat consumption or that they were continuing their meat consumption.

Figure 1. Adjusted mean daily consumption of meat and processed meat (and SEM) at the inclusion in the cohort and closest to the questionnaire on stages of change, according to stage of changes (n = 25,143) (A)<sup>1</sup> and changes in percent energy intake provided by meat (logarithm of the contribution of the given food to total energy intake, n = 24,715) and in healthy PDI (n = 25,143) over time according to the group of individuals in stages of change in French adults participating in the NutriNet-Santé cohort (multivariate linear mixed models)<sup>2</sup> (B).





Stages of change

Precontemplation
 Contemplation
 Preparation
 Action

Maintenance



<sup>1</sup>Mean daily consumptions have been adjusted for sex, age (continuous) and mean total energy intake

<sup>2</sup> The mean predicted trajectories (solid lines) with 95% confidence intervals (indicated with shading) were plotted for a chosen profile of covariates. We chose the mean number of dietary records (7.8), of an average study participant profile at the date of the questionnaire on stages of change: a woman, aged 56.4 years, with a total energy intake equal to 1832 kcal (for hPDI only), with an educational level higher than primary, with an occupational category not corresponding to self-employed, farmer, employee or manual worker, with a monthly household income higher than 1200  $\in$ , not living in alone, living in a city, with a BMI corresponding to WHO categories of "underweight", "overweight" or "obesity", declaring a weight-loss diet and with a moderate or high physical activity. Note that the choice of profile was made to optimize graphical representation and has no influence on the differences in trajectories estimated by the model. Data not shown for the group "Other".

	Contemplation $(n = 916)$	Preparation $(n = 184)$	Action $(n = 5052)$	Maintenance ( <i>n</i> = 10,509)
	0/0 <sup>2</sup>	% <sup>2</sup>	% <sup>2</sup>	% <sup>2</sup>
I don't like the taste of meat				
No motive	98.1	98.4	97	94
Motive, not change-inducing	0.4	0	0.3	0.5
Change-inducing motive	1.5	1.6	2.7	5.5
I don't like the sight or the handling of meat, especia	lly raw meat			
No motive	86.6	91.9	88.1	84.6
Motive, not change-inducing	7.5	4.3	5.3	6.2
Change-inducing motive	5.8	3.8	6.6	9.2
I think it's good to vary my diet and my protein sour	ces by eating someth	ing different th	an meat	
No motive	17.7	14	11.8	9.9
Motive, not change-inducing	33.9	19.9	16.7	18.4
Change-inducing motive	48.4	66	71.4	71.7
I think it's healthier not to eat too much meat				
No motive	23.5	21.3	15.2	12.7
Motive, not change-inducing	25.5	17.7	10.5	11.9
Change-inducing motive	51	61	74.3	75.3
I think it's healthier to avoid meat				
No motive	94.7	97.3	93.1	90.3
Motive, not change-inducing	2	0.9	0.5	1.4
Change-inducing motive	3.3	1.8	6.3	8.3
I care about animal welfare or the lives of animals				
No motive	34.3	34	34.7	29.3
Motive, not change-inducing	32.6	30	22.5	23.2
Change-inducing motive	33.1	36	42.8	47.4

Table 2. Comparison of adjusted frequencies according to different types of motives related to meat reduction and stages of change towards meat reduction, NutriNet-Santé, n=16,661<sup>1</sup>

#### I think it's better for the environment not to eat too much meat

No motive	25	22.9	21.5	17.9
Motive, not change-inducing	29.6	21.6	15.7	15.6
Change-inducing motive	45.4	55.5	62.8	66.5
The people I live with don't like or eat meat				
No motive	95.5	95.5	90.7	87.9
Motive, not change-inducing	1.9	0.7	1.9	3.4
Change-inducing motive	2.6	3.8	7.4	8.8
My doctor advises me to reduce my meat consun	nption			
No motive	96.2	96.9	94.4	94.8
Motive, not change-inducing	0	0	0	0
Change-inducing motive	3.8	3.1	5.6	5.2
I am cutting back on my budget by eating less me	eat			
No motive	57.4	49.3	46.6	45.3
Motive, not change-inducing	21.3	22.2	18.3	18.6
Change-inducing motive	21.3	28.6	35.1	36.1
I have trouble finding meat that I consider to be	of good quality			
No motive	67.5	69.2	65.3	63.7
Motive, not change-inducing	15.5	12.7	9.4	8.3
Change-inducing motive	17	18.1	25.3	28
I have difficulty preserving the meat I buy				
No motive	91.2	93.8	93.5	93.8
Motive, not change-inducing	3.6	2.9	2	1.7
Change-inducing motive	5.2	3.3	4.6	4.5

<sup>1</sup>This subsample includes participants who declared a meat reduction in contemplation, preparation, action and maintenance stages, which explains the variations in the total number of participants (data for the "Other" group not shown)

<sup>2</sup>Percentage adjusted for sex, age (continuous), educational level, monthly household income classes, occupational category, household composition, size of urban residence unit, BMI categories, last weight-loss diet and level of physical activity.

