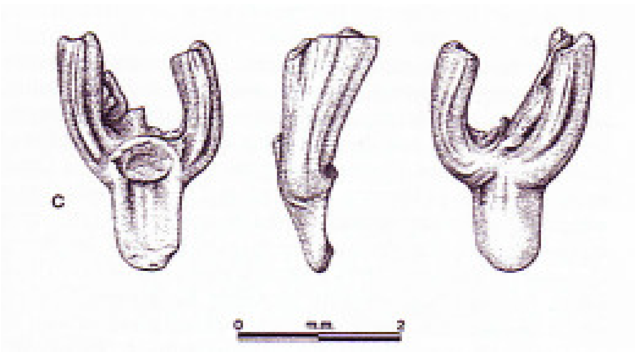
Identification of cereal remains from archaeological sites

2nd edition

2006



Spikelet fork of the “new glume wheat” (Jones et al. 2000)

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English translation partly by James Greig

CEREALS: CEREALIA

Fam. Poaceae /Gramineae (Grasses)

Systematics and Taxonomy

All cereal species belong botanically (taxonomically) to the large family of the Gramineae (Poaceae). This is one of the largest Angiosperm families with >10 000 different species. In the following the systematics for some of the most imporant taxa is shown:

class: Monocotyledoneae

order: Poales

familiy: Poaceae (= Gramineae) (Süssgräser)

subfamily: Pooideae

Tribus: Triticeae

Subtribus: Triticinae

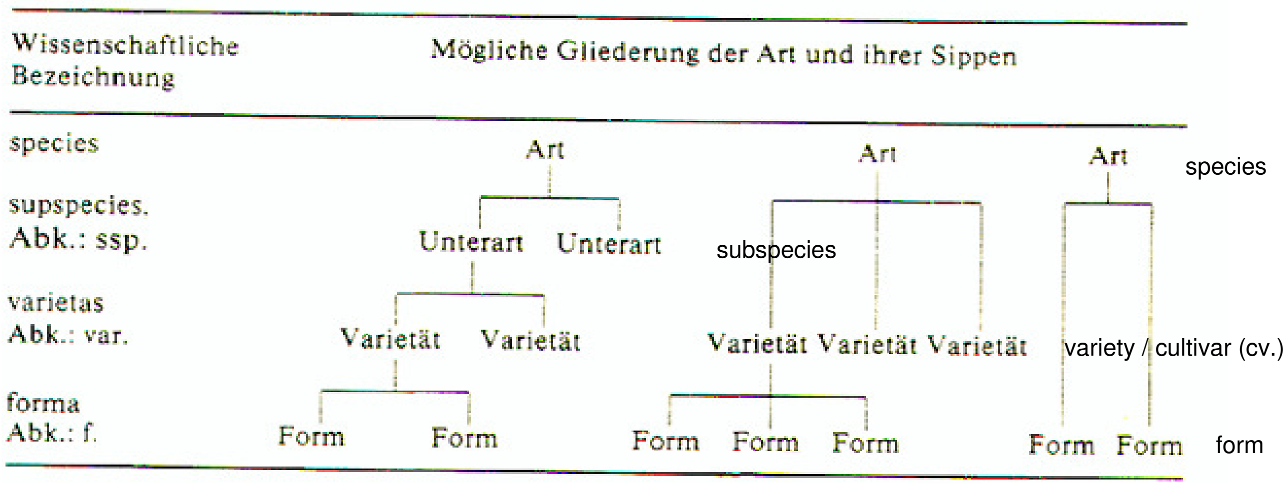
genera: **Triticum** (Weizen, wheat); **Aegilops**; **Hordeum** (Gerste; barley); Elymus; Hordelymus; Agropyron; **Secale** (Roggen, rye)

<u>Note</u>: Avena and the millets belong to other Tribus.

The identification of prehistoric cereal remains assumes understanding of different subject areas in botany. These are mainly morphology and anatomy, but also phylogeny and evolution (and today, also genetics). Since most of the cereal species are treated as domesticated plants, many different forms such as subspecies, varieties, and forms appear inside the genus and species (see table below). In domesticates the taxonomical category of variety is also called "sort" (lat. cultivar, abbreviated: cv.). This refers to a variety which evolved through breeding. Cultivar is the lowest taxonomic rank in the domesticated plants. Occasionally, cultivars are also called races: e.g. landraces evolved through genetic isolation, under local environmental conditions whereas „high-breed-races" were breed by strong selection of humans. Anyhow: The morphological delimitation of cultivars is difficult, sometimes even impossible. It needs great experience and very detailed morphological knowledge.

The species and its taxonomic subdivision

Schubert/Wagner 1988



Introduction, conditions for identification

The starch- and protein-rich grains of the cereals represent the most important basic foodstuff from the time of the arrival of Neolithic culture. Cereals were cultivated from the earliest Neolithic in the Near East, and in Central Europe Cereal since around the 6th millenium BC. The study of their remains from archaeological excavations is therefore of very great importance. They play a great role in research into the origins of nutrition; additionally, they can offer useful information on the immigration routes but also social aspects of certain cultures (for the latter see e.g. Bogaard 2004).

The individual cereal species had a varying importance in the different epochs of the past. The oldest central European cereals are various wheat species (genus *Triticum*) and barley (genus *Hordeum*). (Mostly) after the Neolithic, millet species, oats and rye arrived in central Europe.

