



**HAL**  
open science

## The grandeur of death – Monuments, societies, and diets in middle Neolithic Paris Basin

Christina Cheung, Estelle Herrscher, Guy Andre, Lisandre Bedault, Lamys Hachem, Annelise Binois-Roman, Daniel Simonin, Aline Thomas

### ► To cite this version:

Christina Cheung, Estelle Herrscher, Guy Andre, Lisandre Bedault, Lamys Hachem, et al.. The grandeur of death – Monuments, societies, and diets in middle Neolithic Paris Basin. *Journal of Anthropological Archaeology*, 2021, 63, pp.101332. 10.1016/j.jaa.2021.101332 . mnhn-03296188

**HAL Id: mnhn-03296188**

**<https://mnhn.hal.science/mnhn-03296188>**

Submitted on 2 Aug 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.



Distributed under a Creative Commons Attribution - NonCommercial 4.0 International License

# 1 **The Grandeur of Death – Monuments, Societies, and Diets in Middle** 2 **Neolithic Paris Basin**

3  
4 Christina Cheung<sup>1,2\*</sup>, Estelle Herrscher<sup>2</sup>, Guy Andre<sup>2</sup>, Lisandre Bedault<sup>3</sup>, Lamys Hachem<sup>3,4</sup>,  
5 Annelise Binois-Roman<sup>5,6</sup>, Daniel Simonin<sup>7</sup>, Aline Thomas<sup>1\*</sup>

6  
7 <sup>1</sup> EA – Eco-anthropologie (UMR 7206), Muséum National d'Histoire Naturelle, CNRS, Université Paris Diderot,  
8 Paris, France

9 <sup>2</sup> UMR 7269, LAMPEA, Aix-Marseille Université, CNRS, Minist Culture, Aix-en-Provence, France

10 <sup>3</sup> UMR 8215 Trajectoires – De la sédentarisation à l'Etat, CNRS/Université Paris 1 Panthéon Sorbonne, Paris,  
11 France

12 <sup>4</sup> INRAP – Institut National de Recherches Archéologiques Préventives

13 <sup>5</sup> Université Paris 1 Panthéon Sorbonne, Paris, France

14 <sup>6</sup> ArScAn - Archéologies et Sciences de l'Antiquité (UMR 7041), Nanterre, France ”

15 <sup>7</sup> Musée de Préhistoire d'Île-de-France, Nemours, France

16  
17 \* Corresponding authors

18 Email: christina.cheung@mnhn.fr (CC); aline.thomas@mnhn.fr (AT)

## 19 20 **Abstract**

21 This study investigates the relationship between monumental funerary structures, social  
22 organizations, and diets in Middle Neolithic France. Focusing on the Cerny culture based in the  
23 Paris Basin region, we analysed and compared bone collagen stable carbon, nitrogen, and sulfur  
24 isotope values of 113 individuals from three different types of Cerny cemeteries: the Passy type  
25 (Cerny STP), slab burials (Cerny Slab), and burials without major superstructure (Cerny Flat).  
26 Published stable isotopic data from one other Cerny Flat and two contemporaneous non-Cerny  
27 cemeteries (n=140), together with new and published faunal isotopic data (n=267) from across  
28 six different river valleys in the region are also included in the analysis. The results of this study  
29 have shown that 1) the Cerny diet was likely rich in animal protein; 2) comparing to all other  
30 cemetery types, Cerny STP sites were considerably homogenous isotopically and culturally, and  
31 3) individuals buried in aberrant funerary arrangements tend to have outlying isotopic  
32 compositions, suggesting strong correlations between diets and burial practices. Interestingly, as  
33 oppose to the distinctly sex-related funerary arrangements, no obvious pattern can be observed in  
34 the isotopic compositions between males and females in Cerny cemeteries.

## 35 36 37 **Keywords**

38 Cerny culture; Neolithic; Passy-type monument; Slab burials; Stable isotope analysis

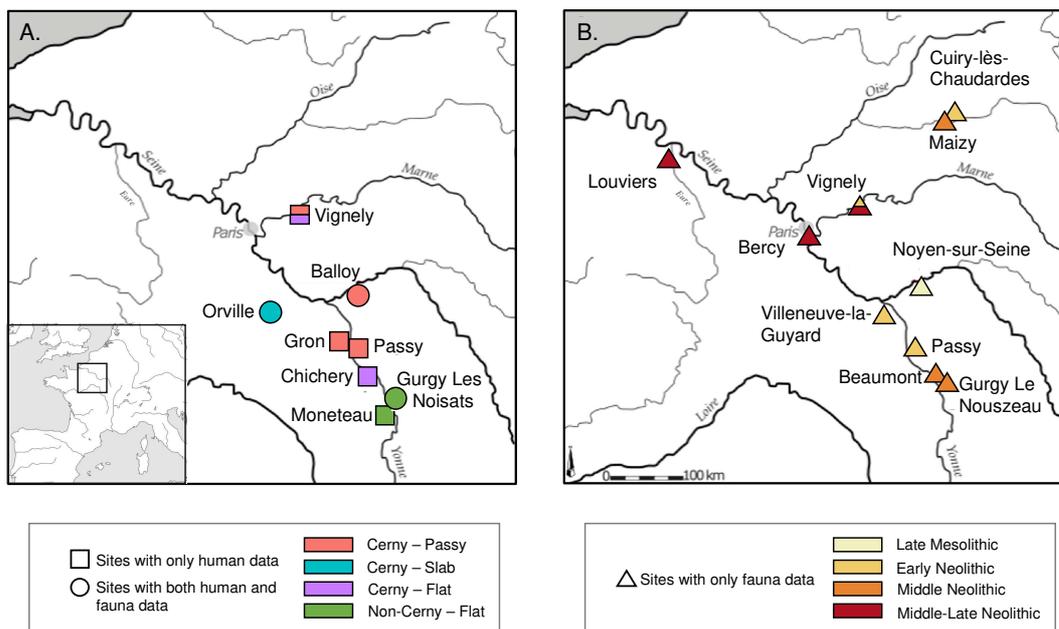
39

## 1 **1. Introduction**

2           The Paris Basin (*Bassin parisien*) is an intracratonic basin located in the northern part of  
3 France, encompasses all or parts of several modern French administrative regions, including  
4 Normandy, Pays de la Loire, Centre–Val de Loire, Île–de–France, Hauts–de–France, Grand Est,  
5 and Bourgogne–Franche–Comté (Figure 1). Supported by an expansive river system, together  
6 with favourable climatic conditions, fertile soil, and gentle relief (Jones 1947), the Paris Basin  
7 region has been occupied by human settlers as early as the Palaeolithic and Mesolithic periods  
8 (Bodu, et al. 2014; Leroi-Gourham and Brézillon 1972; Pigeot 2004; Valentin, et al. 2013). By  
9 the end of the 5<sup>th</sup> millennium BC, the Paris Basin region appeared to be a crossroads between  
10 two main routes of Neolithic dissemination in Western Europe (e.g.(Manen and Hamon 2018)).  
11 While many sites in the area had Danubian roots, the region received further influences from the  
12 Mediterranean Neolithic sphere in terms of material culture (Constantin and Vachard 2004;  
13 Lichardus-Itten 1986) as well as genetic signatures (Rivollat, et al. 2015). These interactions  
14 have created remarkable cultural diversity in the Paris Basin area during the Middle Neolithic  
15 period (c. 4700 – 3500 BC), in a scale that is observed neither in the preceding nor following  
16 periods (Chambon and Leclerc 2003; Chambon, et al. 2013). One particularly notable  
17 observation is the emergence of the first monumental cemeteries in western Europe (Chambon  
18 and Thomas 2010). From massive, earthen long–barrows up to 300 m in length, to large stone  
19 slabs weighing several tonnes, these labour intensive, physically imposing ceremonial structures  
20 are seen by many as a tell–tale sign that communities are moving away from simple, egalitarian  
21 structures to more stratified, hierarchal social systems during this period (Duhamel and Midgley  
22 2004; Midgley 2005). At the same time, these monumental graves stood in stark contrast to their  
23 contemporary modest counterparts – cemeteries without superstructure, or the “flat” cemeteries  
24 (Thomas, et al. 2011b). Based on burial arrangements and recovered ceramics, the monumental  
25 cemeteries are all considered part of the Cerny Culture, while the flat cemeteries can be further  
26 divided into three major groups under varying degrees of Cerny influence: major (Bostyn, et al.  
27 2018; Chambon, et al. 2010), minor (Chambon, et al. 2006), and completely absent (Augereau  
28 and Chambon 2011; Constantin, et al. 1997; Rottier, et al. 2005). These contrasting cemetery  
29 architectures are further complicated by other differing but correlated burial traditions such as  
30 body positions (flexed vs. supine) (Chambon, et al. 2007) and compositions of grave goods  
31 (Thomas 2011). Thus, during the Middle Neolithic period, in a small area of about 100 km in  
32 radius around the Seine–Yonne confluence (Figure 1), several types of stylistically distinctive  
33 cemeteries coexisted.

34           Focusing on the Cerny groups, this study examines the relationship between subsistence  
35 economy, burial rites, cultural affiliations, and social organization by reconstructing and  
36 comparing the palaeodietary and funerary patterns of eight Cerny sites with two “Non-Cerny”  
37 sites (cemeteries with no significant Cerny features) in the Paris Basin area. Using a multi–  
38 isotope approach, we present the stable carbon (C), nitrogen (N), and sulfur (S) isotopic  
39 compositions of a total of 113 humans and 90 animals from the area. In addition, published C, N,  
40 and S isotope measurements of a total of 140 humans and 177 animals from contemporaneous or

1 near contemporaneous sites are included to provide additional insights into the regional isotopic  
 2 variations (Balasse 1999; Bocherens, et al. 2005; Bocherens, et al. 2011; Drucker, et al. 2018;  
 3 Naito, et al. 2013; Rey, et al. 2017; Rey, et al. 2019). The main objectives of this study are  
 4 threefold: 1) to advance our current understanding of the subsistence economy of populations  
 5 living in the Paris Basin region during the Middle Neolithic period, when funerary  
 6 monumentalism began to emerge in western Europe, 2) to investigate whether there was any  
 7 difference in the subsistence economy between the Cerny and non-Cerny groups, and 3) to  
 8 explore connections between funerary monumentality and social differentiations (e.g. gender,  
 9 social-economic status, etc) among Cerny sites.



10  
 11 *Figure 1 Maps of the Paris Basin showing locations of all sites mentioned in this study, with reference to the modern city of Paris.*  
 12 *A: ■ corresponds to sites with only human data; ● corresponds to sites with human and corresponding faunal data. B: ▲*  
 13 *corresponds to sites with faunal data not directly associated with the humans analysed in this study.*

## 14 2. The Cerny Culture

### 15 2.1 The Cerny way of death

16 The Cerny culture was a Middle Neolithic culture that flourished between 4700 and 4300  
 17 BC in the Paris Basin region, also refer to as the Cerny territory *stricto sensu* (Constantin, et al.  
 18 1997). In the general absence of residential sites, most of our knowledge of the Cerny social  
 19 organisation comes from its cemeteries (Thomas 2011). Although first identified and defined by  
 20 its unique ceramic style (Bailloud 1964), today, the Cerny culture is possibly best known for  
 21 building some of the first monumental cemeteries in Western Europe (Midgley 2005;  
 22 Wunderlich, et al. 2019). In the Paris Basin region, there are three major varieties of Cerny  
 23 cemeteries: two monumental types and one without superstructure or “flat”. A brief description  
 24 of these cemetery types is provided below.

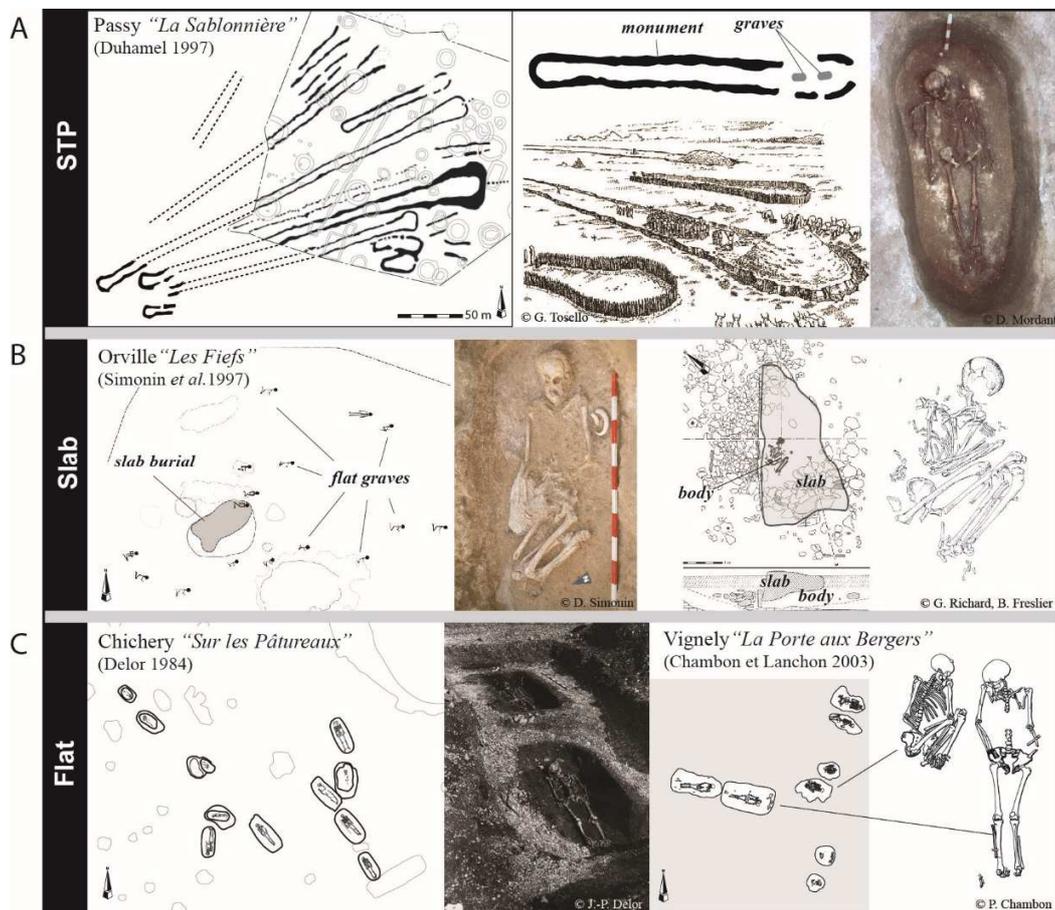
1  
2 *Cemeteries with Passy-type structures (Structures de Type Passy, or STP – Figure 2A):* named  
3 after the eponymous cemeteries in Passy (Duhamel 1997), this type is possibly the most famous  
4 of all Cerny cemetery types. STP cemeteries are consisted of long barrows constructed out of  
5 timber and earth, where the total lengths of each structure can vary from 25 to 300 m (Duhamel  
6 and Mordant 1997). Only a few individuals were buried within each monument, and in some  
7 cemeteries, some individuals were buried outside. There appeared to be certain rules about social  
8 identities (most apparent categories are sex and age) and burial locations, where only certain  
9 individuals were allowed to be buried within, or even associated with the monuments (Chambon  
10 1997; Thomas, et al. 2011a; Thomas, et al. 2011b). Most of the individuals were buried in the so-  
11 called Balloy-type graves, which is consisted of a coffin placed inside a vault, where the body is  
12 laid in an extended supine position (Chambon, et al. 2007; Chambon and Thevenet 2014). In this  
13 study, five sites, namely Balloy “Les Réaudins” (BLR), Vignely “La Noue Fenard” (VNF), Gron  
14 “Les Sabons” (GLS), Passy “La Sablonnière” (PLS), and Passy “Richebourg” (PR), belong to  
15 this category. A total of 70 individuals from these five sites are analysed. A variation of STP  
16 cemeteries is the so called Rots-type cemeteries. These cemeteries have monuments similar to  
17 those of STP cemeteries, but are only found in Normandy, which is generally considered as  
18 Cerny sphere *lato sensu* (Desloges 1997; Ghesquière, et al. 2019). As it is located outside of our  
19 concerned area, groups buried in this type of cemeteries are not addressed in this paper.

20  
21 *Cemeteries with “slab” burials, or the Malesherbes-type (Figure 2B):* “Slab” burials are burials  
22 marked by a megalith, either a flat stone (slab) or standing stone (menhir). These types of burials  
23 are often found in the western part of the Paris Basin region, along the banks of the Essonne. In  
24 this study, we analysed a total of 20 individuals from Orville “Les Fiefs” (OLF), the biggest  
25 “Slab” cemetery found thus far. In OLF, the slab burial is the key grave surrounded by at least 21  
26 flat burials (Simonin, et al. 1997). All but one individual from this site were buried in a flexed  
27 position, most of them on the left side.

28  
29 *Flat cemeteries (Figure 2C):* as suggested by the name, these types of cemeteries have no major  
30 superstructure. Most of the individuals were buried in an extended supine position inside a  
31 Balloy-type grave, only few were buried in flexed position on the side (Bostyn, et al. 2018;  
32 Chambon, et al. 2010). Two sites associated with this cemetery types are Vignely “La Porte aux  
33 Bergers” (VPB) and Chichery “Sur les Pâturaux” (CLP). A total of 30 individuals from VPB  
34 are analysed. Isotopic measurements of eight individuals from CLP are obtained from a recently  
35 published report (Rey, et al. 2019). Note that even though both cemeteries are categorized as  
36 “Cerny flat”, VPB is considered more closely related to STP cemeteries than CLP (Thomas  
37 2014a).