	<b>Precontemplation</b> $(n = 3,141)$	Contemplation $(n = 518)$
	<b>%</b>	<b>%</b>
Lanjoy esting mest		
No motive	12.3	20.3
Motive not change hindering	12.5	12.5
Change-hindering motive	73.9	67.1
I have trouble changing my meat-eati	ing habits	
No motive	55.4	39.3
Motive, not change-hindering	8.3	9.2
Change-hindering motive	36.3	51.5
I think meat is good for my health		
No motive	22.1	43.6
Motive, not change-hindering	14.4	12.5
Change-hindering motive	63.6	43.9
I want to support farmers and meat p	producers	
No motive	39.8	51.8
Motive, not change-hindering	23.6	19.8
Change-hindering motive	36.6	28.3
I think eating meat allows me to reac	h satiety	
No motive	36.4	44.1
Motive, not change-hindering	20.1	20.3
Change-hindering motive	43.5	35.6
The people I live with like meat and v	vant to eat it	
No motive	29.3	32.5
Motive, not change-hindering	29.6	22.9
Change-hindering motive	41.1	44.5

Table 3. Comparison of adjusted frequencies according to different types of motives hindering meat reduction and stages of change toward meat reduction, NutriNet-Santé (n = 3659)<sup>1</sup>

#### I don't know what to eat as a substitute of meat

No motive	79.2	65.3
Motive, not change-hindering	4.1	4.1
Change-hindering motive	16.7	30.6
Meat is part of my culture		
No motive	21.4	22.6
Motive, not change-hindering	28.9	24.4
Change-hindering motive	49.7	53
I feel pressure from those around me to e	eat meat	
No motive	99.2	97.8
Motive, not change-hindering	0.7	1.9
Change-hindering motive	0.1	0.3
I think meat is a good source of protein		
No motive	10.7	17.7
Motive, not change-hindering	25.3	28.9
Change-hindering motive	64	53.4
I think meat gives me strength		
No motive	49	57.7
Motive, not change-hindering	9.3	8.2
Change-hindering motive	41.8	34.1

Change-hindering motive 41.8 34.1 <sup>1</sup>This sample includes participants who declared meat continuation in precontemplation and contemplation stages, which explains the variations in the total number of participants (data for the "Other" group not shown).

<sup>2</sup>Percentage adjusted for sex, age (continuous), educational level, monthly household income classes, occupational category, household composition, size of the urban residence unit, BMI categories, last weight-loss diet and level of physical activity.

# Stages of change toward meat reduction: Associations with motives and longitudinal dietary data on animal-based and plant-based food intakes in

# French adults. Reuzé al. 2023

Supplemental Table 1: Items for meat reduction (for contemplation, preparation, action and maintenance stages) and meat continuation (for precontemplation and contemplation stages)

Meat reduction	Meat continuation
I don't like the taste of meat	I enjoy eating meat
I don't like the sight or the handling of meat, especially raw meat	I have trouble changing my meat-eating habits
I think it's good to vary my diet and my protein sources by eating something different than meat	I think meat is good for my health
I think it's healthier not to eat too much meat	I have the will to support the farmers and the meat producers
I think it's healthier to avoid meat	I think eating meat allows me to reach satiety
I care about animal welfare or the lives of animals	The people I live with like meat and want to eat some
I think it's better for the environment not to eat too much meat	I don't know what to eat as a substitute of meat
The people I live with don't like or eat meat	Meat is part of my culture
My doctor advises me to reduce my meat consumption	I feel pressure from those around me to eat meat
I am cutting back on my budget by eating less meat	I think meat is a good source of protein
I have trouble finding meat that I consider to be of good quality: origin, traceability, hygiene, labeled meat, organic meat, or other quality criteria	I think meat gives me strength
I have difficulty preserving the meat I buy	

Supplemental Table 2: Food groups used to calculate PDI, healthy PDIs and unhealthy PDIs.

			PDI	hPDI	uPDI
Plant-based foods	Healthy	Whole grains Fruits Vegetables Nuts Legumes Vegetable oil Tea and coffee	Positive score (1 to 5 based on consumption quintiles)	Positive score (1 to 5 based on consumption quintiles)	Reverse score (5 to 1 based on consumption quintiles)
	Unhealthy	Refined grains Potatoes Sugar sweetened beverages <sup>1</sup> Sweets and desserts Miscellaneous plant-based foods <sup>2</sup>		Reverse score (5 to 1 based on consumption quintiles)	Positive score (1 to 5 based on consumption quintiles)
		Plant-based Range		12 to 60	l
Animal-based foods		Animal added fats Dairy foods Eggs Fish and seafood Meat Miscellaneous animal-based foods Animal-based Range	Reverse score (5 to 1 based on consumption quintiles)	Reverse score (5 to 1 based on consumption quintiles) 6 to 30	Reverse score (5 to 1 based on consumption quintiles)
Total Range		Inninan Dusen Kunge	18 to 90	01030	
roun runge			10 10 70		

Abbreviations: PDI: Plant-based Diet Index

#### List of modifications from the original study Satija et al.

<sup>1</sup> Clustering of "Fruit juices" and "Sugar-sweetened beverages" groups

<sup>2</sup> Creation of the "Miscellaneous plant-based foods "group, including plant-based sugary or salty snacks, nuts and peanut butter, and plant-based meat and dairy substitutes. including all plant products used as substitutes for animal and all processed vegetarian products (protein substitutes, plant-based processed meats, dairy substitutes, plant-based salty snacks and fast food)

Supplemental Figure 1: Flowchart of the study.