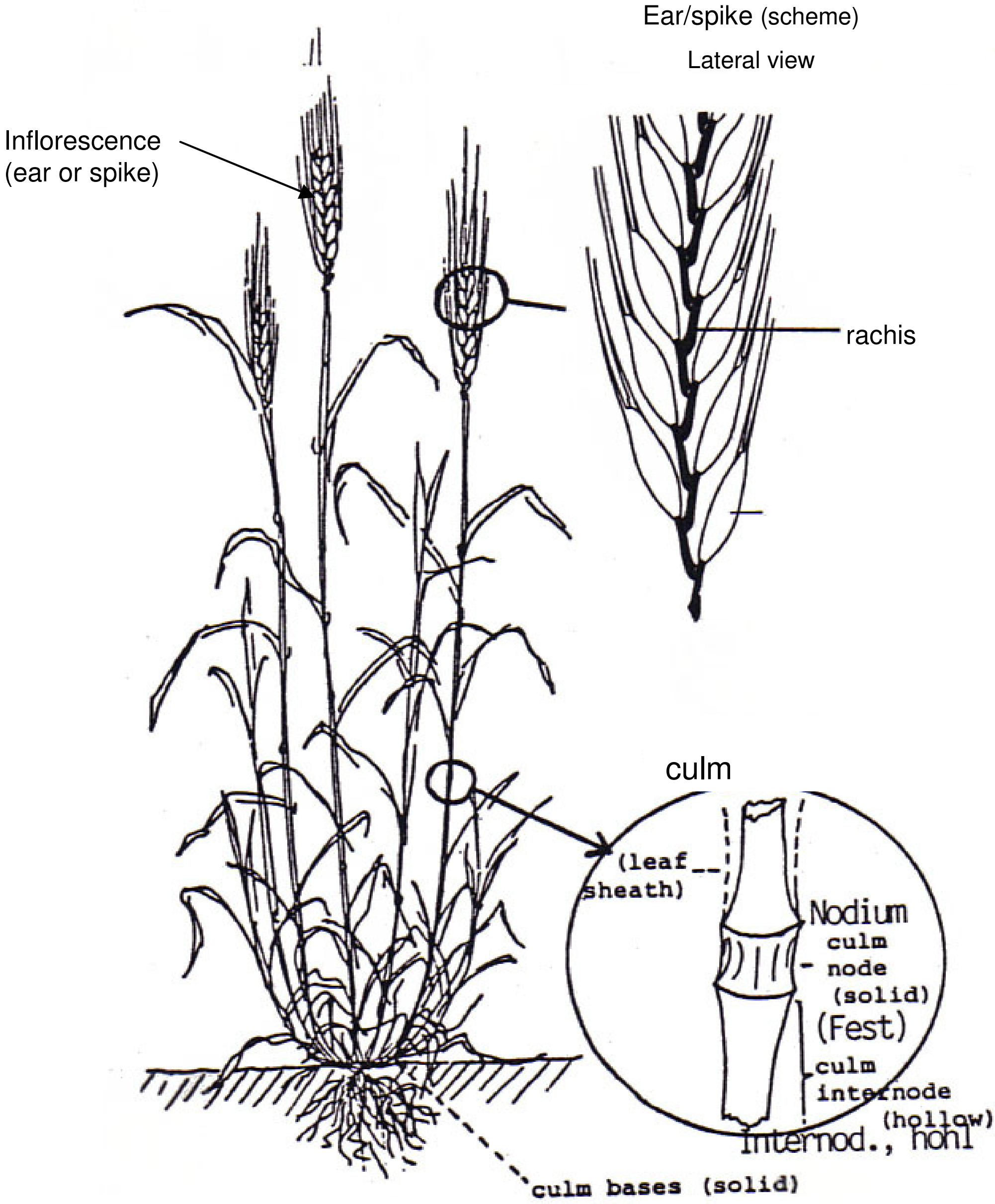
In the following we try to give an overview of the present state of knowledge concerning cereal identification, including also at least some aspects of papers published on the topic since the first edition of our “Cereal Identification manual” (Jacomet 1987). In addition to information from the current literature, we included many of our own results which have arisen in our long-term work with archaeological and recent remains of domesticated plants.

All existing plant-identification books (Floras) are hardly useable for archaebotanical purposes, since plant parts which contain important diagnostic characters are either not or only fragmentarily preserved. One finds whole plants or at least whole inflorescences only in the rarest instances - in the case of the cereals mostly ears. In >95% of cases we encounter cereals in the form of single grains, parts of the rachis, glumes, awns and finally straw (culm) fragments (see figures on the following pages). The remains are present mostly in a charred state, so that it is difficult to compare their dimensions with those of modern material. Uncharred cereal remains, mostly remains of rachis and glume bases, have their original size, but are mostly very fragmentary, often badly corroded or pressed (and therefore deformed).

The identification of cereal remains always depends principally upon morphological criteria. Measurement data can be used additionally to assist identification. This last is also useful for the comparison of different sites under investigation. Occasionally, one must fall back on anatomical characters for identification. It is also important to record precisely the state of preservation of plant remains. Also, when cereal remains can often be identified on the basis of their morphological and also anatomical characters, measurement is of use only when the state of preservation is good enough for them not to be deformed. Also, shape changes resulting from charring are often hard to estimate.

The nomenclature follows Van Zeist 1984 (tables on the following pages). For a comparison of modern and traditional taxonomical grouping see Zohary & Hopf 2000.