38  
39 While most Cerny cemeteries in the Paris Basin region show connections with cultural spheres  
40 from north-eastern France, such as the Rössen Culture, within the same temporal and

1 geographical framework, there are also cemeteries that bear components of other cultures, such  
 2 as the Chasséen Culture from southern France. Two of such cemeteries included in this study are  
 3 Gurgy “Les Noisats” (GLN) (Rottier, et al. 2005) and Monéteau “Macherin” (MON) (Augereau  
 4 and Chambon 2011). GLN and MON are located in the Yonne river valley, about 10 km south of  
 5 the Cerny flat cemetery of CLP (Figure 1A). With more than 180 burials in total, most of the  
 6 burials from these two sites carried no clear Cerny components, and were buried in a flexed  
 7 position, mainly on the left side. Other than burial positions, individuals from GLN and MON  
 8 were buried in several grave types that are distinct from the typical Balloy-type seen in most  
 9 Cerny cemeteries (Chambon, et al. 2013). Interestingly, three individuals in MON (#02–685;  
 10 #04–89; #04–99 ) show evidence of affiliation with the Cerny culture, where they were buried in  
 11 a Balloy-type grave (Chambon, et al. 2006). For the purpose of this study, these two cemeteries  
 12 are categorized as “non-Cerny”. A total of 132 C, N, and S isotope measurements from GLN and  
 13 MON are obtained from two recently published reports (Rey, et al. 2017; Rey, et al. 2019).  
 14



15  
 16 Figure 2 The three major types of Cerny cemeteries in Paris Basin, monumental (STP, Slab) and flat, also showing the typical  
 17 burial positions of the deceased seen in the three types of cemeteries, respectively.

## 1 **2.2 The Cerny way of life**

2 Unfortunately, so far, residential sites from the Cerny contexts remain few and far in  
3 between (Bostyn, et al. 2016; Last 2013; Mordant and Simonin 1997). As a result, relatively little  
4 is known about the details of their lifeways. Based on limited archaeological evidence and  
5 research on related neighbouring sites, it is generally agreed that the Cerny subsistence economy  
6 was based primarily on agriculture (agronomy and animal husbandry), supplemented by some  
7 limited hunting activities. In terms of staple crops, the Cerny people grew both hulled (emmer  
8 wheat: *Triticum dicoccum* and einkorn wheat: *Triticum monococcum*) and naked (likely bread  
9 wheat: *Triticum aestivum*) varieties of wheats (Bakels 1999; Bakels 2009). Other crops exploited  
10 include barley (*Hordeum vulgare*), pea (*Pisum sativum*), and poppy (*Papaver somniferum*)  
11 (Bakels 2009). Zooarchaeological assemblages are composed predominantly of domestic animals,  
12 with cattle being the most numerous, followed by pigs and sheep/goats (Bostyn, et al. 2016;  
13 Colas, et al. 2018; Hachem 2010; Hachem 2011; Sidéra 2000; Tresset 1997). Thus far there is no  
14 direct evidence for dairying from the Cerny contexts. However, evidence of dairying was present  
15 at a nearby Middle Neolithic site Bercy, (Balasse, et al. 2012), therefore, it is possible that the  
16 Cerny groups exploited cattle and sheep/goat for both their meat and dairy products. Other than  
17 domestic animals, wild animals such as red deer, wild boars, and aurochs were also consumed –  
18 albeit to a much lesser extent (Bostyn, et al. 2016; Tresset 1997). Furthermore, despite the lack  
19 of fish bones in the Cerny zooarchaeological assemblages, based on the proximity of Cerny sites  
20 to the rivers, the occasional discovery of fishing related artefacts such as hooks in these sites  
21 (Bostyn, et al. 2018:276), as well as the continuous practice of fishing throughout earlier and  
22 later periods in the region (Augereau and Chambon 2011; Clavel and Arbogast 2005; Dauphin  
23 1989; Drucker, et al. 2018; Naito, et al. 2013), it is safe to assume freshwater resources were  
24 utilized to a certain extent.

## 26 **3. Methods and materials**

### 27 **3.1 Principles of stable isotope analysis**

28 Stable isotope analysis is a well-established methodology for reconstructing past  
29 lifeways, allowing archaeologists to address different archaeological questions, including but not  
30 limited to topics such as lifestyles, food technology, socio-economic organizations, trading  
31 networks, and many more (Katzenberg 2008; Makarewicz and Sealy 2015; Schwarcz and  
32 Schoeninger 2012).. Traditionally, the most common isotopes used by archaeologists are those of  
33 carbon ( $^{13}\text{C}/^{12}\text{C}$ ) and nitrogen ( $^{15}\text{N}/^{14}\text{N}$ ), but recently the suite has grown to include more  
34 elements, such as oxygen ( $^{18}\text{O}/^{16}\text{O}$ ), sulfur ( $^{34}\text{S}/^{32}\text{S}$ ), and strontium ( $^{87}\text{Sr}/^{86}\text{Sr}$ ), allowing  
35 archaeologists to draw from a wider range of assessments, thus improving the resolution of the  
36 analysis. Among these elements, the isotopic analyses of C, N, and S isotopes reveal primarily  
37 diet-related information, while those of O and Sr often relayed information regarding to  
38 seasonality and/ or mobility. As this study mostly concerns the palaeodietary practices of the  
39 Cerny people, the stable isotopes of C, N, and S are analysed.

1 Stable carbon isotope analysis (expressed as  $\delta^{13}\text{C}$ ) is primarily used to identify the  
2 consumption of food groups with distinctive  $\delta^{13}\text{C}$  values, most commonly between  $\text{C}_3$  plants,  $\text{C}_4$   
3 plants, the marine system, and/ or the terrestrial system (Boutton 1991; Chisholm, et al. 1982;  
4 van der Merwe 1982). As both native and cultivated flora of continental Europe during this  
5 period are predominately  $\text{C}_3$  (Ehleringer and Cerling 2002; Motuzaite-Matuzeviciute, et al. 2013),  
6 and our study area is at least 200 km away from the closest coastline, the diets of those involved  
7 in this study are likely predominantly based on  $\text{C}_3$ -based terrestrial resources. Thus,  $\delta^{13}\text{C}$  values  
8 will be mainly used to identify individuals with unusual dietary components that have carbon  
9 isotope signatures deviate from those of the main food source groups, such as freshwater  
10 resources, or wild games. Stable nitrogen isotope analysis (expressed as  $\delta^{15}\text{N}$ ) is typically used to  
11 infer trophic positions of consumers within a biological system (Hedges and Reynard 2007;  
12 O'Connell, et al. 2012). In this study,  $\delta^{15}\text{N}$  values will be primarily used to evaluate animal  
13 protein intake among different social groups. Comparing to the stable isotopes of carbon and  
14 nitrogen, the stable isotopes of sulfur (expressed as  $\delta^{34}\text{S}$ ) are more tied to the geology, and can  
15 vary greatly from area to area, especially in freshwater systems (Nehlich 2015). With adequate  
16 baseline information,  $\delta^{34}\text{S}$  values can help to detect the consumption of freshwater resources  
17 (Drucker, et al. 2018; Nehlich, et al. 2010; Privat, et al. 2007), as well as mobility (Cheung, et al.  
18 2017a; Richards, et al. 2001) among past populations. In this study,  $\delta^{34}\text{S}$  values will be used  
19 alongside  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values, to help elucidate the dietary practices of these Cerny groups.  
20

### 21 ***3.2 Methods and Instrumentation***

22 All bone samples were prepared at the Preparation Laboratory at UMR 7269 LAMPEA,  
23 Aix-en-Provence (France), and the extracted collagen were analysed at Iso-Analytical Limited  
24 (U.K.). Bone collagen was extracted following a modified ABA procedure combining the  
25 methodologies outlined in Brock et al. (2010) and Szpak et al. (2017a): bone samples were  
26 demineralized in 0.5M HCL solution at 4°C in chunks (solution changed ever 2–3 days, until  
27 bones were fully demineralized); demineralized bones were then placed in 0.125M NaOH at  
28 room temperature for successive 30-minute sessions (until solution stopped changing colour);  
29 followed by a 0.5M HCL treatment at room temperature for 1 hour. Samples were thoroughly  
30 rinsed with deionized water in between each change of solution. The samples were then  
31 gelatinized in pH3 solution ( $10^{-3}\text{M}$  HCL) at 75°C for 48 hours. The resultant soluble collagen  
32 was filtered with Ezee filters<sup>TM</sup> and subsequently lyophilized.

33 At Iso-Analytical, samples were analysed with a Europa Scientific<sup>TM</sup> elemental analyzer,  
34 coupled to a mass spectrometer. One in every five samples were measured in duplicates.  
35 Precision of measurements were further monitored using an in-house lab standard that has been  
36 extracted alongside the archaeological bone samples (CC\_REF – cattle bone collage). Reported  
37 carbon and nitrogen isotope values are reported in “per mil (‰)” and are calibrated to VPDB and  
38 AIR, respectively, using IA-R068, IA-R038, IA-R069, and a mixture of IA-R046 and IAEA-  
39 C7 are used as control check standards. IA-R068, IA-R038, and IA-R069 are calibrated and

1 traceable to the international standards IAEA-CH-6 and IAEA-N-1. IA-R046 is calibrated  
2 against and traceable to the international standards IAEA-N-1 and IAEA-C7.

3 For sulfur isotope analysis, all measurements are reported in “per mil (‰)”. Results are  
4 calibrated to VCDT using IA-R061. IAEA-SO-5, IA-R068, and IA-R069 are used as control  
5 check standards. IA-R061 is calibrated against and traceable to the international standards NBS-  
6 127 and IAEA-S-1. IA-R068 and IA-R068 are calibrated against and traceable to the  
7 international standards NBS-127 and IAEA-SO-5.

8 Based the formulae provided in Szpak, et al. (2017b)’s paper, the precision ( $u(R_w)$ ) of the  
9 measurements is determined to be  $\pm 0.07\text{‰}$ ,  $\pm 0.10\text{‰}$ , and  $\pm 0.24\text{‰}$ , for  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$ ,  
10 respectively, on the basis of repeated measurements of calibration standards, check standards, in-  
11 house lab standard, and sample replicates. Accuracy or systematic error ( $u(bias)$ ) is determined  
12 to be  $\pm 0.14$  for  $\delta^{13}\text{C}$ , and  $\pm 0.15$  for  $\delta^{15}\text{N}$ , and  $\pm 0.33$  for  $\delta^{34}\text{S}$ , on the basis of the difference  
13 between the observed and known  $\delta$  values of the check standards and the long-term standard  
14 deviations of these check standards. The total analytical uncertainty was estimated to be  $\pm 0.16$   
15 for  $\delta^{13}\text{C}$ , and  $\pm 0.18$  for  $\delta^{15}\text{N}$ , and  $\pm 0.41$  for  $\delta^{34}\text{S}$ . The formulae sheet with details of all  
16 measured standards are provided in the supplement S1.

17 The quality of the collagen is assessed using the conventional criteria: %collagen  
18 between 0.5% and 22% by weight, %C between 15.3% and 47%, %N between 5.5% and 17.3%,  
19 %S between 13% and 35%, atomic C/N ratio between 2.9 and 3.6, atomic C/S ratio between 300  
20 and 900, and atomic N/S ratio between 100 and 300 (Ambrose 1990; Bocherens, et al. 2011;  
21 DeNiro 1985; Harbeck and Grupe 2009; Nehlich and Richards 2009; van Klinken 1999). Only  
22 samples with elemental compositions within these ranges are accepted for analysis.

### 24 3.3 Materials

25 This study examines the bone collagen C, N, and S isotope compositions of humans from  
26 10 Middle Neolithic sites, as well as fauna from 13 contemporaneous or roughly  
27 contemporaneous sites in Paris Basin. Skeletal remains from a total of 119 humans and 104  
28 faunas are analysed. An additional 140 humans and 177 faunas from published reports are  
29 included for comparison. Not all reports published their data along with collagen quality  
30 indicators, for those that do, only data from samples with well-preserved collagen (see previous  
31 section for detailed criteria) are included.

32 All humans have been osteologically analysed, detailed results are described in Thomas’  
33 (2011:83-103) report, and general information of each analysed individual is provided in  
34 supplement S2. Age-at-death are determined by established methods (Moorrees, et al. 1963;  
35 Scheuer and Black 2000; Schmitt 2005). Sex identification are conducted using the morphology  
36 and morphometry of the mature *ossa coxae* (Bruzek 2002; Murail, et al. 2005).

37 Table 1 summarizes the principal data of each site where human samples are obtained,  
38 listing the major archaeological cultural affiliations, types of cemetery, major burial  
39 arrangements, and references for published data.

1 *Table 1 Summary of sites where human samples were obtained. N refers to total number of individuals analysed.*

River Valley	Site Code	Site	Culture	Cemetery type	Cemetery category	Body position and grave type	N	Reference for isotopes	
Essonne Valley	OLF	Orville “Les Fiefs”	Cerny	Monumental	Slab	Predominately flexed bodies	18	This study	
Seine Valley	BLR	Balloy “Les Réaudins”	Cerny	Monumental	STP	Supine bodies in Balloy type graves	36		
Marne Valley	VNF	Vignely “La Noue Fenard”	Cerny	Monumental	STP	Supine bodies in Balloy type graves	4		
	VPB	Vignely “La Porte aux Bergers”	Cerny	Flat	STP Associated	Predominately supine bodies in Balloy type graves	29		
Yonne Valley	GLS	Gron “Les Sablons”	Cerny	Monumental	STP	Supine bodies in Balloy type graves	5		
	PLS	Passy “La Sablonnière”	Cerny	Monumental	STP	Predominately supine bodies in Balloy type graves	10		
	PR	Passy “Richebourg”	Cerny	Monumental	STP	Predominately supine bodies in Balloy type graves	11	(Rey, et al. 2019)	
	CLP	Chichery “Sur Les Pâtureaux”	Cerny	Flat		Predominately supine bodies in Balloy type graves	8		
	MON	Monéteau “Macherin”	Non-Cerny (Chasséen + some Cerny component)	Flat		Predominately flexed bodies	45		
	GLN	Gurgy “Les Noisats”	Non-Cerny	Flat		Flexed bodies	87	(Rey, et al. 2017; Rey, et al. 2019)	

2  
3  
4 As all the human samples come from cemeteries, faunal samples directly associated with  
5 the humans are not found at all sites. Thus, when directly associated faunal samples are not  
6 available, faunal samples from roughly contemporaneous period in the area are used to establish  
7 the regional isotopic baseline. Despite not examining any human data from the northern part of  
8 the Paris Basin, faunal samples from the Aisne valley: Maizy “Les Grands Aisements” (Le  
9 Bolloch, et al. 1986) and Cuiry-lès-Chaudardes “Les Fontinettes”(Ilett and Hachem 2001), and  
10 Eure valley: Louviers “La Vilette” are included to provide a clearer picture of the overall  
11 isotopic variability within the region. Table 2 provides the principal data of each site where  
12 faunal samples are obtained, listing the major archaeological cultural affiliations, periods, and  
13 references for published data.

14 *Table 2 Summary of sites where faunal samples were obtained. N refers to total number of individuals analysed. For*  
15 *archaeological cultures, RFBS stands for Rubané final du bassin de la Seine, BVSG stands for Blicquy/Villeneuve-Saint-Germain.*  
16 *For periods, Late Mesolithic period corresponds to c. 7000-5000 BC; Early Neolithic corresponds to c. 5000-4700 BC; and*  
17 *Middle Neolithic corresponds to c. 4700-3500 BC.*

River Valley	Site code	Site	Culture	Period	N=	Reference
Aisne Valley	CCF	Cuiry-lès-Chaudardes “Les Fontinettes”	RFBS	Early Neolithic	24	(Balasse 1999)
	MGA	Maizy “Les Grands Aisements”	Michelsberg	Middle Neolithic	14	
Eure Valley		Louviers “La Vilette”	Chasséen	Middle Neolithic	34	(Bocherens, et al. 2005)
Essonne Valley	OLF	Orville “Les Fiefs”	Cerny	Middle Neolithic	9	This study
Marne	VNF	Vignely “La Noue	Michelsberg	Middle Neolithic	5	

Valley		Fenard"				
	VPB	Vignely "La Porte aux Bergers"	RFBS-BVSG	Early Neolithic	26	
Seine Valley	BLR	Balloy Les Réaudins"	Cerny	Middle Neolithic	24	
		Paris Bercy	Chasséen	Middle Neolithic	9	(Balasse, et al. 1997)
		Noyen-sur-Seine "Hauts des Nachères"		Late Mesolithic	36	(Bocherens, et al. 2011; Drucker, et al. 2018; Naito, et al. 2013)
Yonne Valley	VLG	Villeneuve-la-Guyard		Early Neolithic	7	This study
	PAS	Passy "La Sablonnière"	BVSG	Early Neolithic	20	
	GLN	Gurgy "Les Noisats"		Early/Middle Neolithic	18	(Rey, et al. 2017; Rey, et al. 2019)
	NZ	Gurgy "Le Nouveau"	Cerny	Middle Neolithic	5	(Rey, et al. 2019)
	BMT	Beaumont "Le Crôt aux Moines"	Chasséen	Middle Neolithic	37	

1

## 2 **3.4 Statistical methods**

3 All statistical tests are performed using R version 3.6.0 (R Core Team 2019) with RStudio  
4 (RStudio Team 2018). Data are visualized using the package 'ggplot2' (Wickham 2016) and  
5 'ggpubr' (Kassambara 2020). Distribution normality is tested using a Shapiro-Wilk test.  
6 Variance equality is tested using the Levene's test. For groups with normally distributed data  
7 and/or sufficient sample size ( $n > 15$ ), the parametric tests, unpaired independent 11Student's  $t$   
8 tests and one-way ANOVA, are used to determine differences between group means for  $\delta^{13}\text{C}$ ,  
9  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$  values. For groups where data are not normally distributed and/or have small  
10 sample size ( $n < 15$ ), the non-parametric Wilcoxon and Kruskal-Wallis tests are used. For  
11 ANOVA, when differences are detected, post-hoc comparisons are conducted using the Tukey  
12 honest significant difference (HSD) tests. For Kruskal-Wallis, when differences are detected,  
13 post-hoc comparisons are conducted using the Dunn's test using the package 'dunn.test' (Dinno  
14 2017). A 0.05 probability ( $p < 0.05$ ) is considered significant.