	Precontem (n=3,1	plation 41)	Contemp (n=1,4	olation 154)	Prepar (n=1	ation 84)	Act (n=5	tion 5,052)	Mainter (n=10,4	nance 509)	Othe (n=4,8	ers <sup>1</sup> 803)	
	n	%	n	%	n	%	n	%	n	%	n	%	$P^2$
Sex													< 0.0001
Men	1232	39.2	436	30.0	47	25.5	985	19.5	2657	25.3	969	20.2	
Women	1909	60.8	1018	70.0	137	74.5	4067	80.5	7852	74.7	3834	79.8	
Age (y)	57.6 (14.4)		54.1 (14.6)		55.0 (14.2)		54.3 (14	4.0)	57.2 (13.2)		56.7 (13.	9)	< 0.0001
Age (y, category)					. ,		,	,	. ,			<i>,</i>	< 0.0001
[18-30]	84	2.7	55	3.8	7	3.8	196	3.9	211	2.0	130	2.7	
[30-50]	885	28.2	525	36.1	55	29.9	1642	32.5	2677	25.5	1343	28.0	
[50-65]	908	28.9	425	29.2	69	37.5	1816	36.0	3920	37.3	1605	33.4	
[65+[	1264	40.2	449	30.9	53	28.8	1398	27.7	3701	35.2	1725	35.9	
Monthly household income class (per c.u.)													< 0.0001
< 1200 €	452	14.4	239	16.4	25	13.6	702	13.0	1172	11.2	703	14.6	< 0.0001
1200 - 1800 €	4 <i>52</i> 706	22.5	346	23.8	16	25.0	1003	21.6	1876	17.0	077	20.3	
1800 - 2700 €	700	22.5	354	23.8	40	25.0	1132	21.0	2546	24.2	1131	20.5	
> 2700 €	703 804	24.3	380	24.4	40 52	21.7	1648	22.4	4020	24.2	1/8/	20.0	
Refused to declare	326	10.4	135	9.3	21	11.4	477	9.4	895	8.5	508	10.6	
Occupational category													< 0.0001
Self-employed, farmer, employee, manual worker	063	30.7	401	27.6	52	28.3	1346	26.6	2371	22.6	1377	28.7	< 0.0001
Intermediate profession	738	23.5	380	27.0	52 47	26.5	1246	20.0	2571	22.0	1217	20.7	
Managerial staff, intellectual profession	1215	23.5	571	20.1	47 60	23.5	2040	40.6	4683	44.6	1217	25.5	
Unemployed	203	56.7	91	63	20	10.0	2049	40.0	4085	7.4	364	7.6	
No occupation	203	0.5	11	0.8	5	2.7	35	0.7	53	0.5	35	0.7	
Educational level													< 0.0001
None or Primary	95	27	27	1.0	2	1.6	00	17	125	1.2	00	1.0	< 0.0001
Secondary	1000	2.7	408	29.1	57	21.0	1264	25.0	2401	1.5	90 1277	1.9	
Undergraduate and others	1099	33.0 20.5	408	20.1	51	27.7	1204	23.0	2491	23.7	1577	20.7	
Post graduate	1030	32.8	532	36.6	73	39.7	2018	39.9	4506	42.9	1320	37.8	
Household composition													< 0.0001
Alone without children	5.00	10 1	105	12.7	10	0.8	062	171	1070	10.0	1007	21.0	< 0.0001
Alone with at least one child	569	18.1	185	12.7	18	9.8	803	1/.1	1970	18.8	100/	21.0	
Two adults living as a couple without children	194	0.2	80	5.5 12.6	10	5.4	355	0.0	690	0.0	312	0.5	
Two adults living as a couple with at least one child	1394	44.4	619	42.0	82	44.0	2041	40.4	4605	45.8	2059	42.9	
Two or more adult without children	945	30.1	549	5/.8	69	31.5	1/52	34.3	30/5	29.5	1544	28.0	
i we of more adult without emilaten	39	1.2	21	1.4	5	2.1	ð1	1.0	109	1.0	ð1	1./	

Supplemental Table 3: Sociodemographic, anthropometric and lifestyle characteristics of participants according to stages of change, NutriNet-Santé, 2009-2018, n=25,143