Morphology of the Cereal plant (ex. wheat)

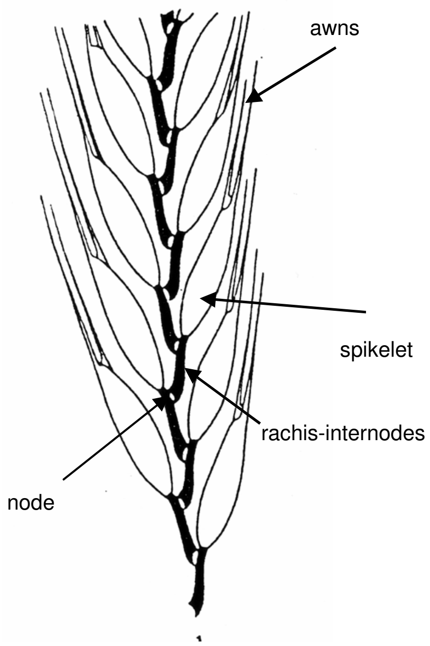


Hillman 1984

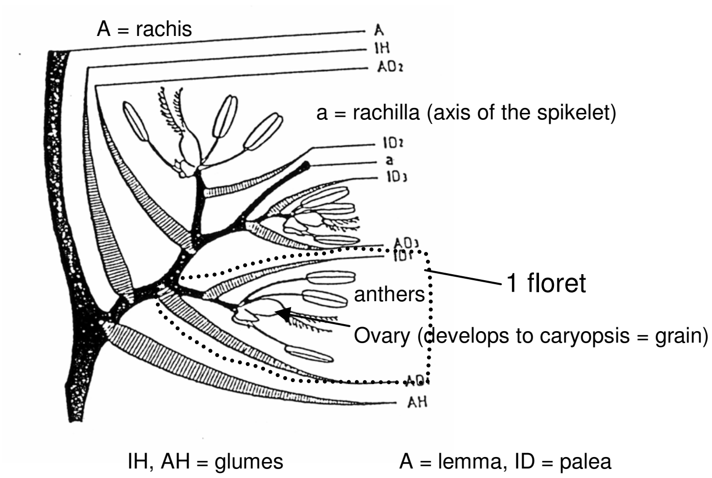
General morphology of cereal infloresences

The commonest type of inflorescence in the cereals is the ear. All wheat and barley species and also rye have ear (spike) inflorescences. An ear is defined in the following way: the flowers (spikelets = partial inflorescences in the case of the grasses) are arranged in rows on a main axis (see part 1).
Oats and millets have their inflorescences in panicles attached to the main axis (in the case of Italian Millet, the stalks of the spikelets are very short).
In the following we shall concentrate upon ears (spikes)

Ear/spike (scheme)
Lateral view



Spikelet (scheme)



Kaussmann & Schiewer 1989

Ear:
A cereal ear (spike) consists of a rachis (central axis) with attached spikelets, each with florets. The rachis (central axis) consists of rachis segments (internodes).
The rachis can be of two different kinds:
- **brittle**, that is easily broken into segments (spikelet with a rachis segment) at the nodes. Particularly characteristic of all wild grasses of the sub-family Triticinae (wild wheats and wild barley). The domesticated glume wheats such as einkorn and emmer have a moderately brittle rachis.
- **tough**, that is hardly breaking into single segments at threshing. Typical domesticated plant characteristic, particularly characteristic for example for free-threshing wheats (<u>Triticum aestivum</u>, <u>T. turgidum, T.durum</u>).

Spikelet:
basic type of inflorescence in the Gramineae (Poaceae). It consists of a group of florets on a very shortened rachis. In wild cereals the spikelet (with one rachis segment attached) is the unit of dispersal. The spikelet is one-flowered or many-flowered. It is enclosed in two glumes which can have various shapes (compare the single species).

Florets:
A grass floret is made up of 4 parts; a lemma and a palea, which enclose the ovary (which develops to the caryopsis = grain) and anthers. The lemma can have a long or short extension - an awn. When the grain is held fast in the lemma and palea, one is dealing with a hulled (glumed) cereal. With these the grain needs to be got out from the lemma and palea by processes such as parching in an oven of pounding in a mortar. When the grain is only loosely held between the lemma and palea, these are the free-threshing or naked cereals.

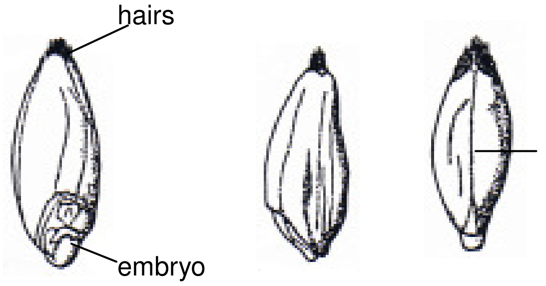
The cereal grain (caryopsis)

(= one-seeded, syncarpous nutlet, pericarp and testa fused)

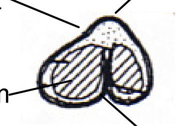
On the dorsal side of the grain one can see the embryo, which will develop into the young plant. It is more or less sunk into a cavity. The interior of the grain consists of endosperm, a nutritional tissue which mainly contains starch. On the ventral side is, sunk into a furrow, the elongated (lineal) hilum. The grain is enclosed in a series of layers:

- the pericarp which contains vitamins and minerals
- the testa (seed coat)
- the aleurone layer, which mainly contains proteins.