15 Bivariate standard ellipses are created using the package 'SIBER' (Jackson, et al. 2011),  
16 with  $p$  value set at 66% (for visualization purpose). Variability of different groups are quantified  
17 using the following area metrics: convex hull areas (TA), standard ellipse areas (SEA), standard  
18 ellipse areas corrected ( $\text{SEA}_C$ ), and standard ellipse areas with Bayesian estimate ( $\text{SEA}_B$ )  
19 (Jackson, et al. 2011). 3-dimensional graphics are created using the packages 'Rcmdr' (Fox, et al.  
20 2015) and 'Rgl' (Adler, et al. 2015). Ellipsoids representing the point concentration of each  
21 group has the expected proportion ( $\alpha$ ) of multivariate-normal observations set as 0.5. Example  
22 scripts for the statistical analyses and graphical visualisations of the results are provided in  
23 supplement S3.

24

## 25 **3.5 Adjustment for regional pattern in isotopic baselines**

26 The sites in this study are scattered across six different river valleys. In order to ensure  
27 differences in the isotopic compositions of the humans were due to actual differences in dietary

1 practices but not geographical factors, faunal isotopic data are used to establish the local  
2 isotopic baseline of each valley. If a regional pattern in an isotopic system is observed, the  
3 following equation is used to estimate the weighted overall shift in the baseline value of the  
4 valley relative to the whole region:

$$5 \quad \text{baseline\_shift} = \sum_{i=1}^y \left( (\mu_{\text{site}_i} - \mu_{\text{overall}_i}) \left( \frac{n_i}{N} \right) \right) \quad (1)$$

6

7 where  $y$  is the number of taxa involved,  $i$  refers to each individual taxon,  $\mu$  is the mean isotopic  
8 value of a particular taxon (site of interest or overall),  $n$  is the number of samples of each taxon  
9 from the site of interest, and  $N$  is the total number of samples from the site of interest.

10 Equation (1) is designed so that only selected taxa are considered, and that likes are  
11 compared with likes. Archaeologists are encouraged to select taxa most commonly consumed at  
12 site/region based on other archaeological evidence. The shift is weighted by the proportion of  
13 each taxon among the total assemblage, hence taxa with higher sample numbers (i.e. with better  
14 represented means) will contribute heavier towards the offset calculation. The resulting offset  
15 (%) can then be applied to address the shift in human isotopic compositions caused by  
16 geographical differences in isotopic baseline values. This adjustment only shifts the isotope data  
17 of the concern site(s) along the x- and/or y- axis(axis) to allow better inter-site comparisons.  
18 However, it does not change the relative variability of the data. Therefore, the internal spatial  
19 patterns of the biplot remain unaltered for intra-site analyses.

20

#### 21 **4. Results**

22 The summary statistics of all humans and faunas are provided in Table 3. The detailed  
23 contextual information and elemental compositions of all analysed specimens are provided in  
24 supplement S2.

25

26

Table 3 Summary statistics of all human and faunal data discussed in this study, including both original and published data. *N* refers to the total number of accepted data. The human data from the two Marne sites has not been adjusted for the baseline shift. A key for the site codes is provided in Table 1.

Valley	Site	$\delta^{13}\text{C}$						$\delta^{15}\text{N}$						$\delta^{34}\text{S}$					
		Min	Max	Mean	Median	SD	N=	Min	Max	Mean	Median	SD	N=	Min	Max	Mean	Median	SD	N=
Essonne	OLF	-21.2	-20.3	-20.7	-20.7	0.3	18	+9.7	+12.9	+10.4	+10.2	0.7	18	+6.4	+10.1	+8.3	+8.4	1.0	15
Marne	VNF	-21.2	-20.9	-21.0	-21.0	0.1	4	+11.6	+13.0	+12.0	+11.7	0.6	4	+6.1	+8.1	+7.3	+7.5	0.9	4
	VPB	-22.7	-20.8	-21.2	-21.0	0.5	29	+11.1	+15.5	+12.5	+12.2	1.0	29	+5.4	+9.6	+7.6	+7.8	1.2	20
Seine	BLR	-21.5	-20.4	-21.0	-20.9	0.3	36	+9.5	+14.7	+11.2	+11.0	1.1	36	-1.1	+9.7	+5.8	+5.9	2.6	22
Yonne	CLP	-20.9	-20.2	-20.6	-20.7	0.3	8	+10.5	+11.6	+10.9	+10.9	0.4	8	+2.3	+6.3	+4.5	+4.8	1.5	6
	GLN	-21.3	-20.3	-20.7	-20.7	0.2	87	+9.9	+13.4	+11.7	+11.6	0.5	87	+0.2	+6.3	+3.3	+3.4	1.4	27
	GLS	-21.1	-21.0	-21.0	-21.0	0.1	5	+11.3	+11.5	+11.4	+11.4	0.1	5	+7.1	+9.6	+8.4	+8.4	0.9	5
	MON	-21.2	-19.8	-20.6	-20.7	0.3	45	+8.7	+12.1	+10.8	+11.0	0.8	45	+1.6	+10.0	+5.2	+4.9	2.3	17
	PLS	-21.6	-20.7	-21.2	-21.2	0.3	10	+10.2	+14.9	+11.6	+11.4	1.2	10	+4.7	+8.9	+7.4	+7.8	1.4	8
	PR	-21.2	-20.8	-21.0	-21.0	0.1	11	+9.7	+14.4	+11.6	+11.5	1.4	11	+7.5	+10.3	+8.7	+8.7	0.9	9
<b>Total</b>		<b>-22.7</b>	<b>-19.8</b>	<b>-20.8</b>	<b>-20.8</b>	<b>0.3</b>	<b>253</b>	<b>+8.7</b>	<b>+14.9</b>	<b>+11.3</b>	<b>+11.3</b>	<b>0.9</b>	<b>253</b>	<b>-1.1</b>	<b>+10.3</b>	<b>+6.1</b>	<b>+6.4</b>	<b>2.5</b>	<b>133</b>
	<b>Fauna</b>																		
Aisne		-24.5	-20.2	-22.9	-23.0	1.0	38	+5.1	+9.2	+6.7	+6.8	1.0	38	—	—	—	—	—	—
Eure		-24.6	-20.3	-22.0	-22.1	1.0	34	+4.6	+10.8	+7.2	+7.0	1.4	34	—	—	—	—	—	—
Essonne		-22.7	-19.1	-20.3	-19.6	1.5	9	+5.0	+10.9	+8.2	+9.0	2.2	9	+7.2	+11.1	+9.7	+10.1	1.5	5
Marne		-23.8	-19.0	-21.6	-21.9	1.2	31	+4.9	+13.8	+8.3	+7.8	1.9	31	+2.0	+11.8	+8.2	+8.4	2.4	16
Seine		-26.7	-19.1	-22.5	-22.7	1.6	68	+3.4	+12.4	+7.2	+6.8	2.0	68	-19.0	+10.1	+2.3	+4.4	7.0	31
Yonne		-23.7	-19.3	-21.7	-21.6	1.3	87	+3.3	+11.0	+6.9	+6.8	1.3	87	-10.0	+15.1	+5.8	+6.8	5.6	34
<b>Total</b>		<b>-26.7</b>	<b>-19.0</b>	<b>-22.1</b>	<b>-22.3</b>	<b>1.4</b>	<b>267</b>	<b>+3.3</b>	<b>+13.8</b>	<b>+7.2</b>	<b>+6.9</b>	<b>1.6</b>	<b>267</b>	<b>-19.0</b>	<b>+15.1</b>	<b>+5.2</b>	<b>+6.4</b>	<b>+6.0</b>	<b>86</b>

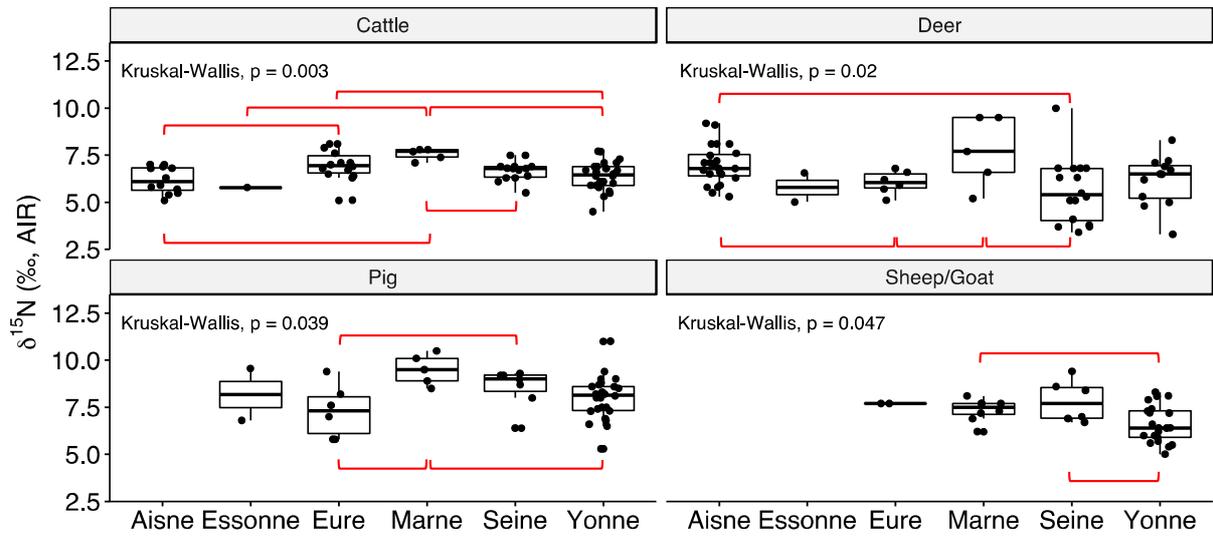
#### 1 **4.1 Faunal data**

2 Out of the 104 faunal samples analysed, 90 samples have produced well preserved collagen for  
3 isotopic analysis. Including the 177 additional previously published fauna data from  
4 neighbouring sites, the  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values for all faunas range from  $-26.7\text{‰}$  to  $-19.0\text{‰}$  and  
5  $+3.3\text{‰}$  to  $+13.8\text{‰}$ , respectively (n=267). The  $\delta^{34}\text{S}$  values of all faunas range from  $-19.0\text{‰}$  to  
6  $+15.1\text{‰}$  (n=86). As a vast majority of the faunal samples are not directly associated with the  
7 human analysed, the faunal isotopic values will only be used to establish regional isotopic  
8 baselines, and will not be used to evaluate husbandry practices at these sites.

9 The  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  baselines of the six river valleys are examined based on the four most  
10 common faunal species found in the region: cattle (n=70), deer (n=64), pig (n=46), and  
11 sheep/goat (n=37). Kruskal-Wallis tests reveal that differences in  $\delta^{15}\text{N}$  values among the six  
12 valleys are statistically significant in all four species (cattle:  $p = 0.0031$ ; pig:  $p = 0.039$ ;  
13 sheep/goat:  $p = 0.047$ ; deer:  $p = 0.021$ ), while differences in  $\delta^{13}\text{C}$  values are only significant in  
14 sheep/goat ( $p = 0.015$ ). Post-hoc Dunn-tests confirm that faunas from the Marne valley have  
15 higher mean  $\delta^{15}\text{N}$  value than those from other valleys (Figure 3). The strongest difference is  
16 observed between the  $\delta^{15}\text{N}$  values of cattle from the Marne and the Yonne valleys ( $\Delta_{\text{mean}} = 0.9\text{‰}$ ,  
17  $p=0.0007$ ), and the biggest difference is observed between the  $\delta^{15}\text{N}$  values of deer from the  
18 Marne and the Seine valleys ( $\Delta_{\text{mean}} = 2.1\text{‰}$ ,  $p=0.0079$ ). In terms of  $\delta^{13}\text{C}$  values, sheep/goat from  
19 the Seine valley have relatively negative  $\delta^{13}\text{C}$  values compare to all other valleys ( $\Delta_{\text{means}}$ :  $0.7 -$   
20  $1.3\text{‰}$ ;  $p < 0.01$ ).

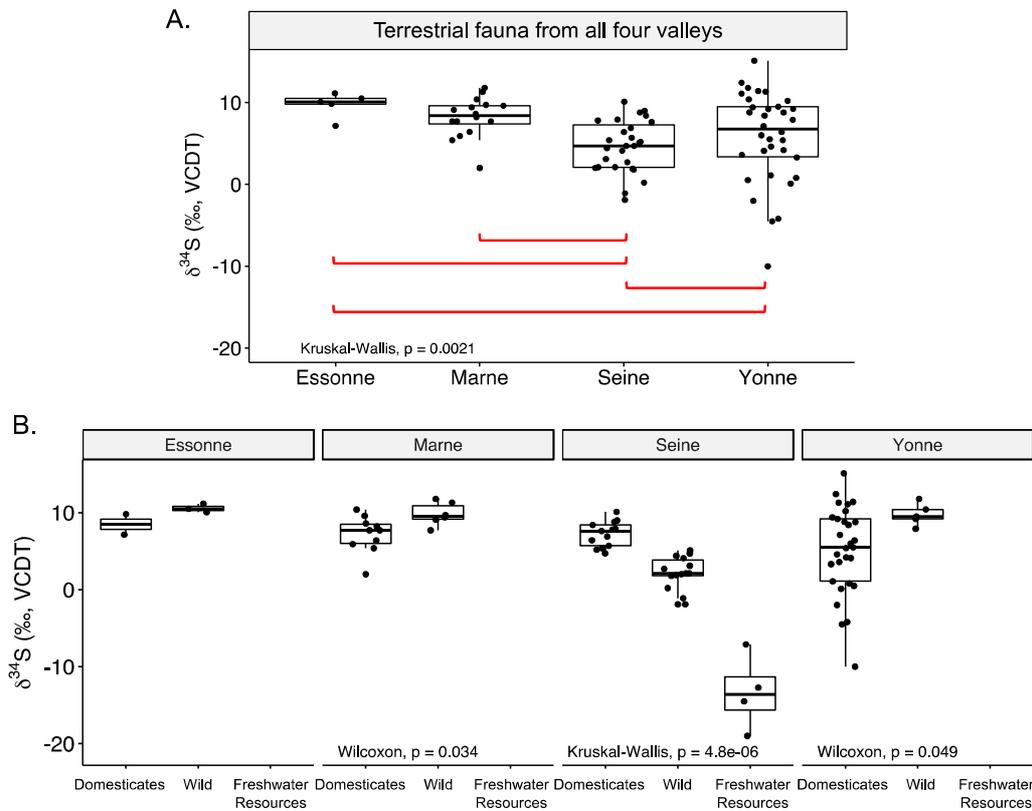
21 In general, the differences in  $\delta^{13}\text{C}$  values among the six valleys are relatively small. Thus,  
22 for the purpose of this study, we will consider the regional differences in  $\delta^{13}\text{C}$  baseline negligible.  
23 For  $\delta^{15}\text{N}$  values, fauna from the Marne valley consistently produce the highest mean values  
24 (except for sheep/goat), therefore it is possible that the  $\delta^{15}\text{N}$  baseline in Marne valley is higher  
25 than the other valleys in the region. Equation (1) is used to calculate the difference in the basal  
26  $\delta^{15}\text{N}$  values between Marne Valley and the general region. The four most abundant species:  
27 cattle, pig, sheep/goat, and deer are used (see supplement S4 for a detailed breakdown of the  
28 calculations). Note that despite the small sample size, the faunal samples from the Marne valley  
29 come from two different sites, one pre-dating and one post-dating the Cerny period, thus we  
30 believe the isotopic ranges shown in these faunas should adequately encapsulate the baseline of  
31 the region.

32 According to Equation (1), the  $\delta^{15}\text{N}$  baseline of the Marne Valley is about  $1.0\text{‰}$  higher  
33 than that of the general Paris Basin region. This adjustment will be applied to all of the humans  
34 from the Marne Valley (VPB and VNF) for subsequent analysis, unless noted otherwise.



1  
 2 *Figure 3 A comparison of the  $\delta^{15}\text{N}$  values of the four most common species of animals found in the area: cattle, deer, pig, and*  
 3 *sheep/goat. Red brackets indicate pairings with statistically significant differences as determined by post-hoc Dunn tests. Data*  
 4 *included both original and published data. For references of published data please refer to Table 2.*

5  
 6 Stable sulfur isotope data are only available from four river valleys: Essonne, Marne,  
 7 Seine, and Yonne. Based on the  $\delta^{34}\text{S}$  values of all terrestrial animals, some regional patterns in  
 8  $\delta^{34}\text{S}$  values can be observed among the four different valleys (Figure 4A). The strongest  
 9 differences are observed between Seine and Essonne ( $\Delta_{\text{mean}}$ : 5.1‰;  $p = 0.0012$ ), and Seine and  
 10 Marne ( $\Delta_{\text{mean}}$ : 3.5‰;  $p = 0.0013$ ) valleys. The terrestrial faunal  $\delta^{34}\text{S}$  baseline at the Yonne valley  
 11 is particularly variable, ranging from  $-10.0\text{‰}$  to  $+15.1\text{‰}$ , interestingly, both are pigs from  
 12 Beaumont (Rey, et al. 2019). Apart from the Essonne valley, where the sample size is too small  
 13 for meaningful statistical analysis, the domesticates from all three valleys have statistically  
 14 significant differences in their mean  $\delta^{34}\text{S}$  values comparing to the wild animals (Figure 4B:  
 15  $\Delta_{\text{mean\_Marne}}$ : 2.6‰;  $\Delta_{\text{mean\_Seine}}$ : 5.0‰;  $\Delta_{\text{mean\_Yonne}}$ : 4.7‰). S isotope measurements from freshwater  
 16 resources are only available from the Seine valley. Figure 4B shows that at the Seine valley, the  
 17 mean  $\delta^{34}\text{S}$  value of the freshwater resources are significantly negative comparing to the  
 18 terrestrial fauna.