Size of the urban residence unit													< 0.0001
Rural	814	25.9	351	24.1	34	18.5	1168	23.1	2198	20.9	1037	21.6	
< 20.000 inhabitants	514	16.4	231	15.9	31	16.9	815	16.1	1576	15.0	710	14.8	
20.000 - 200.000 inhabitants	591	18.8	278	19.1	38	20.7	900	17.8	1935	18.4	965	20.1	
> 200.000 inhabitants	1222	38.9	594	40.9	81	44.0	2169	42.9	4800	45.7	2091	43.5	
Last weight-loss diet followed													< 0.0001
Not declaring a weight-loss diet	1213	38.6	505	34.7	58	31.5	1634	32.3	4133	39.3	2072	43.1	
< 5 years	189	6.0	106	7.3	9	4.9	370	7.3	741	7.1	285	5.9	
> 5 years	1739	55.4	843	58.0	117	63.6	3048	60.3	5635	53.6	2446	50.9	
BMI													< 0.0001
Underweight	95	3.0	43	3.0	6	3.3	179	3.5	448	4.3	269	5.6	
Normal	1577	50.2	821	56.5	94	51.1	3017	59.7	6800	64.7	3117	64.9	
Overweight	1003	31.9	413	28.4	50	27.2	1315	26.0	2421	23.0	1027	21.4	
Obesity	466	14.8	177	12.2	34	18.5	541	10.7	840	8.0	390	8.1	
Physical activity													< 0.0001
Low physical activity	625	19.9	337	23.2	44	23.9	938	18.6	1610	15.3	757	15.8	
Moderate physical activity	1129	35.9	596	41.0	67	36.4	2121	42.0	4093	39.0	1834	38.2	
High physical activity	1387	44.2	521	35.8	73	39.7	1993	39.5	4806	45.7	2212	46.1	

<sup>1</sup> Other: participants who answered "No, it's for another reason" and "No, because I was already eating little meat." to the question "*In recent years, have you reduced your meat consumption?*". <sup>2</sup> Chi2 tests or ANOVA

Supplemental Table 4: Percentage of consumers and adjusted mean daily consumption and dietary indices (mean and SEM), among consumers, at the inclusion in the cohort and at the latest available follow-up, according to stages of changes, NutriNet-Santé, n=25,143<sup>1</sup>

	Precontemplation (n=3,141)								Conten (n=1	nplation 1,454)			Preparation (n=184)					
	Inc	lusion		Latest foll	availab ow-up	le	Inc	lusion		Latest foll	availabl ow-up	le	Inc	lusion		Latest foll	availab ow-up	le
	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM
Plant-based foods																		
Fruits (g/d)	89.9	200.3	2.8	89.0	191.9	2.8	92.2	203.1	4	89.8	193.2	4	93.5	203.3	11.1	92.9	198.5	11.1
Vegetables (g/d)	99.2	229.3	2.7	98.6	222.4	2.7	99.0	237.3	3.9	98.7	234.3	4	99.5	259.3	10.9	100.0	261	11
Legumes (g/d)	26.5	37.2	1.2	23.2	39.3	1.4	27.8	40.7	1.8	24.5	39.3	2	27.2	33.8	5.1	27.2	38.7	5.2
Potatoes and other tubers (g/d)	68.2	66	1.1	66.0	66.9	1.1	70.9	67.2	1.5	67.5	68.2	1.5	66.3	60.1	4.4	65.2	66.2	4.4
Whole grains (g/d)	48.7	52.1	1.3	48.2	57.5	1.3	57.3	54.2	1.8	55.8	55.2	1.8	63.0	60.2	4.6	56.0	59.4	4.9
Refined cereals and grains (g/d)	98.2	155	1.5	96.8	137	1.4	98.4	160.4	2.1	97.2	140.5	2	98.9	156.9	5.9	97.3	137.9	5.7
Sweet and desserts (g/d)	97.3	98.9	1.2	95.3	95.9	1.2	97.9	97.5	1.7	96.5	96.7	1.7	97.3	105.5	4.8	96.7	96.5	4.8
Nuts (g/d)	21.7	10.9	0.6	25.0	9.3	0.6	23.0	11.5	0.9	28.5	9.9	0.8	28.8	9.9	2.3	31.5	9	2
Vegetable oil (g/d)	75.2	9.4	0.2	72.2	8.4	0.2	79.8	9.7	0.3	73.8	8.5	0.3	81.5	9.8	0.7	72.3	7.9	0.7
Uncooked cereals and seeds (g/d)	2.1	12.9	1.6	2.3	15.7	1.6	2.1	11.1	2.3	3.7	10.2	1.9	3.8	9.6	4.8	7.1	15	3.8
Miscellaneous (g/d)	22.8	14.3	0.6	20.2	16.4	0.9	22.6	13.1	0.9	21.1	12.1	1.2	19.6	12.6	2.8	22.3	17	3.4
Dairy substitutes (g/d)	2.0	85.6	6.3	2.5	78.6	6.1	4.8	74.9	6	4.1	74.5	7.2	6.0	58.5	15.1	4.3	63.2	19.1
Meat substitutes (g/d)	0.4	38.3	5.8	0.5	43.3	6.9	0.6	39.9	6.4	1.6	48.1	6	0.5	30.6	19.3	1.1	30.7	20
Fermented and coagulated foods (g/d)	0.3	27.5	7.1	0.1	37.6	12.6	0.5	38.5	8.1	0.4	41.5	10.3	0.5	1	21.3	1.1	26.8	18
Animal-based foods																		
Meats (all types) (g/d)	98.9	123.2	1	98.4	117	1	98.6	119.3	1.5	98.8	111.1	1.4	98.9	113.1	4.1	99.5	107.4	4
Meat products <sup>2</sup> (g/d)	96.5	98.9	0.9	95.8	92	0.9	96.1	93.8	1.3	95.1	88.2	1.3	95.7	88.1	3.7	96.2	82.6	3.6
Meat (g/d)	80.5	66.9	0.7	75.8	62.6	0.7	80.2	63.2	1.1	75.0	63.2	1.1	78.3	62	3.1	70.1	58.9	3.2
Offal (g/d)	13.0	41.8	1.2	79.9	42.8	1.3	12.9	41.2	1.7	10.5	39.3	2.1	12.0	40	5	12.5	35.8	5.3
Processed meat (g/d)	81.7	44.6	0.6	56.8	44.2	0.6	80.4	42.5	0.9	78.7	40.4	0.9	76.1	40.2	2.5	77.7	42.2	2.5
Poultry (g/d)	57.6	45.9	0.8	56.8	47.7	0.8	61.0	45.2	1.1	56.8	45	1.2	63.6	43.6	3	62.5	43.9	3.1
Eggs (g/d)	47.5	27.3	0.6	48.9	28.3	0.7	46.6	26.1	0.9	50.0	28	1	55.4	28.5	2.3	48.4	27.5	2.7