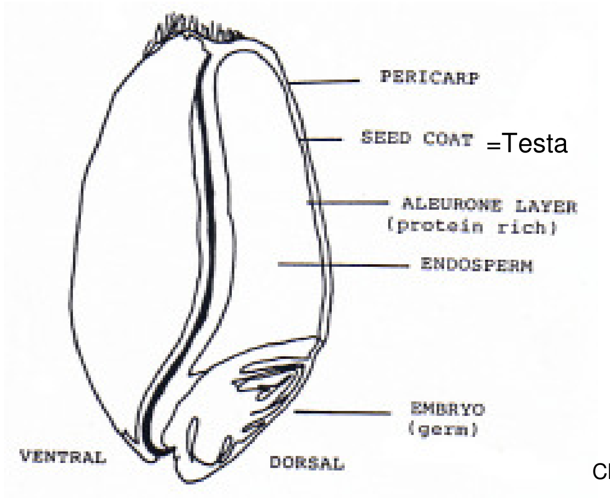
outside view:



cross section:

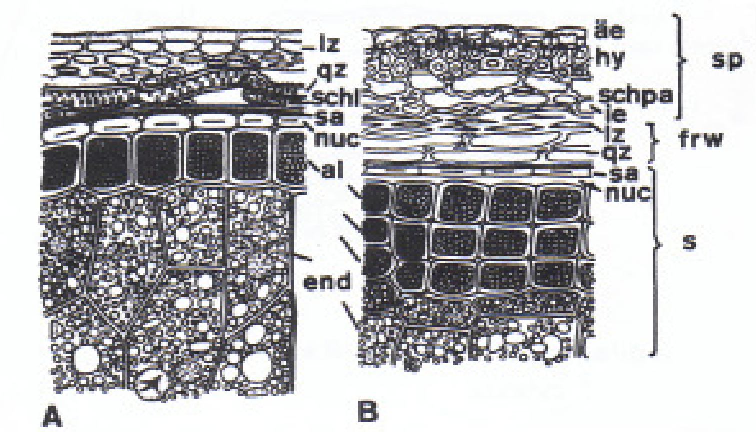


section:



Charles 1984

cross section through pericarp, testa etc.



(the same holds for all grass fruits)

A *Secale cereale*: lz=longitudinal cells; qz=cross cells; schl=tube cells; sa=testa (seed coat); nuc=remains of the nucellus; al=aleurone cells; end=endosperm

B: *Hordeum vulgare*: äe=outer epidermis; ie=inner epidermis; hy=hypodermis; schpa=spongy parenchyma; sp=lemma; frw=pericarp; s=seed; other abbrev. see A.

After Gassner 1951

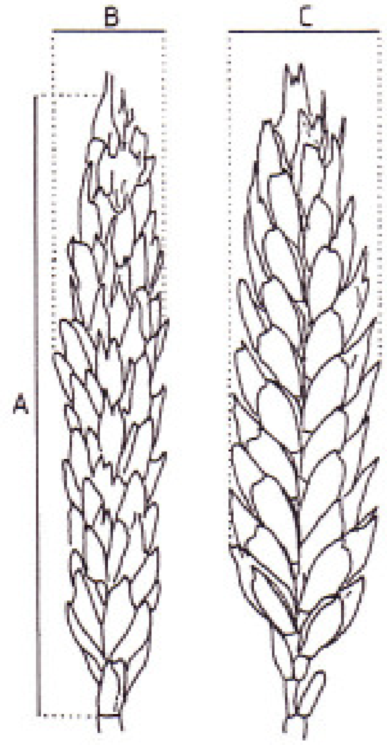
Kaussmann & Schiewer 1989

Practical procedure for identification

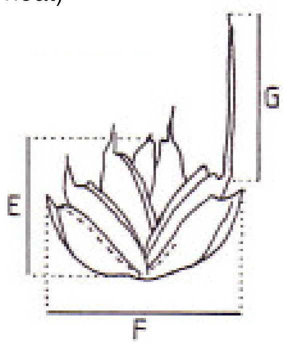
The diagnostically important characters of the remains are given in the tables (see list). Well-preserved objects are measured at the points given (Measurements: see Fig.'s). Various indices are calculated from the collected measurement data (see single species). The objects are assigned to a particular taxon according to the morphological data and the interpretation of the metrical data. The objects are also drawn or photographed for publication.

measurement points in cereals (1)

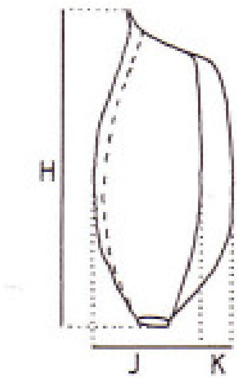
Ears (here naked wheat as ex.)



Spikelet (naked wheat)



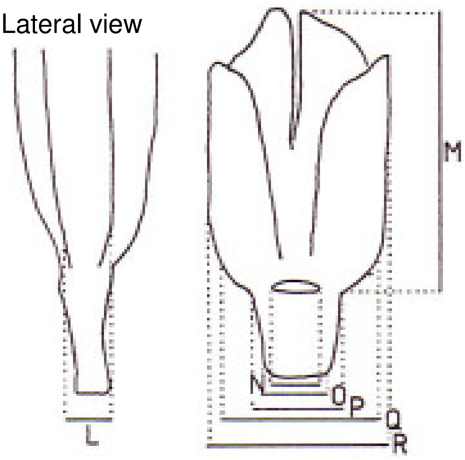
Glume (wheat)



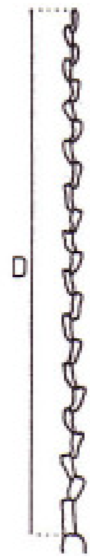
Spikelet, spikelet fork (glume wheat)

Lateral view

(ab)axial view



Rachis, with several internodes

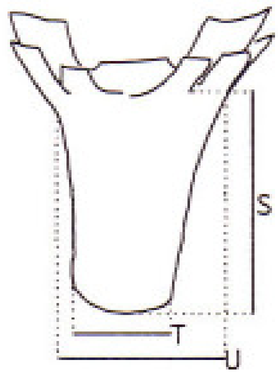


More details see under glume wheat chaff!