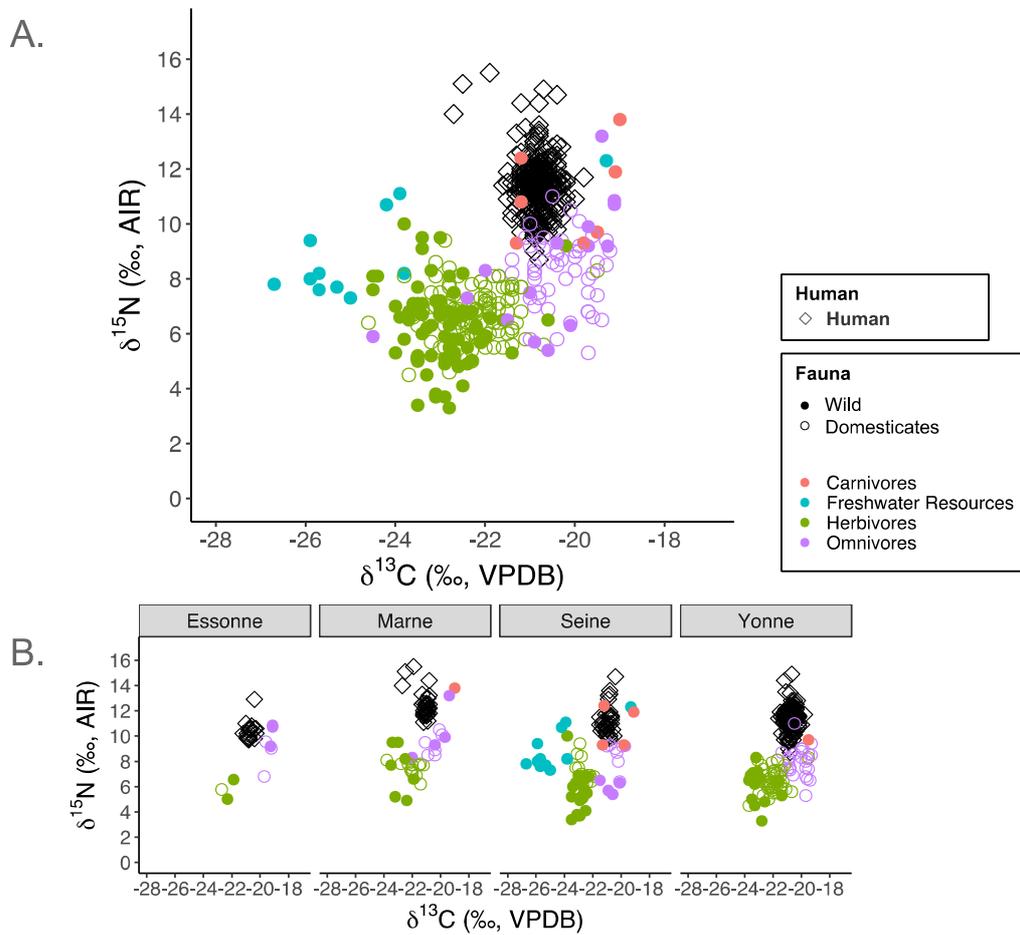
1  
2 *Figure 4*  $\delta^{34}\text{S}$  values from fauna from the Paris Basin region. A. boxplot comparing the  $\delta^{34}\text{S}$  values of all terrestrial fauna. Red  
3 brackets indicate pairings with statistically significant differences as determined by post-hoc Dunn tests. B. boxplot comparing  
4 the  $\delta^{34}\text{S}$  values of all domesticated vs. wild fauna from four river valleys, and freshwater resources from the Seine valley. Data  
5 included both original and published data. For references of published data please refer to Table 2.

6

## 7 **4.2 Human data**

8 A total of 119 human samples are analysed, of which 113 have yielded well preserved collagen  
9 for isotopic analysis. Including the 140 published human data from related sites, all humans have  
10  $\delta^{13}\text{C}$  values ranging from  $-22.7$  to  $-19.8$ ‰,  $\delta^{15}\text{N}$  values range from  $+8.7$ ‰ to  $+15.5$ ‰ ( $n=253$ ),  
11 and  $\delta^{34}\text{S}$  values range from  $-1.1$ ‰ to  $+10.3$ ‰ ( $n=132$ ). In total, 66 individuals come from Cerny  
12 STP contexts, 18 individuals come from Cerny Slab context, 37 individuals come from Cerny  
13 Flat contexts, and 132 individuals come from non-Cerny contexts. The  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of  
14 all human and faunal data are plotted in Figure 5. Note that in this figure, the human data from  
15 the Marne valley have not been adjusted for the baseline shift.

1



2

3 *Figure 5 Overall human and fauna (baseline shift for the Marne Valley not applied). Data included both original and published*  
 4 *data. For references of published data please refer to Table 1 (for human data) and Table 2 (for faunal data). VNF and VPB data*  
 5 *are not adjusted for the baseline shift in  $\delta^{15}\text{N}$  values.*

6

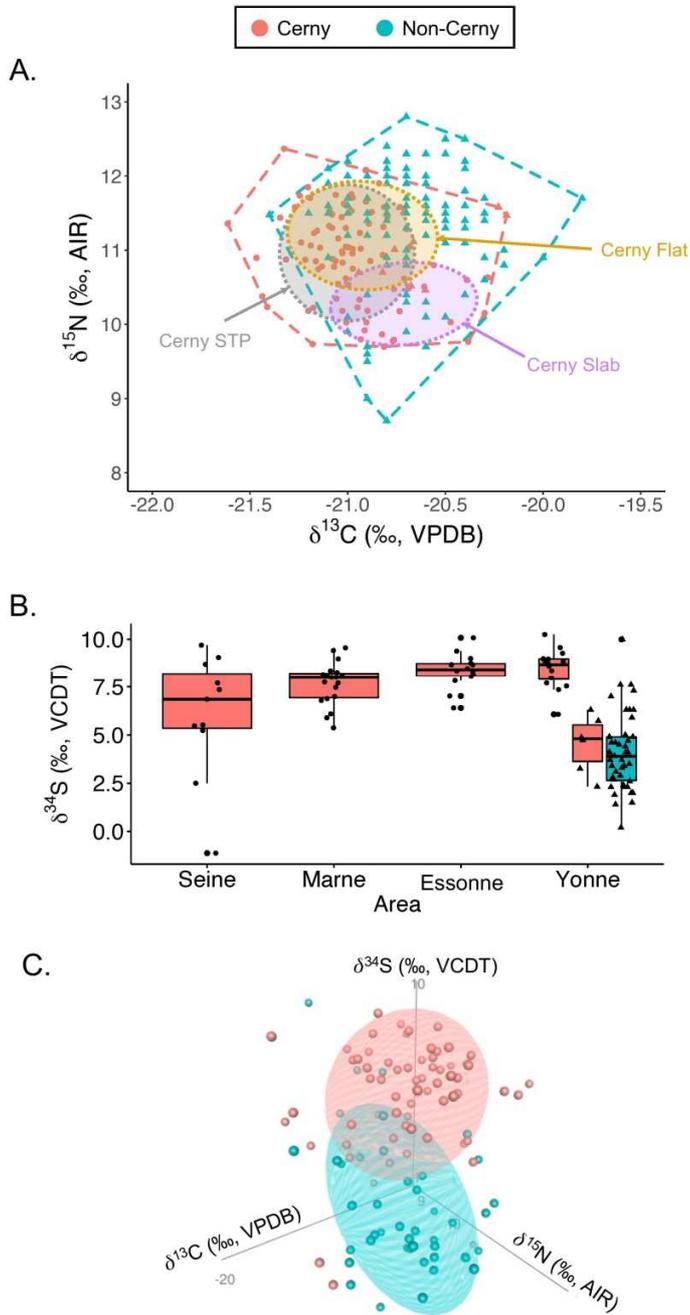
7 Individuals under the age of 4 have relatively elevated  $\delta^{15}\text{N}$  values ( $+12.5 \pm 1.4\text{‰}$ )  
 8 comparing to those above the age of 4 ( $+11.3 \pm 0.8\text{‰}$ ). This is likely due to the breastfeeding  
 9 effect in very young children (Dupras, et al. 2001; Fuller, et al. 2006; Herrscher, et al. 2017). In  
 10 order to focus our analysis on social organisations, all individuals under the age of 4 (n= 35) are  
 11 excluded in subsequent analyses.

12

### 13 **4.2.1 Inter-site comparisons**

14 Hereinafter, all human data from the Marne Valley has been adjusted for the baseline shift in  
 15  $\delta^{15}\text{N}$  values. Comparing to those from non-Cerny contexts, ANOVA tests reveal that the humans  
 16 from the Cerny contexts have slightly lower mean  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values ( $\Delta_{\text{mean}} \delta^{13}\text{C} = 0.2\text{‰}$ ,  $p <$

1 0.001;  $\Delta_{\text{mean}} \delta^{15}\text{N} = 0.4\text{‰}$ ,  $p < 0.001$ ) (Figure 6A), and a higher mean  $\delta^{34}\text{S}$  value ( $\Delta_{\text{mean}} \delta^{34}\text{S} =$   
 2  $3.4\text{‰}$ ;  $p < 0.001$ ) (Figure 6B).



3

4 *Figure 6 Comparing human data by culture. A: stable carbon and nitrogen isotope compositions of the two cultural groups, each*  
 5 *group described by a convex hull (outer dotted line). Cemetery types are described by bivariate standard ellipses (shaded area);*  
 6 *B: stable sulfur isotope compositions of two cultural groups, organized by river valleys; C: 3D plot comparing all three isotope*  
 7 *measurements between the two cultural groups. In A, “Cerny STP” refers to samples from BLR, GLS, PLS, PR, VNF; “Cerny*  
 8 *Flat” refers to samples from CLP and VPB; “Cerny Slab” refers to samples from OLF; and “Non-Cerny” refers to samples*

1 from GLN and MON. In A and B, ● corresponds to original data from this study; ▲ corresponds to data obtained from  
 2 published reports. VNF and VPB data have been adjusted for the baseline shift.

3  
 4 The sites are further divided into four groups based on the cemetery types: Cerny STP,  
 5 Cerny Slab, Cerny Flat, and non-Cerny (Figure 6A). One-way ANOVA tests reveal statistically  
 6 significant differences between the means of all three measurements ( $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$ ) ( $\delta^{13}\text{C}$ :  
 7  $p < 0.001$ ;  $\delta^{15}\text{N}$ :  $p < 0.001$ ;  $\delta^{34}\text{S}$ :  $p < 0.001$ ). In terms of  $\delta^{13}\text{C}$  values, the strongest difference is  
 8 observed between non-Cerny and Cerny STP groups ( $\Delta_{\text{mean}} = 0.3\text{‰}$ ,  $p < 0.001$ ). For  $\delta^{15}\text{N}$  values,  
 9 the strongest difference is observed between non-Cerny and Cerny Slab groups ( $\Delta_{\text{mean}} = 1.1\text{‰}$ ,  $p$   
 10  $< 0.001$ ). For  $\delta^{34}\text{S}$  values, the strongest difference is observed between non-Cerny and Cerny  
 11 Slab groups ( $\Delta_{\text{mean}} = 4.3\text{‰}$ ,  $p < 0.001$ ). Overall, the non-Cerny group stands out the most, not  
 12 only in terms of its mean  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$  values, but also in terms of its range and overall  
 13 variability in isotopic compositions (Table 4).

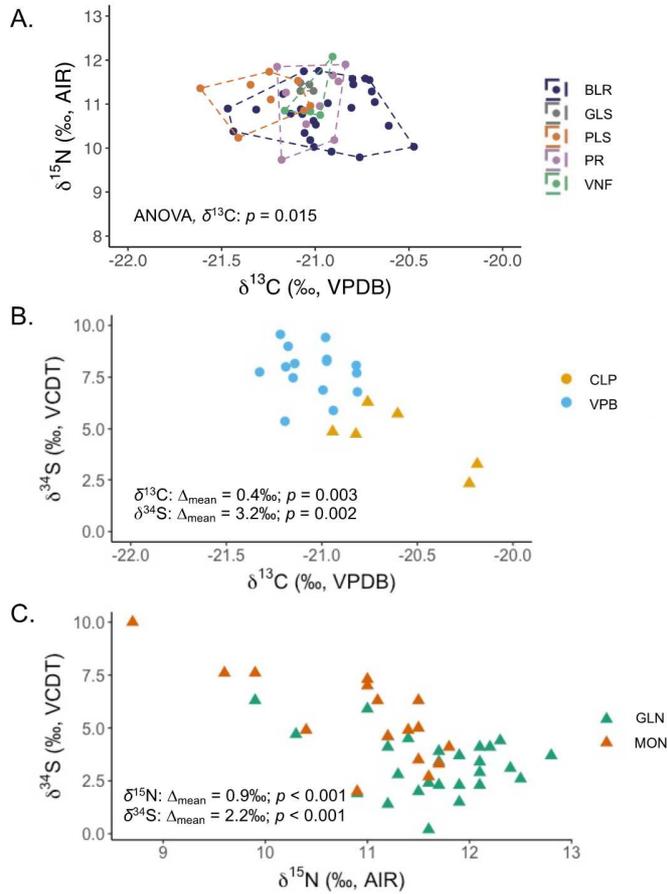
14  
 15 Table 4 Area metrics based only on carbon and nitrogen isotope compositions of all humans above the age of 5 ( $n=218$ ). TA  
 16 refers to convex hull areas; SEA refers to standard ellipse areas; SEAc refers to standard ellipse areas corrected, and SEAb  
 17 refers to standard ellipse areas with Bayesian estimate. See Figure 6A for the visualisation of the convex hulls and standard  
 18 ellipses described by these metrics.

	Cerny STP ( $n=51$ )	Cerny Slab ( $n=17$ )	Cerny Flat ( $n=32$ )	Non-Cerny ( $n=118$ )
TA	1.995	0.872	1.515	3.465
SEA	0.465	0.306	0.405	0.608
SEAc	0.474	0.326	0.418	0.614
SEAb.modes	0.456	0.276	0.390	0.604

19  
 20 Despite having the highest number of sites ( $n=5$ ), and distributed over three river valleys  
 21 (Seine, Marne, and Yonne), Cerny STP is relatively homogenous in terms of isotopic  
 22 compositions (ANOVA;  $\delta^{13}\text{C}$ :  $p = 0.018$ ;  $\delta^{15}\text{N}$ :  $p = 0.352$ ;  $\delta^{34}\text{S}$ :  $p = 0.090$ ) (Figure 7).  
 23 Individuals from PLS have a slight but significantly lower mean  $\delta^{13}\text{C}$  value than those from BLR  
 24 (ANOVA:  $\Delta_{\text{mean}} = 0.3\text{‰}$ ,  $p = 0.006$ ) (Figure 7A).

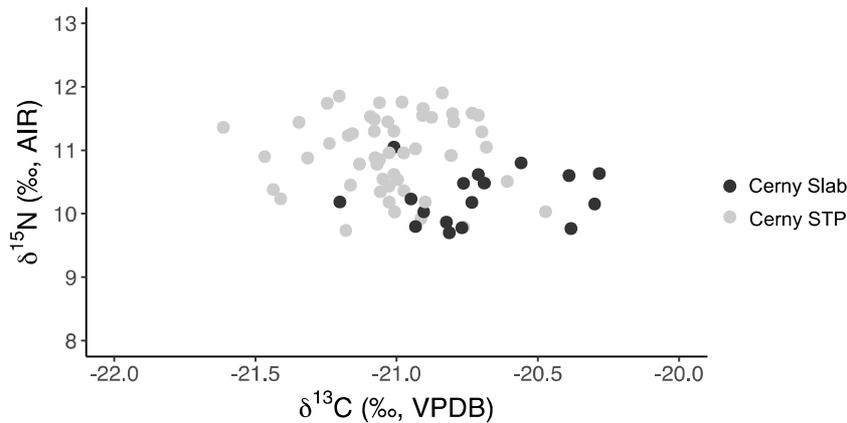
25 Among the Cerny Flat group (VPB and CLP), the two sites show significant disparity in  
 26 the means of  $\delta^{13}\text{C}$  and  $\delta^{34}\text{S}$  values (t-tests;  $\delta^{13}\text{C}$ :  $p = 0.003$ ;  $\delta^{15}\text{N}$ :  $p = 0.127$ ;  $\delta^{34}\text{S}$ :  $p = 0.002$ ).  
 27 Individuals from VPB have lower mean  $\delta^{13}\text{C}$  ( $\Delta_{\text{mean}} = 0.4\text{‰}$ ) and higher mean  $\delta^{34}\text{S}$  ( $\Delta_{\text{mean}} =$   
 28  $3.2\text{‰}$ ) values than those from CLP (Figure 7B). Generally speaking, VPB is more isotopically  
 29 similar to other Cerny sites than CLP, while CLP shares more affinity with the non-Cerny group  
 30 in all C, N, and S isotope values.

31 Among the non-Cerny group (GLN and MON), despite the two sites are located in close  
 32 proximity to each other ( $< 3\text{km}$ ), there are strong differences in the means of  $\delta^{15}\text{N}$  and  $\delta^{34}\text{S}$   
 33 values between the two sites (t-tests;  $\delta^{13}\text{C}$ :  $p = 0.097$ ;  $\delta^{15}\text{N}$ :  $p < 0.001$ ;  $\delta^{34}\text{S}$ :  $p = 0.001$ ).  
 34 Individuals from GLN have higher mean  $\delta^{15}\text{N}$  ( $\Delta_{\text{mean}} = 0.9\text{‰}$ ) and lower mean  $\delta^{34}\text{S}$  ( $\Delta_{\text{mean}} =$   
 35  $2.2\text{‰}$ ) values than those from MON (Figure 7C).



1  
 2 *Figure 7 Significant isotopic comparison within groups: A. Comparison between the  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of individuals from the*  
 3 *Cerny STP sites; B. Comparison between the  $\delta^{13}\text{C}$  and  $\delta^{34}\text{S}$  values of individuals from the Cerny Flat sites; C. Comparison*  
 4 *between the  $\delta^{15}\text{N}$  and  $\delta^{34}\text{S}$  values of individuals from the non-Cerny sites. ● corresponds to original data from this study; ▲*  
 5 *corresponds to data obtained from published reports. VNF and VPB data have been adjusted for the baseline shift.*

6 Results show that all  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$  values in humans are significantly different  
 7 among the two types of Cerny monumental necropolises, Cerny STP and Cerny Slab (Figure 8).  
 8 Comparing to those buried in Cerny STP cemeteries (i.e. BLR, VNF, PR, PLS, GLS), those  
 9 buried in Cerny Slab (i.e. OLF) have significantly elevated mean  $\delta^{13}\text{C}$  ( $t$ -test:  $\Delta_{\text{mean}} = 0.3\text{‰}$ ,  $p <$   
 10  $0.001$ ) and  $\delta^{34}\text{S}$  values ( $t$ -test:  $\Delta_{\text{mean}} = 0.9\text{‰}$ ,  $p = 0.049$ ), and relatively depleted mean  $\delta^{15}\text{N}$  value  
 11 ( $t$ -test:  $\Delta_{\text{mean}} = 0.7\text{‰}$ ,  $p < 0.001$ ).

