Neandertal cannibalism and Neandertal bones used as tools in Northern Europe

Hélène Rougier, Isabelle Crevecoeur, Cédric Beauval, Cosimo Posth, Damien Flas, Christoph Wißing, Anja Furtwängler, Mietje Germonpré, Asier Gómez-Olivencia, Patrick Semal, Johannes van der Plicht, Hervé Bocherens & Johannes Krause

Almost 150 years after the first identification of Neandertal skeletal material, the cognitive and symbolic abilities of these populations remain a subject of intense debate. We present 99 new Neandertal remains from the Troisième caverne of Goyet (Belgium) dated to 40,500–45,500 calBP. The remains were identified through a multidisciplinary study that combines morphometrics, taphonomy, stable isotopes, radiocarbon dating and genetic analyses. The Goyet Neandertal bones show distinctive anthropogenic modifications, which provides clear evidence for butchery activities as well as four bones having been used for retouching stone tools. In addition to being the first site to have yielded multiple Neandertal bones used as retouchers, Goyet not only provides the first unambiguous evidence of Neandertal cannibalism in Northern Europe, but also highlights considerable diversity in mortuary behaviour among the region’s late Neandertal population in the period immediately preceding their disappearance.

Neandertal funerary practices remain at the forefront of palaeoanthropological research, generating heated debates following the revision of old data and new excavations at key sites such as La Chapelle-aux-Saints, Roc de Marsal, Saint-Césaire and La Ferrassie. More generally, attention has focused on the variability of Neandertal mortuary practices to evaluate their cognitive and symbolic implications, especially as they may provide insights concerning the social systems of this fossil human group. Neandertals are known to have buried their dead and are associated with mortuary behaviours that are often difficult to interpret in Palaeolithic contexts. The site of Krapina (Croatia) is an instructive example in this sense. Evidence for cannibalism was first proposed for this site as early as 1901 based on the fragmentation and traces of burning from a large collection of early Neandertal remains. This evidence has since been disputed by proponents of alternative explanations for the human bone modifications who argue for natural processes while others maintain that the anthropogenic manipulations are best interpreted in the context of secondary burials. Several studies dedicated to cannibalism have proposed that securely identifying anthropogenic modifications related to this practice should incorporate evidence for the...
Identification of new Neandertal remains at Goyet and their biogeochemical characterization. The reanalysis of the Goyet material comprised (i) the revision of the human skeletal material, (ii) systematic sorting of the faunal collections to check for unidentified human remains (Supplementary Fig. S2), and (iii) a multidisciplinary study of the human remains and their context. Two-hundred and eighty-three human remains were identified from different periods, including 96 bone specimens and three isolated teeth identifiable as Neandertal (Supplementary Table S1 and Supplementary Notes S3, S4 and S5). A good number (n = 47) of the bone specimens refit, reducing the total number of isolated Neandertal remains to 64 (Fig. 1 and Supplementary Table S2), of which 10 were directly radiocarbon (14C) dated, 15 were sampled for stable isotope analyses, and 10 for DNA extraction (Table 1 and Supplementary Table S3). Based on their morphology and morphometric characteristics, developmental stage and side for paired elements, as well as the successful recovery of endogenous mitochondrial DNA (mtDNA) sequences, the minimum number of individuals (MNI) represented by the Goyet sample is estimated at five (four adolescents/adults and one child represented by a single tooth; Supplementary Table S2), of which 10 were directly radiocarbon (14C) dated, 15 were sampled for stable isotope analyses, and 10 for DNA extraction (Table 1 and Supplementary Table S3). Although the Neandertal sample includes cranial and postcranial elements (Fig. 1), with long bones best represented and extremities mostly absent, the minimum number of elements (MNE = 35) demonstrates a very low overall skeletal representation. The best represented elements are, in decreasing order, the tibia (six of the eight tibias expected for four adolescents/adults, 75% representation), femur and cranium (50%), humerus and mandible (25%; Supplementary Table S4).