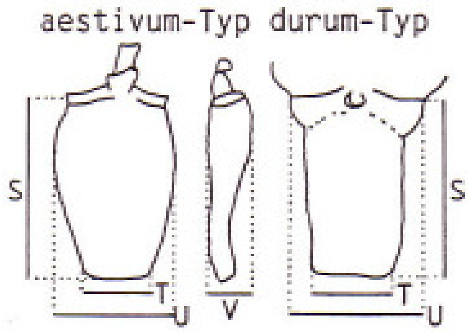
A: length of the ear
B: width of the ear (axial view)
C: width of the ear (lateral view)
D: length of the rachis
E: length of the spikelet
F: max. breadth of the spikelet
G: length of the awn
H: length of the glume
J: width of the glume (between primary and secondary keel)
K: width of the remaining part of the glume
L: width of the glume-base
M: length of the spikelet
N: breadth of the upper scar
O: width of the base of the internode (=lower scar)
Q: width of the spikelet-base (at the upper margin of the upper scar)
R: max. width of the spikelet

measurement points in cereals (2)

Rachis-internodes (barley)



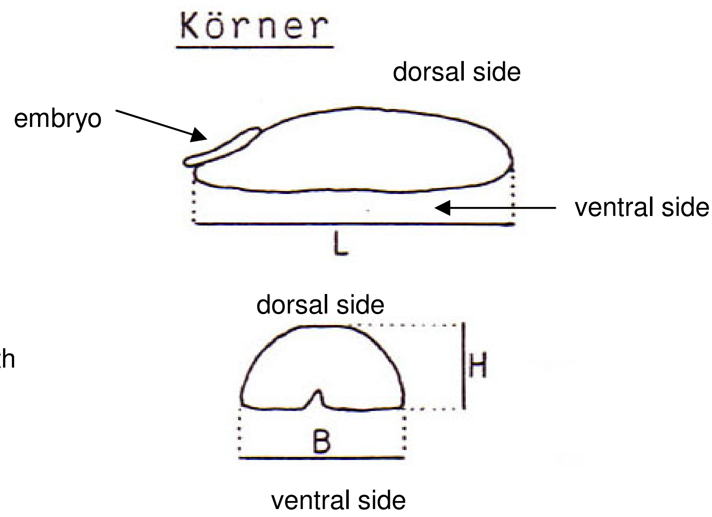
Rachis-internodes (naked wheat)



S: lenth of the internode (rachis segment)
T: breadth of the internode-base (lower scar)
(more details see under naked wheat)

U: max. breadth of the internode
V: max. thickness of the internode

grain



L: length

H: height

B: breadth

SJ 1991

Wheat (*Triticum*)

Inflorescences (1)

Triticum monococcum (diploid, glume wheat)

Triticum dicoccum (tetraploid, glume wheat)

Triticum durum (tetraploid, naked wheat)

Triticum turgidum (Tetraploid, naked wheat)

Zohary & Hopf 2000

wheat (*Triticum*) (inflorescences, contin.)

Triticum spelta
hexaploid, glume wheat

Triticum aestivum (hexaploid, naked wheat)

B: ssp. compactum

ssp. vulgare
C: with awns
D: without awns

Zohary & Hopf 2000

wheat: taxonomy, varieties

Wheat species resp. varities can be classified according to two possible criteria:

a) according to **ploidy level**, also the chromosome number.

b) according to the **type of glume attachment:** there are glumed (hulled) and free-threshing (naked) wheat forms.

b1) **Glumed (hulled) wheats**: thick gripping glumes enclose the grain tightly. The grain cannot be easily extracted from the spikelets; the ears usually break into spikelets. To obtain naked grains the spikelets must be roasted (parched) and also pounded (see e.g. Hillman 1984). In this group belong:

Diploids: Einkorn (Triticum monococcum)

Tetraploids: Emmer (Triticum dicoccum)

Hexaploids: Spelt (Triticum spelta)

b2) **Naked wheats:** The grains are only **loosely** held in the glumes. In ripe ears the grains are visible from the outside. The glumes are generally less thickened and woody than in glume wheats. The grains can be easily freed from the ears with threshing. In this group belong:

Tetraploids: maccaroni wheats (Triticum durum)

rivet (pollard) wheats (T. turgidum)

Hexaploids: bread wheats (Triticum aestivum)

There are > 17 000 sorts (varieties = cultivars) of wheat! See, for example Percival (1974)