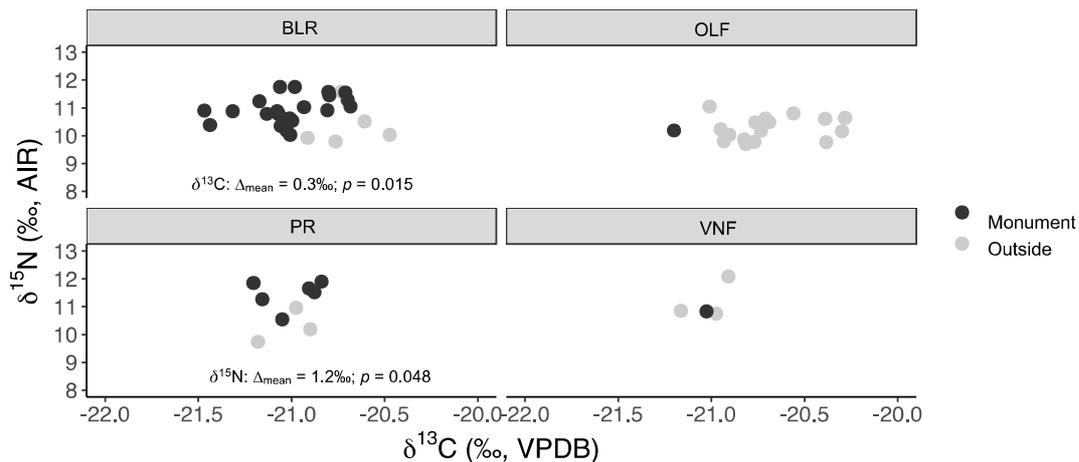


1  
2 *Figure 8 Comparisons between the two types of monumental necropolises in Paris Basin. Cerny Slab refers to OLF, Cerny STP*  
3 *refers to BLR, VNF, PR, PLS, and GLS. All data are original data from this study. VNF data have been adjusted for the baseline*  
4 *shift.*

5  
6 **4.2.2 Intra-site comparisons**

7 Location of burials

8 A total of six monumental cemeteries (STP or Slab) are involved in this study. For four of these  
9 cemeteries (BLR, OLF, PR, and VNF), some burials are located outside of the monumental  
10 structures. We compare the C, N, and S isotope compositions among individuals being buried  
11 within and outside of the monumental structures from these four sites, respectively (Figure 9).  
12 There is statistically significant difference in the mean  $\delta^{13}\text{C}$  values between those buried within  
13 and outside of monumental structures in BLR (Wilcoxon;  $p = 0.02$ ), as well as in  $\delta^{15}\text{N}$  values in  
14 PR (Wilcoxon;  $p = 0.05$ ). No difference can be observed in the mean  $\delta^{34}\text{S}$  values between the  
15 two groups at all four sites.

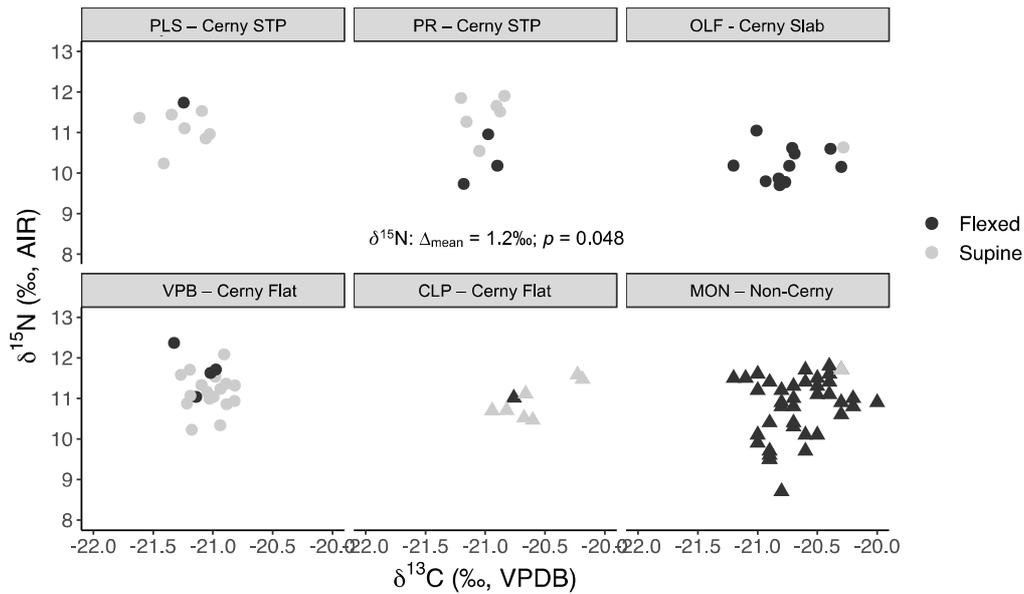


16  
17 *Figure 9 Comparisons between locations of burial in regard to monumental structure(s) in each cemetery. All data are original*  
18 *data from this study. VNF data have been adjusted for the baseline shift.*

1 Burial positions

2 No difference can be observed in the mean  $\delta^{13}\text{C}$  and  $\delta^{34}\text{S}$  values between the two types of burial  
3 positions (supine vs. flexed) at all six sites. However, in PR, those buried in a flexed position  
4 have statistically lower mean  $\delta^{15}\text{N}$  values than those buried in a supine position (Wilcoxon;  $\Delta_{\text{mean}}$   
5 = 1.2‰,  $p = 0.048$ ) (Figure 10). Note that the individual buried in supine position in MON is the  
6 individual buried in a Balloy-type grave (#04-99).

7



8

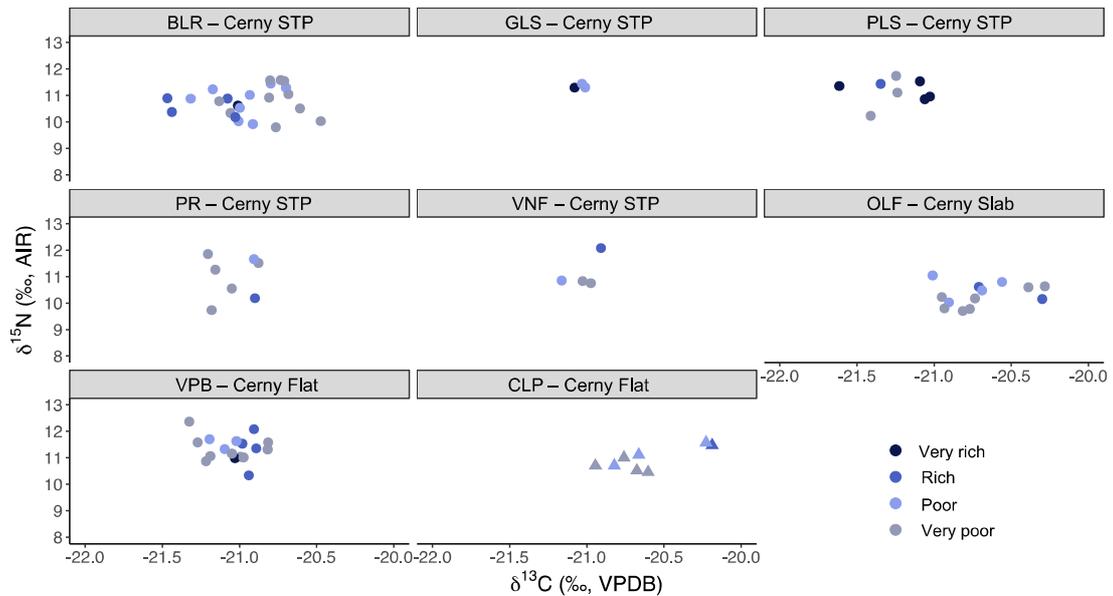
9 *Figure 10 Comparisons between burial positions in each cemetery. ● corresponds to original data from this study; ▲*  
10 *corresponds to data obtained from published reports. VPB data have been adjusted for the baseline shift.*

11

12 Burial goods

13 Following the discussions on the symbolic meanings of Neolithic grave goods in Europe  
14 (Augereau and Chambon 2003; Salanova 1998), individuals are categorized into four groups  
15 according to the quantity and quality of (non-perishable) burial goods (Thomas 2011:577-579;  
16 Thomas and Chambon 2018). Only Cerny sites are considered for this analysis. Quality of burial  
17 goods can be divided in two broad groups: “common” and “precious”, according to the energy  
18 required to procure the object (i.e. labour-intensive production, or involve exotic raw materials)  
19 and the rarity of the object among Cerny burials generally. Common objects include flint blades,  
20 raw flakes, and bone awls. While precious objects include complete ceramics, ornament made  
21 from bones of wild animals (e.g. bear, wolf, boar, deer), and a type of triangular bone spatula  
22 found uniquely in STP burials called the “Eiffel tower” spatula. The four categories are roughly  
23 as follow: very rich (5 or more common goods or at least one precious object), rich (3 to 5  
24 common objects or at least one object made of multiple elements, e.g. neckless made of  
25 numerous beads), poor (less than 3 common objects), and very poor (no grave good). For more  
26 detailed descriptions of grave goods found with each individual, please refer to Supplement S5.

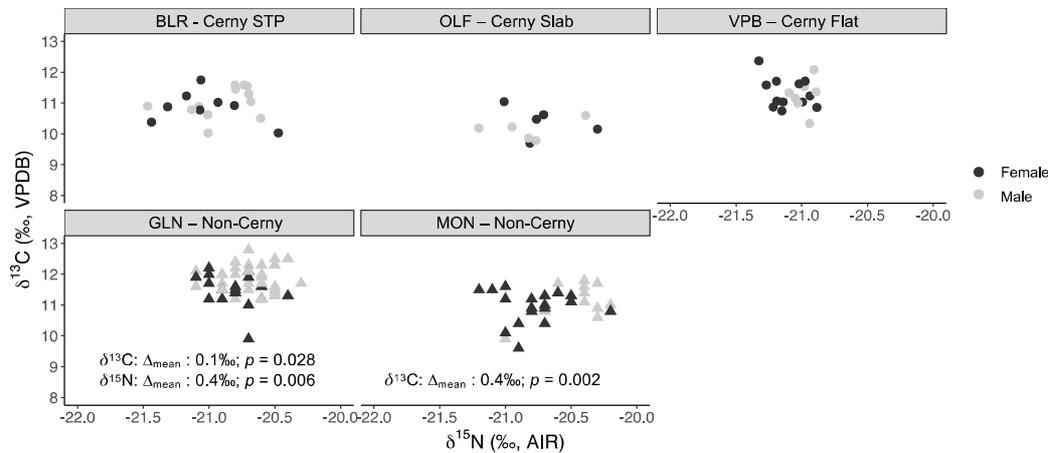
1 As shown in Figure 11, there is no obvious trend observed among those buried in varying  
 2 degrees of grave good richness, except for BLR (Kruskal-Wallis  $\delta^{13}\text{C}$ :  $p = 0.016$ ), where a post-  
 3 hoc Dunn's test reveals that the strongest difference is observed between the rich and the very  
 4 poor ( $\Delta_{\text{mean}} = 0.5\text{‰}$ ,  $p = 0.003$ ). No difference can be observed in the mean  $\delta^{34}\text{S}$  values among  
 5 all level of burial good richness at all seven sites.  
 6



7  
 8 *Figure 11 Comparisons among individuals with varying degree of burial good richness in each cemetery. ● corresponds to*  
 9 *original data from this study; ▲ corresponds to data obtained from published reports. VNF and VPB data have been adjusted*  
 10 *for the baseline shift.*

11  
 12 Sex

13 Only sites with at least 5 of each sex are considered in this comparison. Wilcoxon tests reveal  
 14 that statistically significance differences in  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values are only observed in the two  
 15 Non-Cerny sites (Figure 12). No difference can be observed in the mean  $\delta^{34}\text{S}$  values between the  
 16 two sexes at all five sites.  
 17



1  
2 Figure 12 Comparisons between the two sexes in each cemetery. ● corresponds to original data from this study; ▲ corresponds  
3 to data obtained from published reports. VPB data have been adjusted for the baseline shift.

## 4 5 5. Discussion

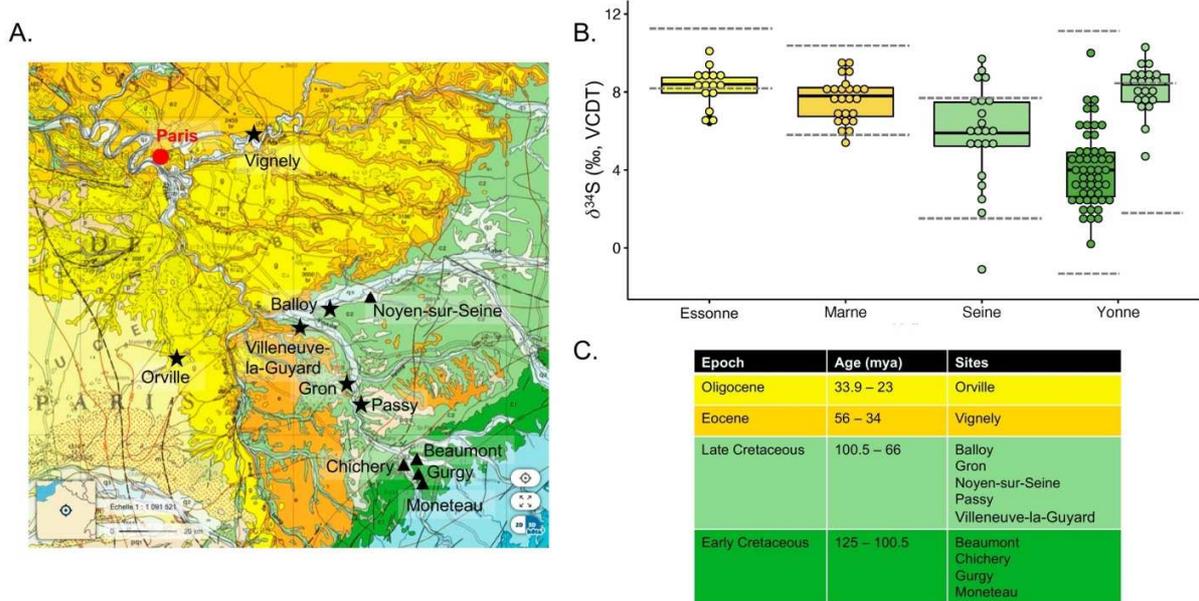
### 6 5.1 $\delta^{13}\text{C}$ , $\delta^{15}\text{N}$ , and $\delta^{34}\text{S}$ baselines

7 While it is possible to separate the fauna by general feeding patterns (i.e. herbivory, omnivory,  
8 and carnivory), most of the species have significant overlapping  $\delta^{13}\text{C}$ ,  $\delta^{15}\text{N}$ , and  $\delta^{34}\text{S}$  values  
9 (Figure 5). Accordingly, it is not possible to qualify or quantify the proportion of different  
10 animal species in the human diets. Hence, the subsequent discussion of human dietary patterns  
11 will refrain from making specific inferences about the respective proportion of each dietary  
12 component. A comparison of faunal isotope measurements from 14 Mesolithic and Neolithic  
13 sites from six river valleys suggested that the geographic variability in the  $\delta^{13}\text{C}$  baseline in Paris  
14 Basin is relatively limited. Some regional patterns can be observed in the  $\delta^{15}\text{N}$  values, notably  
15 from Marne valley (Figure 3). This issue should be rectified after applying the baseline  
16 adjustment on the human data from the Marne valley as calculated by Equation (1). Hence, all  
17 differences observed in  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of humans presented in this study should reflect  
18 actual differences in dietary patterns.

19 The  $\delta^{34}\text{S}$  baseline of the region is much more complicated. At first glance, there is no  
20 apparent pattern observed when only terrestrial faunal  $\delta^{34}\text{S}$  values are considered (Figure 4A).  
21 However, when all human and (terrestrial) faunal data are plotted together, it appears that the  
22 terrestrial  $\delta^{34}\text{S}$  baseline does roughly corresponds with the underlying geological formations  
23 (Figure 13). The bedrocks of the region are mostly consisted of later Mesozoic (Cretaceous) and  
24 early Cenozoic (Eocene and Oligocene) formations. Figure 13 shows that elevated  $\delta^{34}\text{S}$  values  
25 are associated with younger bedrocks, where more depleted  $\delta^{34}\text{S}$  values are associated with older  
26 bedrocks.

27 Therefore, the difference in mean  $\delta^{34}\text{S}$  values observed between Cerny and non-Cerny  
28 groups (Figure 6B) was likely due to geological, rather than cultural factors. While all sites in the

1 Yonne valley are located on Cretaceous age bedrock, the sites in the upper Yonne valley (CLP,  
 2 BMT, GLN, and MON) are situated on older formations than those in the lower Yonne valley  
 3 (VLG, GLS, PR, PLS) (Figure 13). This also explains how CLP, a Cerny Flat site located on the  
 4 same geological formation as the non-Cerny sites, has mean  $\delta^{34}\text{S}$  value more similar to those  
 5 from the non-Cerny sites than those from the Cerny sites (Table 3).