Chemical elemental analyses performed together with stable isotope analyses were used to assess collagen preservation in preparation of 14C dating (see Methods). The ecology of the Goyet Neandertals was also investigated using δ13C and δ15N isotope composition of bone collagen28. Direct 14C dates obtained from the newly identified skeletal material place the Goyet Neandertals to ca. 40.5–45.5 ky calBP. However, when the youngest ages, which likely reflect undetected bone collagen contamination, are excluded (Supplementary Note S6), we cannot rule out the possibility that the Goyet Neandertals represent a single chronological group dating to ca. 44–45.5 ky calBP.
ing37,38 are also suspected on the Neandertal phalanges but are inconclusive (Supplementary Fig. S6). The number of bone surface modifications (Figs 3–5, Table 2, and Supplementary Figs S7 and S8):

| ID     | Specimen Description                                      | Lab #  | 14C age (BP) | Calibrated age (calBP) 95% probability | Genetic analyses | Anthropogenic marks |
|--------|----------------------------------------------------------|--------|--------------|----------------------------------------|-----------------|---------------------|
| C5–1   | Lt paretial frag.                                        | –      | –            | –                                      | –               | –                   |
| Q53–4  | Rt humerus diaph. frag. (humerus III)                   | GrA-54202 | 39,870 + 400, –350 | 44,330–42,920                        | –               | –                   |
| Q55–1  | Lt clavicle frag.                                       | GrA-54257 | 37,860 + 350, –310 | 42,650–41,700                        | –               | C                   |
| Q55–4  | Rt tibia diaph. frag. (tibia IV)                        | –      | –            | –                                      | Nean            | C + N + P + R       |
| Q56–1  | Rt femur diaph. frag. (femur I)                         | GrA-46170 | 38,440 + 340, –300 | 43,000–42,080                        | 1               | C + N + P           |
| Q57–1  |Lt tibia diaph. frag. (tibia II)                         | GrA-46173 | 41,200 + 500, –410 | 45,630–43,910                        | 2               | C + N               |
| Q57–2  |Rt femur diaph. frag. (femur II)                         | GrA-54204 | 36,590 + 300, –270 | 41,800–40,620                        | 2               | C + N + P           |
| Q57–3  |Rt tibia diaph. frag. (tibia VI)                         | GrA-60019 | 38,260 + 350, –310 | 42,900–41,960                        | 2               | C + N               |
| Q119–2 |Lt rib 77 frag.                                          | –      | –            | –                                      | Nean            | –                   |
| Q205–4 |Lt tibia diaph. frag. (tibia I)                          | GrA-46176 | 40,690 + 480, –400 | 45,150–43,430                        | 3               | C + N               |
| Q205–7 |Rt tibia diaph. frag. (tibia III)                        | –      | –            | 1                                      | C + N + P + R   |                      |
| Q374a–1 |Rt rib diaph. frag. (tibia v)                           | –      | –            | 1                                      | C + N + P + R   |                      |
| Q376–1 |Hand prox. phalanx 2–4                                   | GrA-46178 | 39,140 + 390, –340 | 43,650–42,440                        | –               | –                   |
| Q376–20 |Rt humerus diaph. frag. (humerus II)                     | GrA-60018 | 37,230 + 320, –280 | 42,240–41,290                        | –               | C + N               |

Table 1. Sample information and results of the 14C and genetic analyses of the Neandertal remains from Goyet. This specimen may have been barnes resulting in a young age (Supplementary Note S6). For the calibration of the 14C ages, see Supplementary Note S6. Genetic analyses: 1–3 represent three distinct Neandertal mtDNA lineages, Nean: Neandertal status confirmed; Anthropogenic modifications: C: cutmarks, N: percussion notches, P: percussion pits, R: retoucher traces. All of the specimens are part of the RBINS collections and were excavated by E. Dupont in 1868.

Although this appears the most parsimonious hypothesis when individual bone associations, taphonomic aspects and similar anthropogenic modifications observed across the sample are taken into account, we retain the conservative range of ca. 40.5–45.5 ky calBP for the Goyet Neandertals in the absence of definitive evidence.

Out of the 10 samples processed for genetic analysis, seven show three distinct complete or almost complete mtDNA lineages (noted 1–3 in Table 1). The newly reconstructed mtDNAs from Goyet were compared with the mtDNA of 54 modern humans, eight previously sequenced Neandertals and one Denisovan individual29–34. Phylogenetic relationships were assessed using maximum parsimony and maximum likelihood trees (Fig. 2 and Supplementary Fig. S4), confirming the analysed specimens to fall within the known diversity of Neandertal mtDNA. The Goyet Neandertal mtDNAs appear most closely related to late Neandertal mtDNAs from Central and Western Europe, such as those from the Neandertal type-site (Germany), El Sidrón (Spain) and Vindija (Croatia), which all show only modest genetic variation despite large geographic distances when compared to modern humans. As previously suggested31, this might reflect a low effective population size of Neandertals in general, and for the late Neandertals in particular.