Dairy foods (g/d)	98.6	249.8	2.9	97.9	227	2.6	98.7	234.9	4.2	97.6	206.2	3.9	98.4	252.9	11.7	97.8	212.1	10.7
Animal added fats (g/d)	67.5	10.4	0.2	63.3	11.8	0.2	72.1	10.5	0.3	67.4	12	0.3	67.9	9.9	0.7	61.4	11.4	0.8
Fish and other seafood (g/d)	73.1	58.3	0.9	68.0	54.4	0.9	74.8	58.6	1.4	67.2	57.8	1.4	79.9	54.8	3.7	77.2	53.3	3.6
Miscellaneous (g/d)	51.8	63	1.2	50.6	73	1.4	52.8	61.8	1.8	52.8	70.6	2.1	47.8	62.6	5.1	52.2	65.2	5.8
Beverages																		
Sugar-sweetened drinks (mL/d)	61.6	160.6	2.8	50.6	155.8	3	62.3	155.1	4.1	51.7	131.9	4.4	62.0	159.3	11.5	50.0	145	12.5
Tea and coffee (mL/d)	88.9	391.1	6.6	89.0	393	6.4	89.7	392.2	9.6	89.9	397	9.3	89.1	452.8	26.8	91.3	441.9	25.7
Plant-based drinks (mL/d)	2.3	137.3	12.7	3.0	155.1	11.3	3.4	129.4	15.4	5.0	128.4	12.8	7.1	81.6	30	8.2	91.1	27.7
Indices																		
Contribution of meat products <sup>2</sup> (% of TEI)	97.7	10.9	0.1	97.3	10.9	0.1	97.9	10.4	0.2	96.6	10.6	0.2	97.3	9.6	0.4	98.9	10	0.4
Contribution of meat (% of TEI)	85.2	6.6	0.1	82.2	6.5	0.1	86.3	6.2	0.1	81.6	6.8	0.1	82.1	6.1	0.3	79.3	5.8	0.4
Contribution of processed meat (% of TEI)	85.8	5.1	0.1	84.0	5.4	0.1	86.0	4.8	0.1	82.7	4.9	0.1	82.1	4.4	0.3	84.2	5.4	0.3
PDI	100.0	48.1	0.1	100.0	47.5	0.1	100.0	49	0.2	100.0	48.2	0.2	100.0	49.4	0.4	100.0	49	0.4
healthyPDI	100.0	52.7	0.1	100.0	53.7	0.1	100.0	53.6	0.2	100.0	54.5	0.2	100.0	54.2	0.5	100.0	55	0.5
unhealthyPDI	100.0	58.4	0.1	100.0	58.3	0.1	100.0	57.6	0.2	100.0	57.7	0.2	100.0	56.5	0.5	100.0	57.1	0.5

Abbreviations: TEI, total energy intake

<sup>1</sup>Mean daily consumption and mean PDIs, healthy PDIs and unhealthy PDIs have been adjusted for sex, age (continuous) and the mean total energy intake. Contribution of meat, processed meat and meat products to the total energy intake have been adjusted for sex and age.

<sup>2</sup> Including meat, offal and processed meat.