Table 1 | **Species and their derived forms** Salamini et al. 2002

Species names in this review (common name)	Biological species	Genome and ploidy	Ear and seed traits	No. of loci that support B vs NB rachis*	Alleles of loci that affect either glume or glume and ear rachis (chromosome)‡	References
T. boeoticum (wild einkorn)	*T. monococcum* L. ssp. *boeoticum* Boiss.	AA	H, B	2	Sog_A (2S)	27
T. monococcum (cultivated einkorn)	*T. monococcum* L. ssp. *monococcum*	AA	H, NB	2	Sog_A (2S)	27,29
T. urartu (wild *T. urartu*)	*T. urartu* Tuman.	AA	H, B	2	–	–
Ae. tauschii (wild *Ae. Tauschii*)	*Ae. tauschii* Coss.	DD	H, B	1	Tg_D (2S)	51,52
T. dicoccoides (wild emmer)	*T. turgidum* L. ssp. *dicoccoides* Aschers.	AABB	H, B	2; polygenic	$Tg2_B$ (2S), $q_A^{\S}$ (5L), Qft_{5A} (5S), Qft_{6A} (6)	44,50,56,114,115, 116,117
T. dicoccum (cultivated emmer)	*T. turgidum* L. ssp. *dicoccum* Schübl.	AABB	H, NB	2	$Tg2_B^{\parallel}$ (2S), q_A (5L)	50,116
T. durum (hard wheat)	*T. turgidum* L. ssp. *durum* Desf.	AABB	FT, NB	polygenic	$tg2_B$ (2S), Q_A (5L), qft_{5A} (5S), qft_{6A} (6)	50,51,56,114,116,118
T. parvicoccum (*T. parvicoccum*, archaeobotanical)	*T. turgidum* L. ssp. *parvicoccum* Kislev	(AABB)	FT, NB	–	–	–
T. araraticum (wild Timopheev's wheat)	*T. timopheevii* Zhuk. ssp. *araraticum* Jakubz.	AAGG	H, B	–	–	–
T. timopheevii (cultivated Timopheev's wheat)	*T. timopheevii* Zhuk. ssp. *timopheevii*	AAGG	H, NB	–	–	–
T. spelta (spelt)	*T. aestivum* L. ssp. *spelta*	AABBDD	H, NB	2	$Tg2_BTg_D$ (2S), q_A (5L), $Qft_{5A}^{\parallel}$ (5S), $Qft_{6A}^{\#}$ (6)	53,55,108,114,119
T. vulgare (bread wheat)	*T. aestivum* L. ssp. *vulgare* Host.	AABBDD	FT, NB	2	$tg2_Btg_D$, $Q_A^{\P}$, $qft_{5A}^{\P}$, qft_{6A}	44,48,51,116

Nomenclature is taken from REF. 5, with modifications. *Genes that affect rachis but not glume traits. ‡Subscripts indicate genomes. §Designated as *q2* in REF. 56. ||Allele inferred from genotype of wild emmer. ¶Allele inferred from genotype of hard wheat. #The trait is under the control of the single gene *N* (recessive *n*, naked seeds)[80]. *Ae.*, *Aegilops*; B, brittle rachis, ears disarticulating at maturity into spikelets; FT, free-threshing, soft glumes, shorter rachis internode, tougher rachis; H, hulled wheat, in the spikelet, the kernels of H wheats are covered by tenacious glumes, not easily separated from grains during threshing; *H.*, *Hordeum*; NB, non-brittle, non-brittle (tough) rachis that does not disarticulate at maturity; Q, Q factor; *S.*, *Secale*; *Sog*, tenacious glumes; *T.*, *Triticum*; *Tg*, tenacious glumes.

Origin:

Genetics: Wild grasses with 2n=14 chromosomes (wild einkorn = Triticum boeoticum s.l., Aegilops species (genome AA, BB or DD) and finally also Agropyron species) and those with 2n=28 chromosomes (wild emmer = Triticum dicoccoides, genome AABB).

Geography: Near East (Fertile Crescent) (see Zohary & Hopf 2000 and e.g. Salamini et al. 2002)

wheat: phylogeny

(without diploids)

Cultivated (here) = domesticated

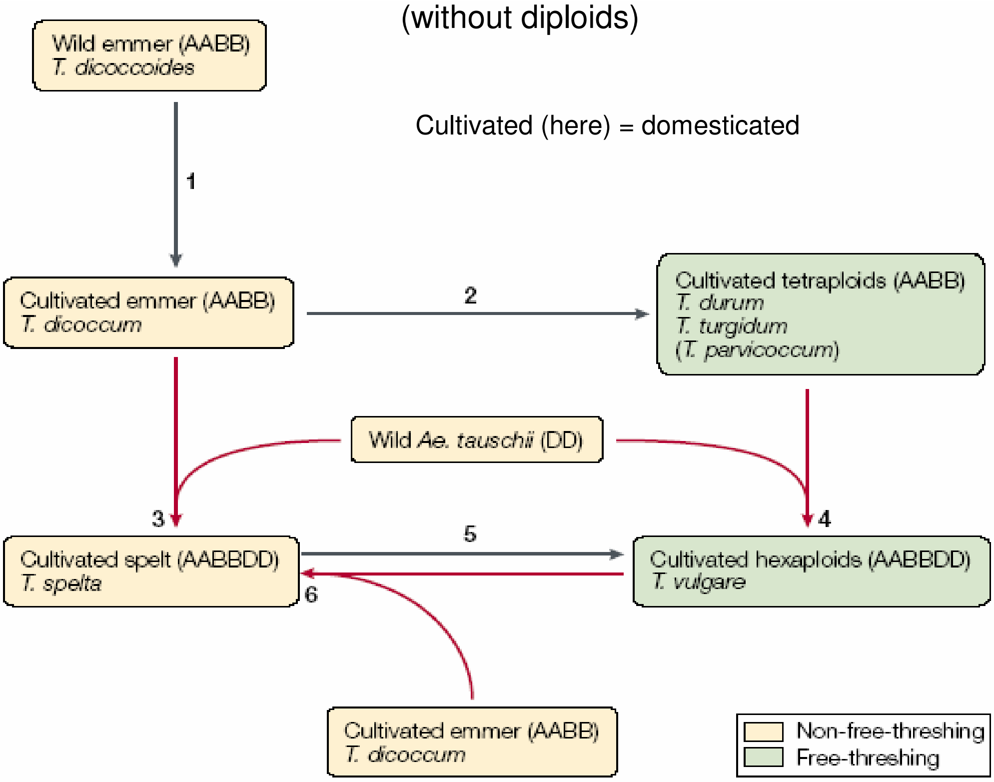


Figure 4 | **Models for the evolution of polyploid wheats under cultivation and domestication.** The red arrows indicate hybridization events; the black arrows show domestication events (see text for details). *Ae.*, *Aegilops*; *T.*, *Triticum*.