Taphonomic analysis of the Goyet Neandertal material and anthropogenic modifications. Overall, the Neandertal remains are highly fragmented. Forty-nine percent of the bone specimens (47 out of 96) were refit to at least one other, with the number of specimens per refit set ranging from 2 to 8 (tibia I; Supplementary Fig. S5). Several examples of refits between levels 1 through 3 were also identified. None of the Neandertal bones are complete, although the proximal extremity of a hand phalanx (2878–37) is only slightly eroded (Fig. 1). Cortical surfaces are well preserved and exhibit limited post-depositional modifications. Most long bones fractures involve green breaks, as indicated by smooth margins and spiral fractures35. Traces of peeling may also provide evidence for the fresh bone fracture of a cranial fragment and several ribs (ref. 11; Supplementary Fig. S5). Although bears can produce such traces36, the presence of cutmarks on several ribs (see below) suggests that the most parsimonious hypothesis is that they are anthropogenic. Traces of human chewing37,38 are also suspected on the Neandertal phalanges but are inconclusive (Supplementary Fig. S6). The numerous unambiguous anthropogenic marks on the Goyet Neandertal remains can be attributed to three categories of bone surface modifications (Figs 3–5, Table 2, and Supplementary Figs S7 and S8):

1. Cutmarks. Nearly a third of the Neandertal specimens bear cutmarks. The locations of the limited number of cutmarks observed on the upper limb may indicate disarticulation whereas those on the lower limb are consistent with defleshing. Several cutmarks on the internal and external surfaces of the ribs may be connected to evisceration, dismemberment of the thoracic cage and removal of the thoracic muscles. An additional cutmark on the medial side of the mandible, close to the mandibular condyle, appears consistent with dismemberment.

2. Two types of percussion marks (notches and pits) were identified. Observed only on a single radius alongside several femurs and tibias, notches are likely connected to the fracturing of fresh diaphyses and marrow extraction. Percussion pits are common and probably indicate failed attempts at fracturing bones. Both
percussion notches and pits were also identified on eight bones (e.g. femur I, Fig. 5).

(3) Retouching marks. These marks, found on a femur and three tibias (Supplementary Figs S9–S12), result from retouching the edges of stone tools. The fact that none of the affected areas overlap on adjacent fragments suggests the bones to probably have first been marrow cracked. Femur III shows two retouching zones on the anterior and postero-medial surfaces, both located at mid-shaft. Interestingly, the traces found on the tibias are located in the same areas of the shaft on all three bones (posterior or postero-medial surface at mid-shaft). The retouchers are made on four different Neandertal bones that represent at least three of the four adolescent/adult Neandertal individuals (Supplementary Note S5).

While animal bone retouchers are common in European Middle Palaeolithic contexts (e.g., refs 39–41), Goyet is one of only four sites (Krapina in Croatia 42, La Quina and Les Pradelles in France 43,16) to have yielded...
retouchers on Neandertal skeletal elements and the sole to have produced multiple examples (Table 3). At Krapina and Les Pradelles, femur shaft fragments were used as retouchers, whereas the La Quina example is on a parietal fragment. According to the criteria proposed by Mallye et al., the blanks used for the Goyet retouchers made on Neandertal bones were most likely green due to the absence of scaled areas, and in addition, two of the five retoucher areas exhibit concentrated and superposed marks which imply prolonged use. The rectilinear morphology of the marks also supports the use of the bones for retouching flint flakes, the most common raw material found at Goyet.