Supplemental Table 4 (continued): Percentage of consumers and adjusted mean daily consumption and dietary indices (mean and SEM), among consumers, at the inclusion in the cohort and at the latest available follow-up, according to stages of changes, NutriNet-Santé, n=25,143<sup>1</sup>

			Ac (n=	tion 5,052)					Mainte (n=10	enance 9,509)			Other (n=4,803)					
	Inc	lusion		Latest foll	availab ow-up	le	Inc	lusion		Latest foll	availab ow-up	le	Inc	lusion		Latest foll	availab ow-up	le
	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM	% of consumers	Mean	SEM
Plant-based foods																		
Fruits (g/d)	93.3	204.3	2.3	92.3	208.6	2.2	95.6	223	1.6	94.3	220.4	1.6	95.1	224.1	2.3	92.9	220.5	2.3
Vegetables (g/d)	99.6	248.5	2.2	99.4	254.2	2.2	99.7	268.8	1.6	99.6	268.1	1.6	99.6	263	2.2	99.6	257.1	2.3
Legumes (g/d)	28.1	37.2	1	26.8	41.9	1.1	28.6	40.5	0.7	28.8	45.3	0.7	27.9	42	1	25.9	44.4	1.1
Potatoes and other tubers (g/d)	66.4	64.1	0.9	62.5	63.2	0.9	64.1	65.2	0.6	60.1	64.6	0.6	64.1	65.6	0.9	59.8	63.2	0.9
Whole grains (g/d)	61.3	56.1	1	64.4	60.5	0.9	67.4	63	0.7	68.6	66.1	0.7	65.9	63	0.9	64.8	63.6	1
Refined cereals and grains (g/d)	98.0	155.8	1.2	96.7	137.2	1.1	97.7	154.9	0.9	95.8	134.8	0.8	97.6	154.9	1.2	95.7	137.7	1.2
Sweet and desserts (g/d)	98.0	103.4	1	96.5	96.6	1	97.9	104.4	0.7	96.9	96.9	0.7	98.0	106.9	1	96.9	101.1	1
Nuts (g/d)	26.5	11.1	0.5	35.9	11.5	0.4	33.1	13	0.3	44.2	13.1	0.3	31.6	13.1	0.5	39.6	12.9	0.4
Vegetable oil (g/d)	79.7	9.9	0.1	75.0	9.1	0.1	81.5	10.4	0.1	76.1	9.5	0.1	79.3	10.2	0.1	74.2	9.3	0.1
Uncooked cereals and seeds (g/d)	5.1	11.6	0.9	6.7	11.8	0.8	6.1	11.2	0.6	9.5	11.3	0.5	6.1	9.9	0.8	7.8	11.7	0.8
Miscellaneous (g/d)	23.1	13.8	0.5	21.6	17.4	0.7	21.3	14.1	0.4	21.7	17.2	0.5	19.8	13.6	0.6	20.0	17.5	0.7
Dairy substitutes (g/d)	5.1	70.1	3.3	6.0	77.9	3.4	7.6	75.2	2	8.1	79.8	2.2	6.7	76.4	3	7.3	81.1	3.1
Meat substitutes (g/d)	1.0	41.7	2.8	3.2	42.5	2.4	1.6	40.9	1.7	3.7	39.9	1.6	1.7	39.8	2.3	2.9	40.8	2.6
Fermented and coagulated foods (g/d)	0.6	33.4	4.1	1.0	31.8	4	1.4	32.9	2.2	1.6	36.1	2.5	1.2	31.8	3.1	1.1	29	3.7
Animal-based foods																		
Meats (all types) (g/d)	98.5	112.7	0.8	96.6	99.6	0.8	96.9	97.5	0.6	93.9	87.5	0.6	96.0	94.2	0.9	94.6	88.2	0.8
Meat products <sup>2</sup> (g/d)	95.8	88.4	0.7	91.4	78.3	0.7	92.3	76.6	0.5	87.6	68.4	0.5	90.8	73.8	0.8	88.5	68.9	0.8
Meat (g/d)	77.7	61.9	0.6	67.5	56.6	0.6	70.0	55.9	0.5	60.2	50.9	0.5	66.4	54.2	0.7	60.9	50.9	0.7
Offal (g/d)	11.6	41.5	1	10.3	41.3	1.1	10.5	41.3	0.7	10.2	40.5	0.8	10.4	40.9	1.1	9.9	41.2	1.2
Processed meat (g/d)	77.6	40.4	0.5	73.2	38.6	0.5	74.5	36.2	0.4	69.8	35.4	0.4	73.0	35.8	0.5	69.9	36	0.6
Poultry (g/d)	59.2	44.5	0.6	54.8	44.4	0.7	56.0	42.2	0.5	51.6	42.8	0.5	55.1	41.6	0.7	52.1	42.7	0.7
Eggs (g/d)	49.3	26.8	0.5	49.7	28.7	0.5	49.3	26.3	0.4	51.0	28.8	0.4	49.7	26.7	0.5	49.8	28.2	0.5