Salamini et al. 2002

Morphological points: Spikelets many-flowered. Glumes wide (broad), lemmas with or without awns.

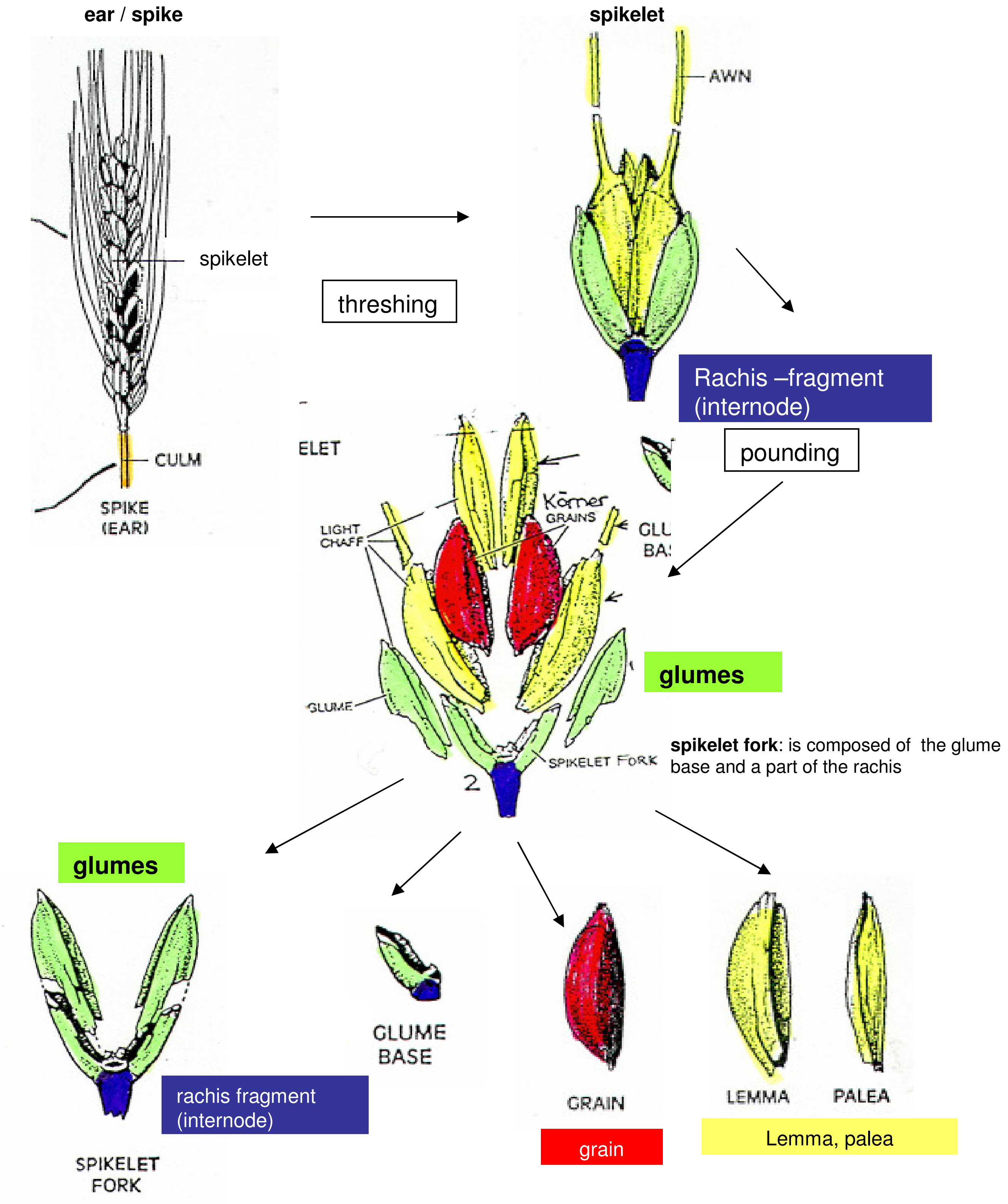
Most important morphological characters of the finds

Grains: wheat grains can - according to species - have very different appearances. They are usually oval or drop-shaped in outline (see figures on the following pages).

Rachis segments: elongated, mostly more or less rectangular, with straight or curved sides. In some species the wide bases of the glumes remain attached to the rachis (see figures on the following pages).

The most important parts of *Triticum* (wheat) ears, spikelets:

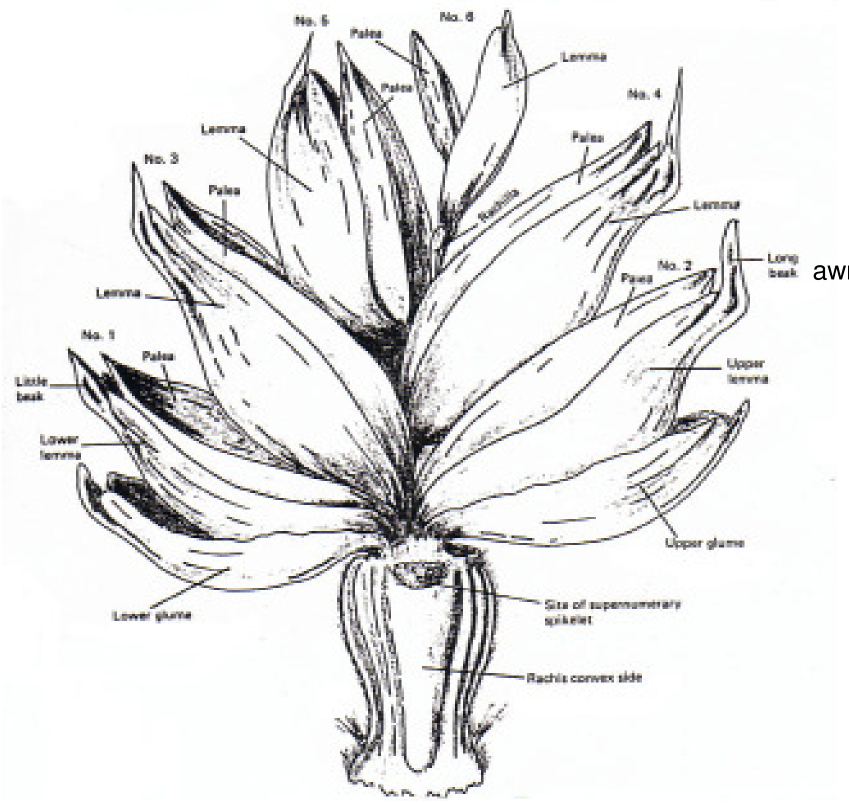
Glume (hulled) wheat (einkorn, emmer, spelt)