Comparative taphonomic analysis of the fauna from the Troisième caverne. Due to the large size of the Goyet faunal collection (>30,000 specimens), only a sample from Dupont’s excavation was examined (see Methods; Supplementary Fig. S2 and Supplementary Table S5). The skeletal material analysed corresponds mostly to long bone shaft fragments from various species that were mixed together within the collection and did not appear to have been previously sorted. We focused on remains from levels 3 and 2, which yielded the Neandertal remains, and on material from the same storage trays containing the human remains in order to have an overview of the associated faunal spectrum and assess food procurement and management strategies. Horse and reindeer are by far the most frequent species in the studied assemblage (86% of the 1,556 identified specimens; Supplementary Table S5). No rodent toothmarks were observed, carnivore remains are relatively sparse and carnivore damage is extremely rare on the Neandertal, horse and reindeer remains (Table 2), indicating carnivores to have had limited access to the bone material.

Anatomical profiles reveal numerous similarities between the Neandertal sample on one hand and horse and reindeer on the other (Supplementary Table S6 and Supplementary Fig. S13). The tibia is the most abundant element of all three species, whereas the axial skeleton and extremities of the forelimb and hindlimb are poorly represented. Bones of the hindlimb are better represented for all three species compared to forelimb elements, this is especially the case with the Neandertal material. The only notable difference between the faunal and Neandertal remains is the high representation of cranial elements for the latter. Unfortunately, the absence of contextual data precludes an analysis of the spatial distribution of both the faunal and Neandertal remains within the Troisième caverne.

The most intensely processed Neandertal elements are femurs and tibias (Supplementary Fig. S7), which are also the bones with the highest nutritional content (meat and marrow). The same pattern was documented for horse and reindeer bones. Overall, anthropogenic marks on the Neandertal remains match those most commonly recorded on the faunal material (Supplementary Figs S14–S16). All three taxa were intensively exploited,
Interestingly, none of these sites produced evidence for the treatment of the corpse similar to that documented for around Goyet produced Neandertal remains reliably dated to between 50–40 ky calBP (Supplementary Fig. S1). Known from two sites in Belgium, Spy and Goyet, with its first appearance dated at other sites to around 43–44 ky calBP, no reliable information is currently available for its regional chronology. Given the direct 14C dates on Palaeolithic sites, large bone fragments of medium and large-sized animals were selected for their exploitation as food sources. At Goyet, as at several French Middle Palaeolithic sites, large bone fragments of medium and large-sized animals were selected, exhibiting evidence of skinning, filleting, disarticulation and marrow extraction. However, the Neandertal remains stand out as they show a high number of percussion pits (Table 2), which may be linked to the thick cortical structure of Neandertal long bones. Although the Neandertal remains show no traces of burning, the possibility that they may have been roasted or boiled cannot be excluded. The high number of cutmarks and the fact that DNA could be successfully extracted are, however, inconsistent with this possibility. Lastly, similar to what has been noted at other sites, the Neandertal retouchers are made on fragments of dense bones with comparable mechanical properties to the horse and reindeer bones. At Goyet, at several French Middle Palaeolithic sites, large bone fragments of medium and large-sized animals were selected. Among the Goyet Neandertal material, the largest and thickest fragments were also selected, as was the case at Les Pradelles and Krapina. Interestingly, a femur and tibias of cave bears were also among the retoucher blanks selected by Neandertals at Scladina.

The observed patterns of faunal exploitation can be interpreted as the selective transport of meat and marrow rich elements to the site that were subsequently intensively processed. However, this apparent pattern may reflect a collection bias favoring the largest and most easily identifiable fragments. Similarities in anthropogenic marks observed on the Neandertal, horse and reindeer bones do, however, suggest similar processing and consumption patterns for all three species.

**Discussion**

Our results show that the Neandertals from the Troisième cave of Goyet were butchered, with the hypothesis of their exploitation as food sources the most parsimonious explanation for the observed bone surface modifications. Goyet provides the first unambiguous evidence of Neandertal cannibalism in Northern Europe and given the dates obtained on the Neandertal remains, it is most likely that they were processed by their fellow Neandertals as no modern humans are known to have been in the region at the time. However, the available data make it impossible to determine whether the modifications observed on the Neandertal skeletal material represent symbolic practices or simply result from the processing of immediately available sources of food. In addition, Goyet is the first site to have yielded multiple Neandertal bone retouchers. It has been proposed that Middle Palaeolithic retoucher blanks were by-products of the processing of carcasses for food consumption, which may have been selected to be re-used. The data at hand do not allow us to propose a different scenario for the Goyet retouchers made on Neandertal bones. However, the freshness of the blanks used suggests that Neandertals may have been aware that they were using human remains. Whether this was part of a symbolic activity or induced by a functional motivation cannot be attested, as was the case for the La Quina Neandertal retoucher.