6  
 7 *Figure 13 Establishing a sulfur baseline for the Paris Basin region: A. geological map of the region obtained from Géoportail*  
 8 *(<https://www.geoportail.gouv.fr/>), indicating the locations of sites mentioned in this study with reference to the modern city of*  
 9 *Paris. ★ corresponds to sites with original sulfur data, ▲ corresponds to sites with sulfur data from published reports. B.*  
 10 *boxplot showing  $\delta^{34}\text{S}$  values of humans from the four valleys, colour coded by the underlying geology of each respective site.*  
 11 *Grey dotted lines indicate the range of standard deviations from the means of terrestrial faunal data from each valley. C. table*  
 12 *showing the age of the four major types of bedrock in concern. For references of published data please refer to Table 1 (for*  
 13 *human data) and Table 2 (for faunal data).*

14  
 15 While the differences in  $\delta^{34}\text{S}$  values between domestic and wild animals (Figure 4B) in  
 16 three of the four valleys are significant, the largely overlapping ranges made it difficult to use it  
 17 to detect casual consumption of wild animal protein. However, this observation may offer a  
 18 novel avenue to examine animal husbandry practices in the region. For example, the ranges of  
 19  $\delta^{34}\text{S}$  values observed among the domesticates (Figure 4A) could indicate different husbandry  
 20 regimes: those characterised by a smaller range of  $\delta^{34}\text{S}$  values among the domesticates, such as  
 21 BLR ( $\sigma$ : 1.7‰) could indicate a relatively heavy-handed management approach, while sites with  
 22 larger  $\delta^{34}\text{S}$  ranges (e.g.,  $\sigma_{\text{BMT}}$ : 7.8‰;  $\sigma_{\text{GLN}}$ : 3.9‰) may be indicative of a “free-range” approach,  
 23 where livestock were raised over a larger area, potentially crossing over to regions with different  
 24 geological bedrocks (Rey, et al. 2019). While current evidence is only limited to stable sulfur  
 25 isotope data, and that not all faunal remains were directly associated with the cultural groups  
 26 analysed, this interpretation remains speculative, but more research on this topic may yield  
 27 further insight into animal husbandry practices in the region.

1 In theory, this pattern in  $\delta^{34}\text{S}$  baseline should allow us to identify possible non-locals  
2 based on outlying  $\delta^{34}\text{S}$  values in humans. Unfortunately, S isotope measurements are only  
3 available from freshwater resources from the Seine River.  $\delta^{34}\text{S}$  values in freshwater systems are  
4 known to be extremely variable and fluctuate greatly depending on seasonality, geology, and  
5 proximity to other water sources. For example, the  $\delta^{34}\text{S}$  values of a 1,050 km stretch of the  
6 Danube water can range from +2.8 to +17.1‰ (Nehlich, et al. 2010; Pawellek, et al. 2002). A  
7 much smaller river, the river Arno (~240km) in northern Tuscany, Italy, has  $\delta^{34}\text{S}$  values between  
8 -10.9 and +16.3‰ (Cortecci, et al. 2002). In the Seine River, even just within the small stretch  
9 between BLR and Noyen-sur-Seine (< 20km), the mean  $\delta^{34}\text{S}$  values of freshwater resources is  
10 quite large (Noyen-sur-Seine:  $-15.4 \pm 3.2\text{‰}$ ; BLR:  $-7.1\text{‰}$ ). Thus, without S isotope  
11 measurements from other rivers in the region, we remain sceptical regarding using  $\delta^{34}\text{S}$  values to  
12 evaluate palaeomobility activities within the Paris Basin region. Having said that, Figure 4B and  
13 Figure 5B show that freshwater resources in the Seine have evidently more negative  $\delta^{13}\text{C}$  and  
14  $\delta^{34}\text{S}$  values than those from the terrestrial systems. Therefore, it is possible to argue that  
15 relatively negative  $\delta^{13}\text{C}$  and  $\delta^{34}\text{S}$  values in humans may be indicative of freshwater resources  
16 consumption, at least in sites along the Seine River.

17

## 18 **5.2 Subsistence economy and general dietary patterns in the Paris Basin region**

19 Generally speaking, the  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values of all humans fall within the expected range  
20 of groups that subsisted primarily on  $\text{C}_3$  terrestrial resources (Figure 5). Constrained by the lack  
21 of baseline data from the Essonne, Marne, and Yonne rivers, the consumption of freshwater  
22 resources can only be evaluated at BLR. The extremely tight range in the  $\delta^{13}\text{C}$  values of the BLR  
23 community ( $\delta^{13}\text{C}$ :  $-21.0 \pm 0.3\text{‰}$ ) suggested that the group likely obtained most of their dietary  
24 protein from a restrictive source, which likely came from the terrestrial ( $\delta^{13}\text{C}$ :  $-22.1 \pm 1.2\text{‰}$ )  
25 rather than freshwater system ( $\delta^{13}\text{C}$ :  $-24.7 \pm 2.0\text{‰}$ ). A weak correlation between the  $\delta^{13}\text{C}$  and  
26  $\delta^{34}\text{S}$  values ( $R = 0.45$ ,  $p = 0.17$ ) further substantiated the proposition that freshwater resources  
27 likely did not constitute a major component of the BLR diet.

28 A comparison between the dietary breadths of the Cerny and non-Cerny groups suggested  
29 that the dietary practices of the Cerny groups were more standardized. As shown in Figure 5 and  
30 Table 4, despite occupying a much smaller geographical range, the isotopic variation of the Non-  
31 Cerny group is considerably larger than those of the Cerny group. One explanation is that the  
32 Cerny groups were more socially and economically organized than the non-Cerny groups. By  
33 definition, the practice of agriculture directs all (or most) food production labour into producing  
34 a smaller range of food products (plants and animals) more efficiently. As a result, agricultural  
35 societies tend to enjoy improved quantity, but reduced diversity of food (Dudley and Alexander  
36 2017). Thus, the relatively homogeneity in isotopic composition among the Cerny sites may have  
37 reflected a standardized dietary pattern associated with an agricultural-dependent lifestyle. This  
38 pattern is especially stark among the Cerny STP group, as comparing to inter-group differences  
39 among the Cerny flat and non-Cerny groups (Figure 7). This suggests that despite being scattered  
40 across three river valleys, the Cerny STP group is strongly connected through burial practices,

1 social organizations, as well as subsistence economy. Moreover, isotopic evidence agrees with  
2 other archaeological evidence, that among the Cerny flat group, VPB was likely more closely  
3 associated with the Cerny STP group than CLP.

4 While it is not possible to further quantify the specific dietary components of these  
5 Middle Neolithic communities, a general comparison between the mean  $\delta^{15}\text{N}$  values of the Cerny  
6 humans ( $+11.5 \pm 1.2\text{‰}$ ; baseline adjustment for the Marne humans not applied) and those of the  
7 overall fauna revealed that the humans have comparable mean  $\delta^{15}\text{N}$  value with those of the  
8 carnivores ( $+11.0 \pm 1.6\text{‰}$ ), and much higher than those of the omnivores ( $+8.2 \pm 1.5\text{‰}$ ) and  
9 herbivores ( $+6.6 \pm 1.2\text{‰}$ ). Considering that the diet–tissue trophic enrichment factor is typically  
10 assumed to be around 3–5‰ per trophic level (Bocherens and Drucker 2003; Hedges and  
11 Reynard 2007), the large spacing between the mean  $\delta^{15}\text{N}$  values of human and fauna suggested  
12 that all these communities consumed a considerable amount of animal protein.

13 Furthermore, a study that looked at the oral health of a total of 10 Cerny sites in the Paris  
14 Basin region (n=160) revealed the raw frequency of carious teeth among the Cerny population is  
15 more in line with hunter-gatherer groups (Thomas 2011:522). Dental caries is often associated  
16 with a high consumption of cariogenic foods, such as cereals (Gupta, et al. 2013; Lingstrom, et al.  
17 2000; Moynihan 2016; Selwitz, et al. 2007; Tayles, et al. 2009). Therefore, it is argued that the  
18 occurrence of dental caries tends to be higher in agricultural populations than in hunter-gatherer  
19 groups (Cohen and Armelagos 1984; Larsen 1995; Powell 1985; Temple and Larsen 2007). The  
20 overall prevalence of dental caries among the Cerny groups is relatively low (4.1%) comparing  
21 to agricultural populations (3 – 40%), and is more comparable with hunter-gatherer populations  
22 (0.1 – 8%) (Caselitz 1998; Larsen, et al. 1991; Walker and Hewlett 1990). Thus, the Cerny  
23 groups were likely agricultural groups that relied heavily on animal protein.  
24

### 25 **5.3 Inter-site comparisons**

26 Regarding the two different types of monumental Cerny sites, other than the types of  
27 funerary monuments, the most significant distinction between Cerny STP and Cerny Slab burials  
28 are the burial positions. Burials in Cerny STP sites are typically buried in a supine position,  
29 where burials in Cerny Slab sites are typically buried in a flexed position. Many archaeologists  
30 working in the region agree that the supine position likely reflected incoming influence from the  
31 Rhine basin's *Mittelneolithikum* cultures (Boës 2003; Chambon, et al. 2007; Chambon and  
32 Thevenet 2016; Jeunesse 1997; Mordant 1997; Simonin, et al. 1997), while the flexed burial  
33 position could be attributed to several cultures, based on the similarity in burial practices and  
34 other archaeological evidence, some archaeologists believe that there are links between the  
35 Cerny Slab site of OLF with those from the local Early Neolithic Blicquy/Villeneuve-Saint-  
36 Germain (BVSG) cultures (Simonin, et al. 1997). As shown in Figure 8, individuals buried in  
37 Cerny Slab (i.e., OLF) have very different isotopic compositions comparing to those buried in  
38 Cerny STP (i.e. BLR, VNF, PR, PLS, GLS). While differences in  $\delta^{34}\text{S}$  values can be explained  
39 by geology (Figure 13), differences in  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values are likely related to diets. The  
40 difference in the mean  $\delta^{15}\text{N}$  values between the two groups suggested the Cerny Slab group

1 either consumed less animal protein, or that their dietary protein was obtained from lower trophic  
2 animals (i.e. herbivores), than those from Cerny STP sites (Figure 8). Without the  $\delta^{13}\text{C}$  baseline  
3 of all major food groups, especially those from plants, the difference in  $\delta^{13}\text{C}$  values is harder to  
4 explain. Nevertheless, based on isotopic evidence, it is clear that the two groups had  
5 systematically distinctive dietary practices. Thus, if burial positions are in fact indicative of  
6 cultural origins, our results would suggest that these two lines of cultural origins also differ  
7 strongly in terms of subsistence economy. Even though our current data cannot fully explain the  
8 difference in isotopic compositions between the two types of Cerny sites, the observation is  
9 nonetheless thought-provoking, and raise further questions about the current cultural  
10 categorizations of communities in Middle Neolithic Paris Basin. What does being part of the  
11 Cerny culture really mean? An osteological study done by Thomas (2011) reported that  
12 individuals from the Cerny Slab contexts (OLF + Malsherbes “La Chaise” + Malesherbes “Les  
13 Marsaules”) were taller than the rest of the Cerny populations (Cerny STP + Cerny Flat). Further  
14 distinctions in skull morphology were also observed and confirmed with multivariate statistical  
15 analyses (Thomas 2011:494-501). All these seem to suggest that other than dietary and burial  
16 practices, individuals from the Cerny Slab context may also be biologically different than those  
17 from other Cerny contexts.

18

#### 19 **5.4 Intra-site comparisons**

20 It is presumed that sites with monumental structures, i.e. Cerny STP and Cerny Slab, would have  
21 stronger social differentiations than those without, i.e. Flat sites (with or without Cerny  
22 component). In many archaeological cultures, hierarchy in socio-economic status is sometimes  
23 reflected in dietary patterns. A common phenomenon is that individuals of higher socio-  
24 economic status – as represented by richer grave goods and/or elaborate tomb structures –  
25 consume a higher proportion of animal protein, and hence have higher  $\delta^{15}\text{N}$  values than those  
26 from a lower social class (Ambrose, et al. 2003; Cheung, et al. 2017b; Le Huray and  
27 Schutkowski 2005; Pearson, et al. 2013). However, this is not the case here. As shown in Figure  
28 9 and Figure 11, the relationships between  $\delta^{15}\text{N}$  values and funerary arrangements are erratic,  
29 suggesting that social differentiation at Cerny sites were not necessarily related to the amount of  
30 animal protein intake. Another interesting observation is that individuals who were buried in a  
31 “special arrangement” – whether it be buried within the monuments (Figure 9) or buried in a  
32 position that was not the “norm” within the site (Figure 10) – also have distinctive isotopic  
33 compositions comparing to the rest of the group. While the sample sizes of these aberrant burials  
34 are generally too small for the difference to be picked up by statistical tests, the pattern is  
35 unmistakable. These burial arrangements clearly reflected certain aspects of the buried  
36 individual’s background, including diets, were different from the rest of the group. Nevertheless,  
37 it is important to stress that in the Middle Neolithic Paris Basin, social-economic status, as  
38 reflected by the variety of the burial features, cannot be merely explained, nor described by the  
39 quantity of animal protein intake, but the association between social groups and dietary practices  
40 was both complex and contentious.

1 Furthermore, there is no consistent pattern in the isotopic compositions of individuals  
2 buried in different burial positions within sites (Figure 10). For example, both PLS and PR are  
3 Cerny STP sites, where individuals were predominately buried in a supine position. However,  
4 the flexed burial in PLS has the highest  $\delta^{15}\text{N}$  value among all, while those from PR has  
5 statistically significant lower  $\delta^{15}\text{N}$  values than the rest of the community (Figure 8). The sample  
6 size of our dataset is too small to draw any definite conclusions, however it is possible that the  
7 factors involved in determining burial positions could be different on the intra- and inter-site  
8 levels.

9 The individual (adult male) from MON buried in a Balloy-type grave (supine position;  
10 #04-99) had relatively elevated  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  values comparing to the rest of the MON  
11 population (Figure 10). However, his isotopic measurements are completely outside of the  
12 “Cerny” convex hull (Figure 6A). This suggested that his diet was not particularly similar to  
13 those coming from the Cerny groups. More isotopic as well as archaeological evidence will be  
14 needed to better explain this individual’s particular burial arrangement.

15 Last but not the least, it is important to point out that while there is no difference  
16 observed in the dietary patterns between the two sexes in any of the Cerny sites, the opposite is  
17 observed in the two Non-Cerny sites (Figure 12). Even though the original report stated that the  
18 differences between the sexes are not clearly distinct but only showed “a slight tendency” (Rey,  
19 et al. 2019), statistical tests revealed that the differences are indeed significant, which is  
20 particularly notable given the isotopic variations of all food sources in this region are rather  
21 limited. This difference is surprising in two ways. First, Thomas (2014b) reported that funerary  
22 arrangements in Cerny STP sites were highly gendered: monumental structures were sex-specific,  
23 and certain grave goods, specifically hunting equipment, were always associated with males.  
24 Thus, some differences in the dietary patterns between the two sexes among the Cerny sites are  
25 expected. The fact that there is no discernible distinction between the isotopic compositions of  
26 the two sexes in any Cerny sites suggests that the “gendered” treatment of males and females did  
27 not extend to diets. This is further supported by oral health data, which revealed that males and  
28 females in Cerny sites suffered similar level of dental pathologies (Thomas 2011). Thus, among  
29 Cerny groups, the two sexes may have different treatments/ status after death, but in life, the two  
30 sexes received similar sustenance, at least in terms of macronutrients intake. Secondly, the  
31 differences observed between the males and females in GLN are mostly in  $\delta^{15}\text{N}$  values, while the  
32 differences in MON are mostly in  $\delta^{13}\text{C}$  values (Figure 12). Note that GLN and MON are located  
33 within 3km from each other with overlapping chronologies (Chambon, et al. 2004). Thus, the  
34 differing isotopic compositions in male vs. female diets in non-Cerny sites are clearly not  
35 geological, but reflected differences in dietary compositions between the two sexes at these sites.  
36 Unfortunately, with current data it is not possible to make explicit inferences about the dietary  
37 differences of the two sexes at these sites.

1

## 2 **Conclusion**

3 This study uses stable carbon, nitrogen, and sulfur isotope analysis to reconstruct and compare  
4 the past dietary patterns of individuals from 10 Middle Neolithic sites in Paris Basin. Eight of the  
5 sites belong to the predominant culture in the region, the Cerny culture, where two of the sites  
6 show significant non-Cerny components. Due to the lack of samples from certain key source  
7 groups (i.e. plants and freshwater resources), we are not able to evaluate the subsistence  
8 economy of both Cerny and non-Cerny groups in more specificity. Nevertheless, our results have  
9 showed that comparing to the non-Cerny groups, Cerny groups, especially STP groups, had  
10 relatively standardized diets. In addition, all groups consumed a considerable amount of animal  
11 protein. The accessibility of animal protein, therefore, likely explain why the amount of animal  
12 protein consumed was not related to one's social-economic standing.

13 Furthermore, our results have demonstrated that during the Middle Neolithic period, the  
14 Paris Basin region was a highly dynamic and culturally diverse region. While the cultural sphere  
15 was dominated by Cerny culture during this time, it is important to stress that "Cerny culture"  
16 was consisted of a number of subgroups, notably expressed through different funerary  
17 arrangements. Of the four main types of groups analysed in this study, the Cerny STP group  
18 (BLR, VNF, GLS, PLS, PR) stood out as a tight knitted group with relatively standardized burial  
19 practices, social organizations, and dietary practices. For the Cerny Flat group, VPB is  
20 isotopically and archaeologically more similar to the STP group than CLP. The two "Non-Cerny"  
21 sites (GLN, MON) shown strong intra-group differences, suggesting this group was less strictly  
22 organized. Moreover, the Cerny Slab group was unique in many ways. Despite being categorized  
23 as a Cerny site, most of the individuals were buried in a flexed position – an unusual practice  
24 among Cerny cemeteries. Previous published osteological evidence also put forward the  
25 proposition that Cerny Slab group were likely culturally and biologically different from the other  
26 Cerny groups. Our stable isotope data from OLF, a Cerny Slab site, also shows statistically  
27 significant distinctions comparing to other Cerny sites. Future works comparing other aspects of  
28 the Cerny Slab group with other Neolithic populations will allow a more comprehensive  
29 evaluation of the nature of this group.

30 On an intra-site level, we observed that most of the aberrant burials – burials that do not  
31 conform to the general funerary pattern at a particular site – have outlying stable isotope  
32 measurements. However, there is no clear pattern between burial patterns and dietary practices.  
33 Therefore, it is not clear how do all these different burial patterns translate in terms of social  
34 organization. Nevertheless, it is clear that certain lifestyles (i.e. expressed in outlying stable  
35 isotope compositions) and distinctions were carried through after one's death and expressed as  
36 differing burial patterns. Interestingly, there is no sex-based difference in all three stable isotope  
37 measurements observed among all Cerny groups. This shows that even though Cerny men and  
38 women were treated differently after death, they likely had similar access to food resources in  
39 life. The opposite is observed in the non-Cerny groups.