Dairy foods (g/d)	98.9	237.2	2.3	97.9	202.7	2.2	98.3	223.5	1.7	97.6	191.8	1.5	98.4	237.1	2.4	97.7	208.7	2.2
Animal added fats (g/d)	69.8	10.1	0.1	64.8	11.3	0.2	68.6	9.8	0.1	64.5	10.9	0.1	67.6	9.9	0.2	63.8	11.1	0.2
Fish and other seafood (g/d)	75.0	60.4	0.8	68.9	56.1	0.8	76.1	59	0.5	70.4	54.7	0.5	76.1	58.3	0.8	68.7	53.8	0.8
Miscellaneous (g/d)	53.0	61.6	1	51.2	70.1	1.2	49.4	60.1	0.7	47.5	69.4	0.9	49.3	61.3	1	47.3	69.8	1.3
Beverages																		
Sugar-sweetened drinks (mL/d)	62.2	146	2.3	49.9	132.1	2.5	60.7	143.8	1.7	49.6	128.8	1.8	60.1	145	2.4	48.6	134.8	2.6
Tea and coffee (mL/d)	90.9	425.2	5.4	91.9	433.2	5.2	93.1	478.4	3.8	93.5	481.1	3.7	91.7	467.7	5.4	92.9	471.5	5.2
Plant-based drinks (mL/d)	4.9	117.1	7.2	8.2	144.7	5.7	7.8	126.8	4.3	10.1	135	3.8	6.6	124.2	6.4	8.0	136.4	5.9
Indices																		
Contribution of meat products <sup>2</sup> (% of TEI)	97.1	9.9	0.1	94.4	9.3	0.1	94.6	8.5	0.1	90.7	8.2	0.1	93.2	8.3	0.1	91.6	8.3	0.1
Contribution of meat (% of TEI)	83.8	6	0.1	75.4	5.9	0.1	76.7	5.4	0	67.8	5.2	0.1	73.2	5.3	0.1	68.2	5.3	0.1
Contribution of processed meat (% of TEI)	83.0	4.6	0.1	79.1	4.7	0.1	79.5	4.1	0	74.9	4.4	0.1	77.6	4.1	0.1	74.7	4.4	0.1
PDI	100.0	49.5	0.1	100.0	49.7	0.1	100.0	51.2	0.1	100.0	51.2	0.1	100.0	50.8	0.1	100.0	50.5	0.1
healthyPDI	100.0	54.1	0.1	100.0	56.2	0.1	100.0	56	0.1	100.0	57.8	0.1	100.0	55.6	0.1	100.0	57	0.1
unhealthyPDI	100.0	57.2	0.1	100.0	56.8	0.1	100.0	56.7	0.1	100.0	56.3	0.1	100.0	57	0.1	100.0	56.9	0.1

Abbreviations: TEI, total energy intake

<sup>1</sup>Mean daily consumption and mean PDIs, healthy PDIs and unhealthy PDIs have been adjusted for sex, age (continuous) and the mean total energy intake. Contribution of meat, processed meat and meat products to the total energy intake have been adjusted for sex and age. <sup>2</sup> Including meat, offal and processed meat.



Supplemental Figure 2: Adjusted mean daily consumption and contribution of plant-based and animal-based foods groups among consumers over the 2009-2019 period, n=25,143<sup>1</sup>

Maintenance



<sup>1</sup> Mean daily consumptions and indices have been calculated among consumers of the given food item. Mean daily consumption and mean PDIs, healthy PDIs and unhealthy PDIs have been adjusted for sex, age (continuous) and the mean total energy intake. Contribution of meat, processed meat and meat products to the total energy intake have been adjusted for sex and age. Data not shown for the group "Other"

"Miscellaneous plant-based foods "group includes plant-based sugary or salty snacks, nuts and peanut butter, and plant-based meat and dairy substitutes. including all plant products used as substitutes for animal and all processed vegetarian products (protein substitutes, plant-based meats, dairy substitutes, plant-based salty snacks and fast food).

"Miscellaneous animal foods "group includes all dressings, sauces and animal-based salty snacks and fast foods.

"Fermented foods": Fermented or coagulated foods (e.g. tempeh, tofu...)

"Sugar-sweet. drinks": Sugar-sweetened drinks

С

Supplemental Table 5: Multivariate linear mixed analysis for the associations between stages of change towards meat reduction and changes in percent energy intake provided by meat, processed meat and meat products (logarithm of the contribution of the given food to total energy intake) over the 2009-2019 period in French adults participating in the NutriNet-Santé cohort  $(n = 25, 143)^1$ 

	Contr to tot	ribution of meat al energy intake n=24,715) <sup>2</sup>		Contribut to to	ion of processed n tal energy intake (n=24,820) <sup>2</sup>	neat	Contribution of meat products <sup>3</sup> to total energy intake (n=25,085) <sup>2</sup>					
	β	95%IC	р	β	95%IC	p	β	95%IC	р			
Intercept	0.29	[-0.07;0.65]	0.12	1.43	[1.06;1.8]	<0.0001	2.13	[1.91;2.36]	<0.0001			
Time	-0.23	[-0.31;-0.15]	<0.0001	-0.13	[-0.21;-0.05]	0.001	-0.09	[-0.14;-0.04]	0.001			
Contemplation	0.05	[-0.12;0.21]	0.57	-0.15	[-0.31;0.02]	0.08	-0.04	[-0.14;0.06]	0.45			
Contemplation*time	0.00	[-0.03;0.04]	0.92	0.00	[-0.03;0.03]	0.98	0.00	[-0.02;0.03]	0.76			
Preparation	-0.38	[-0.77;0.02]	0.06	-0.25	[-0.65;0.15]	0.22	-0.20	[-0.44;0.05]	0.11			
Preparation*time	-0.01	[-0.09;0.08]	0.89	0.04	[-0.05;0.12]	0.39	0.01	[-0.04;0.07]	0.58			
Action	-0.12	[-0.24;0]	0.05	-0.21	[-0.33;-0.08]	0.001	-0.07	[-0.15;0]	0.05			
Action*time	-0.06	[-0.09;-0.04]	<0.0001	-0.04	[-0.07;-0.02]	0.001	-0.04	[-0.06;-0.03]	<0.0001			
Maintenance	-0.77	[-0.88;-0.67]	<0.0001	-0.53	[-0.64;-0.43]	<0.0001	-0.46	[-0.52;-0.39]	<0.0001			
Maintenance*time	-0.08	[-0.1;-0.06]	<0.0001	-0.05	[-0.07;-0.02]	<0.0001	-0.06	[-0.07;-0.04]	<0.0001			