Although the Goyet late Neandertals date to 40.5–45.5 ky calBP, the lack of reliable contextual information makes it impossible to associate them with any of the technocomplexes from the site. However, coeval Mousterian assemblages are known from sites in the Mosan Basin, as at unit 1A of Scladina, located only 5 km from Goyet, layer CI-8 of Walou Cave, and layer II of Trou de l’Abîme at Couvres (Supplementary Note S2). While the LRJ is known from two sites in Belgium, Spy and Goyet, with its first appearance dated at other sites to around 43–44 ky calBP, no reliable information is currently available for its regional chronology. Given the direct 14C dates obtained for the Goyet Neandertals, it is impossible to securely associate them with either the Mousterian occupation(s) or the LRJ.

In terms of the region’s late Neandertal mortuary practices, four sites within an approximately 250 km radius around Goyet produced Neandertal remains reliably dated to between 50–40 ky calBP (Supplementary Fig. S1). Interestingly, none of these sites produced evidence for the treatment of the corpse similar to that documented for Goyet. Two Belgian sites, Walou Cave and Trou de l’Abîme, produced, respectively, a premolar and a molar. Although impossible to infer the behavioural signature represented by these remains, given their state of preservation it is highly unlikely that they involved funerary practices, including burial. In Germany, the Neandertal individuals from Feldhofer, including Neandertal 1, are possibly associated with the “Keilmesser group”, a late

| Area                             | Femur III anterior area | Femur III medial area | Tibia III posterior area | Tibia IV posterior area | Tibia V medial area |
|---------------------------------|-------------------------|-----------------------|--------------------------|-------------------------|---------------------|
| Length (mm)                     | 14.6                    | 19.2                  | 11.4                     | 17.0                    | 20.9                |
| Width (mm)                      | 4.4                     | 7.5                   | 9.0                      | 5.8                     | 13.2                |
| Preparatory scraping             | no                      | no                    | no                       | no                      | no                  |
| Morphology (if concentrated and superposed traces) | --                      | hatched               | --                       | --                      | hatched             |
| Orientation (to the long axis of the fragment) | oblique                 | transverse            | transverse               | transverse             | transversely, slightly oblique |
| Position                        | centered                | centered?             | centered                 | centered               | centered            |
| Concentration                   | dispersed               | concentrated and superposed | dispersed               | dispersed             | concentrated and superposed |
| Morphology                      | rectilinear - smooth    | rectilinear - rough   | rectilinear - smooth     | rectilinear - smooth and rough | rectilinear - smooth |

Table 3. Description of the Neandertal bone retouchers from Goyet using the criteria of Mallye et al. and Daujeard et al.
Middle Palaeolithic technocomplex \(^{58,59}\) unknown at Goyet (Supplementary Note S2). Neandertal 1 comprises elements of the cranial and postcranial skeleton of a single individual. Despite cutmarks on the cranium, clavicle and scapula, the long bones are intact and damage to still articulated skeletal elements during their recovery indicates that at least part of the skeleton may have originally been in anatomical connection \(^{60,61}\). Finally, at Spy, direct dates obtained on the two Neandertal adults place them within the current chronology of the LRJ \(^{62}\), although the association between the human remains and this technocomplex is uncertain due to the lack of contextual information. A recent reassessment of the Spy specimens and their context suggests that both individuals were buried \(^{63}\). And, it is worth noting that the most complete individual, Spy II, was originally described as a complete skeleton found in a contracted position. Moreover, the completeness of the skeleton and the absence of post-depositional alterations suggest the body to have been rapidly protected \(^{63}\).

Considerable diversity is evident in the mortuary behaviour of the late Neandertal populations of Northern Europe, possibly involving both primary and secondary deposits, alongside other types of practices, including cannibalism. Despite low genetic diversity amongst late Neandertal populations, the presence of various late Middle Palaeolithic technocomplexes, as well as the LRJ, nevertheless suggests significant behavioural variability amongst these groups in Northern Europe.