1 This study has provided a basis for examining the social-cultural diversity in Middle  
2 Neolithic Paris Basin within the interconnecting spheres of culture, geography, and biology.  
3 Future studies should try to establish a more comprehensive baseline database of the region, or  
4 even consider additional analytical approaches, such as dental wear, strontium isotope ( $^{87}\text{Sr}/^{86}\text{Sr}$ ),  
5 or compound specific isotope analyses, to better elucidate the relationship between dietary  
6 practices and social organizations in these sites.  
7

## 8 **Acknowledgement**

9 This research was funded by the Agence Nationale de la Recherche (projet NEOGENRE ANR-  
10 17-CE27-0023, directed by A. Thomas <https://anr.fr/Project-ANR-17-CE27-0023>). The authors  
11 are grateful to F. Bostyn (Inrap), V. Brunet (Inrap), P. Duhamel, F. Müller (Inrap), P. Gouge  
12 (Centre de la Bassée), D. Mordant, and the curators of CEREP Sens for allowing access to the  
13 samples. We also thank P. Chambon (CNRS), J. Hepburn (SFU), M. Le Roy (QUB), L. Mion  
14 (LAMPEA), and T. Royle (SFU) for their insightful comments and suggestions. Special thanks  
15 to Ian Begley and Steven Brookes from Iso-Analytical for their analytical work, and to P.  
16 Fernandez (LAMPEA) and L. Termes (SFU) for their assistance in identifying faunal bones. We  
17 also thank the two anonymous reviewers for their constructive comments.  
18  
19

## 20 **References**

- 21  
22  
23 Adler, D, et al.  
24 2015 rgl: 3D Visualization Using OpenGL.  
25 Ambrose, SH  
26 1990 Preparation and Characterization of Bone and Tooth Collagen for Isotopic Analysis.  
27 Journal of Archaeological Science 17(4):431-451.  
28 Ambrose, SH, J Buikstra, and HW Krueger  
29 2003 Status and Gender Differences in Diet at Mound 72, Cahokia, Revealed by Isotopic  
30 Analysis of Bone. Journal of Anthropological Archaeology 22(3):217-226.  
31 Augereau, A, and P Chambon  
32 2003 Nature et statut des mobiliers funéraires de la nécropole chasséenne de Monéteau  
33 (Yonne). In Les pratiques funéraires néolithiques avant 3500 avant J.-C. en France et  
34 dans les régions limitrophes, Table ronde SPF (15-17 juin 2001, Saint-Germain-en-Laye).  
35 P. Chambon and J. Leclerc, eds. Pp. 131-145, Vol. Mémoire XXXIII: Société  
36 préhistorique française.  
37  
38 2011 Les occupations néolithiques de Macherin à Monéteau (Yonne). Volume Mémoire 53.  
39 Paris.  
40 Bailloud, G  
41 1964 Le néolithique dans le bassin parisien: CNRS.  
42 Bakels, C

- 1 1999 Archaeobotanical Investigations in the Aisne Valley, Northern France, from the Neolithic  
2 up to the Early Middle Ages. *Vegetation History and Archaeobotany* 8:71-77.
- 3 Bakels, CC  
4 2009 Heirs to the First Farmers: 4900 BC - 4300 BC. *In The Western European Loess Belt: Agrarian History, 5300 BC - AD 1000*. Pp. 55-64. Dordrecht: Springer.
- 6 Balasse, M  
7 1999 De l'exploitation du lait au Néolithique moyen en Europe tempérée : examen des  
8 modalités de sevrage des bovins, par l'analyse isotopique des ossements archéologiques,  
9 Université Pierre et Marie Curie
- 10 Balasse, M, et al.  
11 1997 Émergence de la production laitière au Néolithique ? Contribution de l'analyse isotopique  
12 d'ossements de bovins archéologiques. *Comptes Rendus de l'Académie des Sciences -*  
13 *Series IIA - Earth and Planetary Science* 325(12):1005-1010.
- 14 Balasse, M, et al.  
15 2012 Stable Isotope Insights (d18O, d13C) into Cattle and Sheep Husbandry at Bercy (Paris,  
16 France, 4th Millennium BC): Birth Seasonality and Winter Leaf Foddering.  
17 *Environmental Archaeology* 17(1):29-44.
- 18 Bocherens, H, D Billiou, and A Tresset  
19 2005 Approche biogéochimique de l'exploitation de l'environnement par les humains. *In*  
20 *Louviers "La Villette" (Eure): Un Site Néolithique Moyen en Zone Humide*. F. Giligny,  
21 ed. Pp. 265-269. Rennes: Documents Archéologiques de l'Ouest.
- 22 Bocherens, H, and D Drucker  
23 2003 Trophic Level Isotopic Enrichment of Carbon and Nitrogen in Bone Collagen: Case  
24 Studies from Recent and Ancient Terrestrial Ecosystems. *International Journal of*  
25 *Osteoarchaeology* 13(1-2):46-53.
- 26 Bocherens, H, DG Drucker, and H Taubald  
27 2011 Preservation of Bone Collagen Sulphur Isotopic Compositions in an Early Holocene  
28 River-bank Archaeological Site. *Palaeogeography, Palaeoclimatology, Palaeoecology*  
29 310(1-2):32-38.
- 30 Bodu, P, et al.  
31 2014 An Open-Air Site from the Recent Middle Palaeolithic in the Paris Basin (France): Les  
32 Bossats at Ormesson (Seine-et-Marne). *Quaternary International* 331:39-59.
- 33 Boës, E  
34 2003 Comportements funéraires, modifications sociales et mentalités, aux VIe et Ve  
35 millénaires avant J.-C. en Alsace. *In Les pratiques funéraires néolithiques avant 3500*  
36 *avant J-C en France et dans les régions limitrophes*. a.L.J. Chambon P, ed. Pp. 33-44:  
37 *Table ronde SPF (15-17 juin 2001, Saint-Germain-en-Laye)*.
- 38 Bostyn, F, et al.  
39 2018 La Néocropole du Néolithique moyen. Présentation des sépultures. *In Habitat du*  
40 *Néolithique ancien et nécropoles du Néolithique moyen I et II à Vignely la "Porte aux*  
41 *Bergers"*, Seine-et-Marne. F. Bostyn, Y. Lanchon, and P. Chambon, eds. Pp. 206-298.  
42 *Mémoire 64 de la Société Préhistorique Française*.
- 43 Bostyn, F, et al.  
44 2016 L'apport du site d'habitat de Conty « ZAC Dunant » (Somme) à la connaissance de la  
45 culture de Cerny. *Bulletin de la Société préhistorique française* 113(2):291-332.
- 46 Boutton, TW

- 1 1991 Stable Carbon Isotope Ratios of Natural Materials: II. Atmospheric, Terrestrial, Marine,  
2 and Freshwater Environments. *In* Carbon Isotope Techniques. D. Coleman, ed. Pp. 173-  
3 186. San Diego: Academic Press.
- 4 Brock, F, et al.  
5 2010 Current Pretreatment Methods for AMS Radiocarbon Dating at the Oxford Radiocarbon  
6 Accelerator Unit (ORAU). *Radiocarbon* 52(1):103-112.
- 7 Bruzek, J  
8 2002 A Method for Visual Determination of Sex Using the Human Hip Bone. *American*  
9 *Journal of Physical Anthropology* 117:157-168.
- 10 Caselitz, P  
11 1998 Caries. Ancient Plague of Humankind. *In* Dental Anthropology Fundamentals, Limits  
12 and Prospects. K. Alt, F. Rösing, and M. Teshler-Nicola, eds. Pp. 203-226. Stuttgart:  
13 Gustav-Fischer.
- 14 Chambon, P  
15 1997 La nécropole de Balloy "Les Réaudins". Approche archéo-anthropologique. *In* La culture  
16 de Cerny Nouvelle économie, nouvelle société au Néolithique. Actes du Colloque  
17 International de Nemours, 9-11 mai 1994: Mémoires du Musée de Préhistoire d'Ile-de-  
18 France. C. Constantin, D. Mordant, and D. Simonin, eds. Pp. 489-498. Nemours:  
19 APRAIF.
- 20 Chambon, P, et al.  
21 2006 Une nécropole chasséenne à Monéteau (Yonne). Actes de la 6e Rencontre Méridionale de  
22 Préhistoire Récente, 2014, Périgueux, 2006, pp. 143-163.
- 23 Chambon, P, et al.  
24 2004 Une nécropole chasséenne à Monéteau (Yonne). Rencontres Méridionales de Préhistoire  
25 Récente, actes de la sixième session, Périgueux (Dordogne), 2004, pp. 143-162.  
26 ADRAHP et Préhistoire du Sud-Ouest.
- 27 Chambon, P, et al.  
28 2010 La nécropole du Néolithique moyen de Sur les Pâturaux à Chichery (Yonne). *Gallia*  
29 *Préhistoire* 52:117-192.
- 30 Chambon, P, and J Leclerc, eds.  
31 2003 Les pratiques funéraires néolithiques avant 3500 avant J.-C. en France et dans les régions  
32 limitrophes, Table ronde SPF (15-17 juin 2001, Saint-Germain-en-Laye). Volume  
33 Mémoire 33.
- 34 Chambon, P, D Mordant, and J-G Pariat  
35 2007 Sépultures du Néolithique moyen en Bassin parisien: le cas des architectures sépulcrales.  
36 *In* *Archaeologia Mosellana*. F. Le Brun-Ricalens, F. Valotteau, and A. Hauzeur, eds. Pp.  
37 445-466, Vol. 7. Luxembourg: Actes du 26e Colloque interrégional sur le Néolithique
- 38 Chambon, P, et al.  
39 2013 Évolution, coexistence et confrontation de pratiques funéraires entre 4700 et 4000 av. J.-  
40 C. sur un micro-territoire dans la vallée de l'Yonne. *In* Transition, ruptures et continuité  
41 durant la Préhistoire. J. Jaubert, N. Fourment, and P. Depaepe, eds. Pp. 213-227. Paris:  
42 Société Préhistorique Française.
- 43 Chambon, P, and C Thevenet  
44 2014 Coffins and Stretchers in Middle Neolithic Burials: A Comparative Study of the Paris  
45 Basin and the Upper Rhine Plain. *Anthropologie* (1962 - ) 52(3):247-262.

- 1 2016 Transporter et installer le corps dans sa dernière demeure : les premiers contenants  
2 mobiles du Néolithique européen (bassin parisien et plaine du Rhin supérieur, Ve  
3 millénaire). *BMSAP* 28(1):24-31.
- 4 Chambon, P, and A Thomas  
5 2010 The First Monumental Cemeteries of Western Europe : the “Passy type“ Necropolis  
6 in the Paris Basin around 4500 BC. *Journal of Neolithic Archaeology [S.I.]*:1-14.
- 7 Cheung, C, et al.  
8 2017a Diets, Social Roles, and Geographical Origins of Sacrificial Victims at the Royal  
9 Cemetery at Yinxu, Shang China: New Evidence from Stable Carbon, Nitrogen, and  
10 Sulfur Isotope Analysis. *Journal of Anthropological Archaeology* 48:28-45.
- 11 Cheung, C, et al.  
12 2017b Examining social and cultural differentiation in early Bronze Age China using stable  
13 isotope analysis and mortuary patterning of human remains at Xin’an Zhuang, Yinxu.  
14 *Archaeological and Anthropological Sciences* 9(5):799-816.
- 15 Chisholm, BS, DE Nelson, and HP Schwarcz  
16 1982 Stable-Carbon Isotope Ratios as a Measure of Marine Versus Terrestrial Protein in  
17 Ancient Diets. *Science* 216(4550):1131-1132.
- 18 Clavel, B, and RM Arbogast  
19 2005 Fish Exploitation from Early Neolithic Sites in Northern France: The First Data.  
20 *Proceeding of the 13th Meeting of the International Council of the ICAZ Fish Remains*  
21 *Working Group in October 4th-9th, Basel, 2005*, pp. 85-91. *Internationale Archäologie*.
- 22 Cohen, MN, and GJ Armelagos  
23 1984 *Paleopathology at the Origins of Agriculture*. Orlando: Academic Press New York.
- 24 Colas, C, et al.  
25 2018 Les ensembles monumentaux du Néolithique moyen de Beaurieux "la Plaine". *In Revue*  
26 *Archéologique de Picardie*, Direction régionale des Antiquités historiques de Picardie. Pp.  
27 11-123, Vol. 3-4: Centre de recherches archéologiques de la vallée de l'Oise.
- 28 Constantin, C, D Mordant, and D Simonin, eds.  
29 1997 *La culture de Cerny: nouvelle économie, nouvelle société au Néolithique*. Nemours:  
30 APRAIF.
- 31 Constantin, C, and D Vachard  
32 2004 Anneaux d'origine méridionale dans le Rubané récent du Bassin parisien. *Bulletin de la*  
33 *Société préhistorique française* 101:75-83.
- 34 Cortecchi, G, et al.  
35 2002 Natural and Anthropogenic SO<sub>4</sub> Sources in the Arno River Catchment, Northern Tuscany,  
36 Italy: A Chemical and Isotopic Reconnaissance. *Applied Geochemistry* 17(2):79-92.
- 37 Dauphin, C  
38 1989 L'ichtyofaune de Noyen/Seine. L'homme et l'eau au temps de la Préhistoire, Actes du  
39 112e Congrès national des sociétés savantes, 1987, Lyon, 1989, pp. 11-32. CTHS.
- 40 DeNiro, MJ  
41 1985 Postmortem Preservation and Alteration of in vivo Bone Collagen Isotope Ratios in  
42 Relation to Palaeodietary Reconstruction. *Nature* 317:806-809.
- 43 Desloges, J  
44 1997 Les premières architectures funéraires de Basse-Normandie. *In La culture de Cerny*  
45 *Nouvelle économie, nouvelle société au Néolithique*. Actes du Colloque International de

- 1 Nemours, 9-11 mai 1994. C. Constantin, D. Mordant, and D. Simonin, eds. Pp. 515-539:  
2 Mémoires du Musée de Préhistoire d'Ile-de-France.
- 3 Dinno, A  
4 2017 dunn.test: Dunn's Test of Multiple Comparisons Using Rank Sums, Vol. R package  
5 version 1.3.5.
- 6 Drucker, DG, et al.  
7 2018 Aquatic Resources in Human Diet in the Late Mesolithic in Northern France and  
8 Luxembourg: Insights from Carbon, Nitrogen and Sulphur Isotope Ratios.  
9 Archaeological and Anthropological Sciences 10(2):351-368.
- 10 Dudley, N, and S Alexander  
11 2017 Agriculture and Biodiversity: A Review. Biodiversity 18(2-3):45-49.
- 12 Duhamel, P  
13 1997 La nécropole monumentale Cerny de Passy (Yonne) : description d'ensemble et  
14 problèmes d'interprétation. *In* La culture de Cerny Nouvelle économie, nouvelle société  
15 au Néolithique. Actes du Colloque International de Nemours, 9-11 mai 1994. Pp. 397-  
16 448: Mémoires du Musée de Préhistoire d'Ile-de-France.
- 17 Duhamel, P, and M Midgley  
18 2004 Espaces, monumentalisme et pratiques funéraires des sociétés néolithiques en voie de  
19 hiérarchisation. Les nécropoles monumentales Cerny du bassin Seine-Yonne. *In*  
20 Archéologie des pratiques funéraires : Approches critiques. Actes de la table ronde de  
21 Bibracte (7-9 juin 2001, Glux-en-Glenne). L. Baray, ed. Pp. 211-248. Bibracte.
- 22 Duhamel, P, and D Mordant  
23 1997 Les nécropoles monumentales Cerny du bassin Seine-Yonne. *In* La culture de Cerny  
24 Nouvelle économie, nouvelle société au Néolithique. Actes du Colloque International de  
25 Nemours, 9-11 mai 1994. C. Constantin, D. Mordant, and D. Simonin, eds. Pp. 481-488:  
26 Mémoires du Musée de Préhistoire d'Ile-de-France.
- 27 Dupras, TL, HP Schwarcz, and SI Fairgrieve  
28 2001 Infant Feeding and Weaning Practices in Roman Egypt. American Journal of Physical  
29 Anthropology 115(3):204-212.
- 30 Ehleringer, JR, and TE Cerling  
31 2002 C3 and C4 Photosynthesis. *In* Encyclopedia of Global Environmental Change. H.  
32 Mooney and J. Canadell, eds. Pp. 186-190, Vol. 2: The Earth System: Biological and  
33 Ecological Dimensions of Global Environmental Change. Chichester: John Wiley & Sons,  
34 Ltd.
- 35 Fox, J, et al.  
36 2015 Rcmdr: R Commander. R Rackage version 2.1-7.
- 37 Fuller, BT, et al.  
38 2006 Isotopic Evidence for Breastfeeding and Possible Adult Dietary Differences from  
39 Late/Sub-Roman Britain. American Journal of Physical Anthropology 129:45-54.
- 40 Ghesquière, E, et al.  
41 2019 Monumental cemeteries of the 5th millenium BC: The Fleury-sur-Orne contribution. *In*  
42 Megaliths - Societies - Landscapes: Early Monumentality and Social Differentiation in  
43 Neolithic Europe. J. Müller, M. Hinz, and M. Wunderlich, eds. Pp. 177-192. Proceedings  
44 of the international conference "Megaliths - Societies - Landscapes. Early Monumentality  
45 and Social Differentiation in Neolithic Europe" (16th - 20th June 2015) in Kiel, Vol. 1.  
46 Bonn: Verlag Dr. Rudolf Habelt GmbH.