<sup>1</sup> Multivariate linear mixed models were performed on the total sample, including participants in precontemplation, contemplation, action and maintenance stages and the group "Other". Nonconsumers were excluded in each sample. Precontemplation stage was used as the category of reference. No significance over time for the group "Other", data not shown.

 $^{2}$  Coefficients  $\beta$  were computed using a linear multilevel mixed model expressing the relationship between stages of change and dietary indices (expressed by the mean) and time (in years). Logarithm of the contribution of meat, processed meat and meat products to the total energy intake was used to increase normality and model's residual fitness. The coefficient for intercept represents the association of individuals in the precontemplation stage (reference) with baseline consumption and the coefficient for time represents the evolution of consumption over time for the precontemplation stage. The coefficient for stages of change with evolution of consumption over time, compared to the evolution of consumption of those in the precontemplation stage.

Models for sex, age (continuous), educational level, number of follow-up at which dietary data were recorded (continuous), monthly household income classes, occupational category, household composition, size of the urban residence unit, BMI category, latest weight-loss diet and physical activity level.

<sup>3</sup> Including meat, offal and processed meat.

Supplemental Table 6: Multivariate linear mixed analysis showing associations between stages of change towards meat reduction and changes in PDI, healthy PDI and unhealthy PDI over the 2009-2019 period in French adults participating in the NutriNet-Santé cohort (n = 25, 143)<sup>1</sup>

		PDI <sup>2</sup>			healthyPDI <sup>2</sup>		unhealthyPDI <sup>2</sup>				
	β	95%CI	р	β	95%CI	р	β	95%CI	р		
Intercept	41.43	[40.67;42.2]	<0.0001	44.91	[44;45.82]	<0.0001	71.62	[70.79;72.44]	<0.0001		
Time	-0.04	[-0.17;0.08]	0.49	1.24	[1.09;1.38]	<0.0001	-0.07	[-0.21;0.07]	0.35		
Contemplation	0.93	[0.62;1.25]	<0.0001	0.78	[0.41;1.15]	<0.0001	-0.63	[-0.97;-0.3]	0.00		
Contemplation*time	-0.04	[-0.09;0.01]	0.16	-0.01	[-0.07;0.04]	0.67	0.02	[-0.04;0.07]	0.55		
Preparation	1.35	[0.6;2.09]	0.00	1.16	[0.28;2.04]	0.01	-1.26	[-2.06;-0.46]	0.00		
Preparation*time	0.00	[-0.12;0.12]	0.96	0.02	[-0.12;0.15]	0.83	0.00	[-0.14;0.13]	0.98		
Action	1.13	[0.91;1.36]	<0.0001	1.11	[0.84;1.38]	<0.0001	-0.94	[-1.18;-0.7]	<0.0001		
Action*time	0.13	[0.09;0.16]	<0.0001	0.16	[0.11;0.2]	<0.0001	-0.04	[-0.08;0]	0.05		
Maintenance	2.63	[2.43;2.83]	<0.0001	2.91	[2.67;3.15]	<0.0001	-1.44	[-1.66;-1.22]	<0.0001		
Maintenance*time	0.10	[0.07;0.13]	<0.0001	0.11	[0.07;0.14]	<0.0001	-0.02	[-0.06;0.01]	0.25		

<sup>1</sup> Multivariate linear mixed models were performed on the total sample, including participants in precontemplation, contemplation, action and maintenance stages and the group "Other".

Precontemplation stage was used as the category of reference. No significance over time for the group "Other", data not shown.

 $^{2}$  Coefficients  $\beta$  were computed using a linear multilevel mixed model expressing the relationship between stages of change and dietary indices (expressed the mean) and time (in days). The coefficient for intercept represents the association of individuals in the precontemplation stage (reference) with baseline consumption and the coefficient for time represents the evolution of consumption over time for the precontemplation stages. The coefficient for stages of change with baseline consumption. The coefficient for the interaction term represents the association of individuals in stages of change with baseline consumption those in the precontemplation stage.

Models were adjusted for sex, age (continuous), educational level, number of follow-up at which dietary data were recorded (continuous), monthly household income classes, occupational category, household composition, size of the urban residence unit, BMI category, latest weight-loss diet, physical activity level and total energy intake.