**Methods**

**Collection assessment.** The assessment of the Goyet collections included material housed at the RBINS and Royal Museums of Art and History (RMAH) in Brussels, which originate from the Troisième caverne, as well as collections from the Grand Curtius Museum (Liège), the Cercle d’Histoire et d’Archéologie du Pays de Genappe (Genappe), and the Préhistosite de Ramioul (Ramioul), whose origin is less secure. The Neandertal remains
presented here were found among the first two collections only. The numbering system of the specimens and their origin are discussed in Supplementary Note S4.

Taphonomic study. After determining the composition of the faunal assemblage sampled from Dupont’s collection (Supplementary Table S5), a total of 442 horse and 287 reindeer remains were observed using a monocular microscope (×10), as were all of the Goyet Neandertal remains. Taphonomic and anthropogenic modifications were recorded and drawn on anatomical charts (Supplementary Figs S8 and S14–S16). Cutmarks and trampling marks were distinguished according to their morphology and placement on bones. Only unequivocal notches with a negative flake scar made on fresh bone and percussion pits (left by impact events after ref. 66) were recorded as percussion marks. The identified bone retouchers are all long bone diaphysis fragments that exhibit marks as described by Mallye et al.40. Finally, toothmarks were recorded using Binford’s typology. Only pits and scores were observed. Some of these pits might have been produced by human chewing but they are not characteristic enough to definitely distinguish them from marks left by carnivores. Following Bello et al.76, the anthropogenic modifications recorded on the Neandertal remains were documented using drawings, close-up photographs and high-resolution imaging. The high-resolution images (Figs 4 and 5, and Supplementary Figs S8–S12) were obtained by using a minidome, a digital imaging device developed by VISICS at KULeuven (http://www.minidome.be). Based on the polynomial texture mapping technique, the dome consists of 260 LEDs and a single fixed camera, which captures an image with each LED individually lit. The results allow to display an object interactively under varying lighting to reveal all of the details of its surface. Additionally, 3D models of the retouchers made on Neandertal bones obtained using a white light 3D measurement system (http://www.mechscan.co.uk/) are available at http://virtualcollections.naturalsciences.be/virtual-collections/anthropology-prehistory/human-remains/goyet.

Sample selection and preparation for isotopic and genetic analyses. All sampled specimens were untreated (glued or varnished), newly identified Neandertal bones, except for tooth 2878–2D (see Table 1).
Collagen extraction at the CIO followed the procedure developed by Longin\(^71\), with additional chemical pretreatment using standard procedures\(^72\). Collagen extraction at Tübingen University followed a procedure modified from Longin\(^7\) described by Bocherens et al.\(^7\). Stable isotopic measurements \((^{13}C, ^{15}N)\) used an elemental analyser NC 2500 connected to a Thermo Quest Delta + XL mass spectrometer. The degree of chemical preservation of collagen is expressed as the atomic ratio of C\(_{coll}\):N\(_{coll}\), whose acceptable range of variation is 2.9–3.6\(^4\), while the nitrogen content (N\(_{coll}\)) should be above 5%\(^75\). The carbon content of the extracted collagen with a custom iterative mapping assembler \(^3\)–\(^8\),\(^3\)–\(^8\) were used to align reads to a reference Neandertal mtDNA and S19). with the same 63 mtDNAs in order to validate the assigned phylogenetic placement (Supplementary Figs S18\(–\)S19). An ancient origin were filtered \(^8\) and used to build new mtDNA consensus sequences. These were co-analysed compared with 63 other hominin mtDNA sequences in gene trees (Fig. 2 and Supplementary Fig. S4) to assess the authenticity of the obtained mitochondrial sequences as endogenous ancient DNA was verified by analysing typical ancient DNA damage patterns (ref. 86 and Supplementary Fig. S17) as well as estimating the percentage of modern human DNA contamination (ref. 30 and Supplementary Table S7). Finally, damaged DNA molecules indicating an ancient origin were filtered \(^8\) and used to build new mtDNA consensus sequences. These were co-analysed with the same 63 mtDNAs in order to validate the assigned phylogenetic placement (Supplementary Figs S18 and S19).

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Author Contributions

H.R. and I.C. designed the research. All authors performed the research. H.R., I.C., C.B., C.P., D.F., C.W., M.G., A.G.-O., P.S., J.v.d.P., H.B. and J.K. analysed the data. H.R., I.C., C.B., C.P., D.F., C.W., M.G., H.B. and J.K. wrote the paper with input from all authors.

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