- 1 Gupta, P, et al.  
2 2013 Role of Sugar and Sugar Substitutes in Dental Caries: A Review. *ISRN Dentistry* 2013:5.
- 3 Hachem, L  
4 2010 La faune. *In* Un bâtiment monumental exceptionnel, Beaurieux « la Plaine », Aisne,  
5 Nord-picardie. Pp. 75-78: Inrap.  
6 2011 Les faunes du Néolithique moyen dans le Nord de la France : bilan et pistes de recherches.  
7 *Revue archéologique de Picardie* 28:313-329.
- 8 Harbeck, M, and G Grupe  
9 2009 Experimental Chemical Degradation Compared to Natural Diagenetic Alteration of  
10 Collage: Implications for Collagen Quality Indicators for Stable Isotope Analysis.  
11 *Archaeological and Anthropological Sciences* 1(1):43-57.
- 12 Hedges, REM, and LM Reynard  
13 2007 Nitrogen Isotopes and the Trophic Level of Humans in Archaeology. *Journal of*  
14 *Archaeological Science* 34(8):1240-1251.
- 15 Herrscher, E, G Goude, and L Metz  
16 2017 Longitudinal Study of Stable Isotope Compositions of Maternal Milk and Implications  
17 for the Palaeo-Diet of Infants. *BMSAP* 29((3-4)):131-139.
- 18 Ilett, M, and L Hachem  
19 2001 Le village néolithique de Cuiry-lès-Chaudardes (Aisne). *In* Communautés villageoises du  
20 Proche-Orient à l'Atlantique, 8000-2000 avant notre ère. Errance. Pp. 171-184.  
21 Séminaire du Collège de France: Collection des Hespérides.
- 22 Jackson, AL, et al.  
23 2011 Comparing Isotopic Niche Widths among And within Communities: SIBER – Stable  
24 Isotope Bayesian Ellipses in R. *Journal of Animal Ecology* 80(3):595-602.
- 25 Jeunesse, C  
26 1997 Les pratiques funéraires de la culture de Cerny et le "Mittelneolithikum" du domaine  
27 rhénan. *In* La culture de Cerny Nouvelle économie, nouvelle société au Néolithique. C.  
28 Constantin, D. Mordant, and D. Simonin, eds. Pp. 543-555, Vol. Actes du Colloque  
29 International de Nemours, 9-11 mai 1994: Mémoires du Musée de Préhistoire d'Ile-de-  
30 France.
- 31 Jones, DL  
32 1947 A Geographic Survey of the French Economy. *The American Journal of Economics and*  
33 *Sociology* 7(1):33-51.
- 34 Kassambara, A  
35 2020 ggpubr: 'ggplot2' Based Publication Ready Plots.
- 36 Katzenberg, MA  
37 2008 Stable Isotope Analysis: A Tool of Studying Past Diet, Demography, and Life History. *In*  
38 *Biological Anthropology of the Human Skeleton*. M. Katzenberg and S. Saunders, eds.  
39 Pp. 413-441. Hoboken, NJ: John Wiley & Sons, Inc.
- 40 Larsen, CS  
41 1995 Biological Changes in Human Populations with Agriculture. *Annual Review of*  
42 *Anthropology* 24:185-213.
- 43 Larsen, CS, R Shavit, and MC Griffin  
44 1991 Dental Caries Evidence for Dietary Change: An Archaeological Context. *In* *Advances in*  
45 *Dental Anthropology*. M. Kelley and C. Larsen, eds. Pp. 179-202. New York: Wiley-Liss.
- 46 Last, J

- 1       2013 The End of the LongHouse. *In* Tracking the Neolithic House in Europe: Sedentism,  
2       Architecture, and Practice. D. Hofmann and J. Smyth, eds. Pp. 261-282. New York:  
3       Springer.
- 4   Le Bolloch, M, J Dubouloz, and M Plateaux  
5       1986 Sauvetage archéologique à Maizy (Aisne) : les sépultures rubanées et l'enceinte de la fin  
6       du IV<sup>e</sup> millénaire. *Revue Archéologique de Picardie* 1-2:3-12.
- 7   Le Huray, JD, and H Schutkowski  
8       2005 Diet and Social Status during the La Tène Period in Bohemia: Carbon and Nitrogen  
9       Stable Isotope Analysis of Bone Collagen from Kutná Hora-Karlov and Radovesice.  
10       *Journal of Anthropological Archaeology* 24(2):135-147.
- 11   Leroi-Gourham, A, and M Brézillon  
12       1972 Fouilles de Pincevent. Essai d'analyse ethnographique d'un habitat magdalénien (le  
13       section 36). Volume 9(2): 7<sup>e</sup> supplément. Paris.
- 14   Lichardus-Itten, M  
15       1986 Premières influences méditerranéennes dans le Néolithique du Bassin parisien,  
16       contribution au débat. *In* Le Néolithique de la France. Hommage à Gérard Bailloud. J.-P.  
17       Demoule and J. Guilaine, eds. Pp. 147-160. Paris: Picard.
- 18   Lingstrom, P, J van Houte, and S Kashket  
19       2000 Food Starches and Dental Caries. *Critical Reviews in Oral Biology & Medicine*  
20       11(3):366-380.
- 21   Makarewicz, Cheryl A., and Judith Sealy  
22       2015 Dietary reconstruction, mobility, and the analysis of ancient skeletal tissues: Expanding  
23       the prospects of stable isotope research in archaeology. *Journal of Archaeological*  
24       *Science* 56:146-158.
- 25   Manen, C, and C Hamon  
26       2018 Les mécanismes de la néolithisation de la France. *In* G (dir.) (Hermann, Paris), p. 11-26.  
27       *In* la Protohistoire de la France D. Garcia and J. Guilaine, eds. Pp. 11-26. Paris: Hermann.
- 28   Midgley, M  
29       2005 The Monumental Cemeteries of Prehistoric Europe. Stroud: Tempus.
- 30   Moorrees, CFA, EA Fanning, and EEJ Hunt  
31       1963 Age Variation of Formation Stages for Ten Permanent Teeth. *Journal of Dental Research*  
32       42:1490-1502.
- 33   Mordant, D  
34       1997 Sépultures et nécropoles des VI<sup>e</sup> et Ve millénaires du Bassin Seine-Yonne. *In* Le  
35       Néolithique danubien et ses marges entre Rhin et Seine. C. Jeunesse, ed. Pp. 135-155.:  
36       Actes du 22<sup>e</sup> Colloque interrégional sur le Néolithique (27-29 oct. 1995, Strasbourg)  
37       Supplément aux Cahiers de l'Association pour la Promotion de la Recherche  
38       Archéologique en Alsace.
- 39   Mordant, D, and D Simonin  
40       1997 Sites d'habitats Cerny. *In* La culture de Cerny Nouvelle économie, nouvelle société au  
41       Néolithique. Actes du Colloque International de Nemours, 9-11 mai 1994. C. Constantin,  
42       D. Mordant, and D. Simonin, eds. Pp. 319-340: Mémoires du Musée de Préhistoire d'Ile-  
43       de-France.
- 44   Motuzaite-Matuzeviciute, G, et al.  
45       2013 The early chronology of broomcorn millet (*Panicum miliaceum*) in Europe. *Antiquity*  
46       87(338):1073-1085.

- 1 Moynihan, P  
2 2016 Sugars and Dental Caries: Evidence for Setting a Recommended Threshold for Intake.  
3 *Advances in Nutrition* 7(1):149-156.
- 4 Murail, P, et al.  
5 2005 DSP: A Probabilistic Sex Diagnosis Tool Using World Wide Variation of Pelvic  
6 Measurements. *Bulletins et Mémoires de la Société d'Anthropologie de Paris* 17:167-176.
- 7 Naito, YI, et al.  
8 2013 Nitrogen Isotopic Composition of Collagen Amino Acids as an Indicator of Aquatic  
9 Resource Consumption: Insights from Mesolithic and Epipalaeolithic Archaeological  
10 Sites in France. *World Archaeology* 45(3):338-359.
- 11 Nehlich, O  
12 2015 The Application of Sulphur Isotope Analyses in Archaeological Research: A Review.  
13 *Earth-Science Reviews* 142:1-17.
- 14 Nehlich, O, et al.  
15 2010 Sulphur Isotope Evidence for Freshwater Fish Consumption: A Case Study from the  
16 Danube Gorges, SE Europe. *Journal of Archaeological Science* 37(5):1131-1139.
- 17 Nehlich, O, and MP Richards  
18 2009 Establishing Collagen Quality Criteria for Sulphur Isotope Analysis of Archaeological  
19 Bone Collagen. *Archaeological and Anthropological Sciences* 1(1):59-75.
- 20 O'Connell, TC, et al.  
21 2012 The Diet-Body Offset in Human Nitrogen Isotopic Values: A Controlled Dietary Study.  
22 *American Journal of Physical Anthropology* 149(3):426-434.
- 23 Pawellek, F, F Frauenstein, and J Veizer  
24 2002 Hydrochemistry and Isotope Geochemistry of the Upper Danube River. *Geochimica et*  
25 *Cosmochimica Acta* 66(21):3839-3853.
- 26 Pearson, J, et al.  
27 2013 Food and Social Complexity at Çayönü Tepesi, Southeastern Anatolia: Stable Isotope  
28 Evidence of Differentiation in Diet According to Burial Practice and Sex in the Early  
29 Neolithic. *Journal of Anthropological Archaeology* 32(2):180-189.
- 30 Pigeot, N, ed.  
31 2004 *Les derniers Magdaléniens d'Étiolles : perspectives culturelles et paléohistoriques.*  
32 *Volume XXXVIIème supplément.* Paris: CNRS.
- 33 Powell, ML  
34 1985 The Analysis of Dental Wear and Caries for Dietary Reconstruction. *In* *Analysis of*  
35 *Prehistoric Diets.* R. Gilbert and J. Mielke, eds. Pp. 307-338. Orlando: Academic Pres.
- 36 Privat, KL, TC O'Connell, and REM Hedges  
37 2007 The Distinction between Freshwater- and Terrestrial- Based Diets: Methodological  
38 Concerns and Archaeological Applications of Sulphur Stable Isotope Analysis. *Journal of*  
39 *Archaeological Science* 34(8):1197-1204.
- 40 R Core Team  
41 2019 *R: A Language and Environment for Statistical Computing.* Vienna, Austria: R  
42 Foundation for Statistical Computing.
- 43 Rey, L, G Goude, and S Rottier  
44 2017 Dietary Patterns in the Neolithic: New Isotopic Evidence ( $\delta^{13}C$ ,  $\delta^{15}N$ ) from the “Les  
45 Noisats” Necropolis at Gurgy in the Paris Basin (5th millennium BC). *BMSAP* 29(1):54-  
46 69.

- 1 Rey, L, et al.  
2 2019 A Multi-Isotope Analysis of Neolithic Human Groups in the Yonne Valley, Northern  
3 France: Insights into Dietary Patterns and Social Structure. *Archaeological and*  
4 *Anthropological Sciences* 11:5591-5616.
- 5 Richards, MP, BT Fuller, and REM Hedges  
6 2001 Sulphur Isotopic Variation in Ancient Bone Collagen from Europe: Implications for  
7 Human Palaeodiet, Residence Mobility, and Modern Pollutant Studies. *Earth and*  
8 *Planetary Science Letters* 191(3-4):185-190.
- 9 Rivollat, M, et al.  
10 2015 When the Waves of European Neolithization Met: First Paleogenetic Evidence from  
11 Early Farmers in the Southern Paris Basin. *PLOS ONE* 10(4):e0125521.
- 12 Rottier, S, et al.  
13 2005 Découverte de plus d'une centaine de sépultures du Néolithique moyen à Gurgy, les  
14 Noisats (Yonne). *Bulletin de la Société préhistorique française* 102(3):641-645.
- 15 RStudio Team  
16 2018 RStudio: Integrated Development Environment for R. Boston, USA: RStudio, Inc.
- 17 Salanova, L  
18 1998 Le statut des assemblages campaniformes en contexte funéraire : la notion de "bien de  
19 prestige". *Bulletin de la Société préhistorique française* 95(3):315-326.
- 20 Scheuer, L, and S Black  
21 2000 *Developmental Juvenile Osteology*. New York: Academic Press.
- 22 Schmitt, A  
23 2005 Une nouvelle méthode pour estimer l'âge au décès des adultes à partir de la surface sacro-  
24 pelvienne iliaque. *Bulletins et Mémoires de la Société d'Anthropologie de Paris* 12:279-  
25 302.
- 26 Schwarcz, HP, and MJ Schoeninger  
27 2012 Stable Isotopes of Carbon and Nitrogen as Tracers for Paleo-Diet Reconstruction. *In*  
28 *Handbook of Environmental Isotope Geochemistry: Vol I*. M. Baskaran, ed. Pp. 725-742.  
29 Berlin, Heidelberg: Springer Berlin Heidelberg.
- 30 Selwitz, RH, AI Ismail, and NB Pitts  
31 2007 Dental Caries. *The Lancet* 369(9555):51-59.
- 32 Sidéra, I  
33 2000 Animaux domestiques, bêtes sauvages et objets en matières animales du Rubané au  
34 Michelsberg : de l'économie aux symboles, des techniques à la culture. *Gallia Préhistoire*  
35 – *Archéologie de la France préhistorique* 42:107-194.
- 36 Simonin, D, et al.  
37 1997 Les sépultures sous dalle de type Malesherbes et la nécropole d'Orville. *In* *La culture de*  
38 *Cerny Nouvelle économie, nouvelle société au Néolithique*. Actes du Colloque  
39 International de Nemours, 9-11 mai 1994. M.D. Constantin C, and Simonin D, ed. Pp.  
40 341-379: *Mémoires du Musée de Préhistoire d'Ile-de-France*.
- 41 Szpak, P, K Krippner, and MP Richards  
42 2017a Effects of Sodium Hydroxide Treatment and Ultrafiltration on the Removal of Humic  
43 Contaminants from Archaeological Bone. *International Journal of Osteoarchaeology*  
44 27(6):1070-1077.
- 45 Szpak, P, JZ Metcalfe, and RA Macdonald

- 1 2017b Best Practices for Calibrating and Reporting Stable Isotope Measurements in  
2 Archaeology. *Journal of Archaeological Science: Reports* 13:609-616.
- 3 Tayles, N, K Domett, and S Halcrow  
4 2009 Can Dental Caries be Interpreted as Evidence of farming? The Asian Experience. *In*  
5 *Comparative Dental Morphology*. T. Koppe, G. Meyer, and K.W. Alt, eds. Pp. 162-166,  
6 Vol. 13: Karger Publishers.
- 7 Temple, DH, and CS Larsen  
8 2007 Dental Caries Prevalence as Evidence for Agriculture and Subsistence Variation during  
9 the Yayoi Period in Prehistoric Japan: Biocultural Interpretations of an Economy in  
10 Transition. *American Journal of Physical Anthropology* 134(4):501-12.
- 11 Thomas, A  
12 2011 Identités Funéraires, Variants Biologiques et Facteurs Chronologiques : Une Nouvelle  
13 Perception du Contexte Culturel et Social du Cerny (Bassin Parisien, 4700-4300 avant J.-  
14 C.), l'université Bordeaux 1.
- 15 2014a Bioarchaeology of the Middle Neolithic: Evidence for Archery among Early European  
16 Farmers. *American Journal of Physical Anthropology* 154(2):279-290.
- 17 2014b Social Discriminations through the Grave: Identity and Status of the Dead in the Cerny  
18 Culture (Middle Neolithic, Paris Basin, France). *Anthropologie* (1962 - ) 52(Special Issue:  
19 Bioarchaeology of European Neolithic Populations Part 2):171-182.
- 20 Thomas, A, and P Chambon  
21 2018 Défunts et Mobilier. *In* *Habitat du Néolithique ancien et nécropoles du Néolithique*  
22 *moyen I et II à Vignely la "Porte aux Bergers"*, Seine-et-Marne. F. Bostyn, Y. Lanchon,  
23 and P. Chambon, eds. Pp. 375-385: Mémoire 64 de la Société Préhistorique Française.
- 24 Thomas, A, P Chambon, and P Murail  
25 2011a Une ou deux nécropoles monumentales à Passy ? Identité biologique et recrutement des  
26 défunts. *In* *Le Néolithique du nord de la France dans son contexte Européen : Habitat et*  
27 *économie aux 4e et 3e Millénaires avant notre ère. Actes du 29e Colloque Interrégional*  
28 *sur le Néolithique* (2-3 oct. 2009, Villeneuve d'Ascq): *Revue archéologique de Picardie*,  
29 Numéro Spécial 28. F. Bostyn, E. Martial, and I. Praud, eds. Pp. 507-514.
- 30 2011b Unpacking Burial and Rank: the Role of Children in the First Monumental Cemeteries  
31 of Western Europe (4600–4300 BC). *Antiquity* 85(329):772-786.
- 32 Tresset, A  
33 1997 L'approvisionnement carné Cerny dans le contexte néolithique du Bassin parisien.  
34 *Mémoires du Musée de préhistoire d'Ile-de-France* 6:299-314.
- 35 Valentin, B, et al.  
36 2013 *Palethnographie du Mésolithique : recherches sur les habitats de plein air entre Loire et*  
37 *Neckar. Volume 2-1*. Paris Editions de la Société Préhistorique française.
- 38 van der Merwe, NJ  
39 1982 Carbon Isotopes, Photosynthesis, and Archaeology: Different Pathways of Photosynthesis  
40 Cause Characteristic Changes in Carbon Isotope Ratios that Make Possible the Study of  
41 Prehistoric Human Diets. *American Scientist* 70(6):596-606.
- 42 van Klinken, GJ  
43 1999 Bone Collagen Quality Indicators for Palaeodietary and Radiocarbon Measurements.  
44 *Journal of Archaeological Science* 26(6):687-695.
- 45 Walker, PL, and BS Hewlett

1 1990 Dental health, Diet and Social Status among Central African Pygmies and Bantu.  
2 American Anthropology 92:383-398.  
3 Wickham, H  
4 2016 ggplot2: Elegant Graphics for Data Analysis. New York: Springer-Verlag.  
5 Wunderlich, M, J Müller, and M Hinz  
6 2019 Diversified Monuments: A Chronological Framework of the creation of Monumental  
7 Landscapes in Prehistoric Europe. *In* Megaliths - Societies - Landscapes: Early  
8 Monumentality and Social Differentiation in Neolithic Europe. J. Müller, M. Hinz, and M.  
9 Wunderlich, eds. Pp. 25-30. Proceedings of the international conference "Megaliths -  
10 Societies - Landscapes. Early Monumentality and Social Differentiation in Neolithic  
11 Europe" (16th - 20th June 2015) in Kiel, Vol. 1. Bonn: Verlag Dr. Rudolf Habelt GmbH.  
12