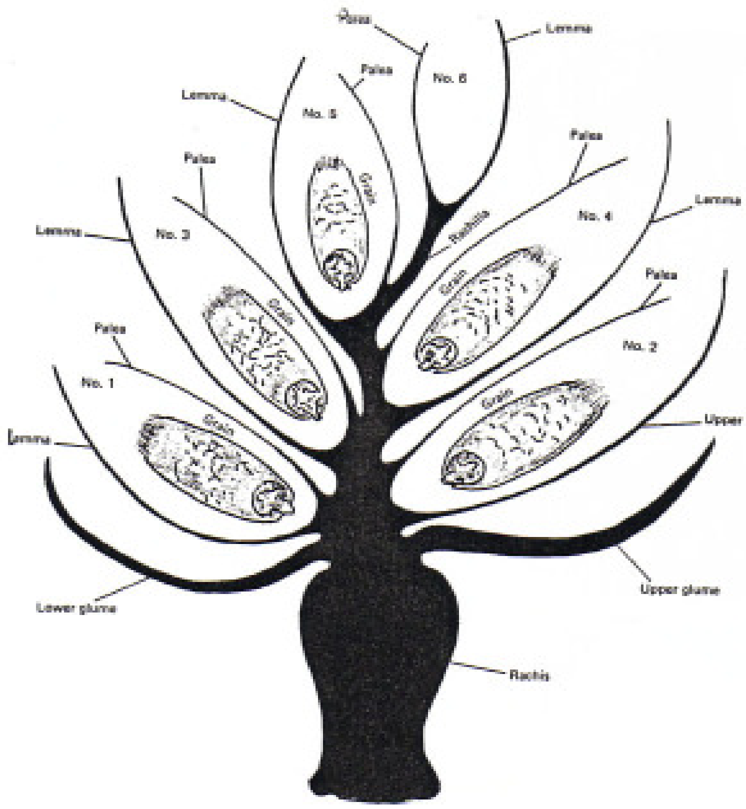
Nesbitt und Samuel 1996, Zohary und Hopf 2000

The most important parts of cereal ears (*Triticum*):
Naked wheat: scheme of a spikelet: bread wheat (6n): *T. aestivum*

Axial view:



axial section:



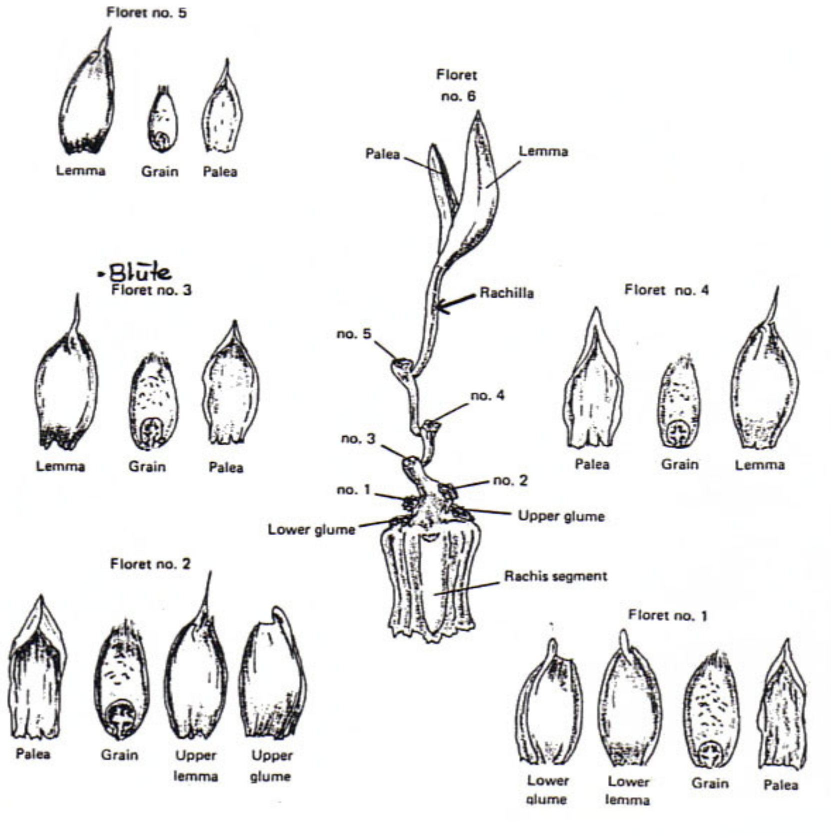
Hervey-Murray 1980

The most important parts of cereal ears (*Triticum*) 4

Naked wheat: parts of the spikelet after threshing

Hillmann 1984

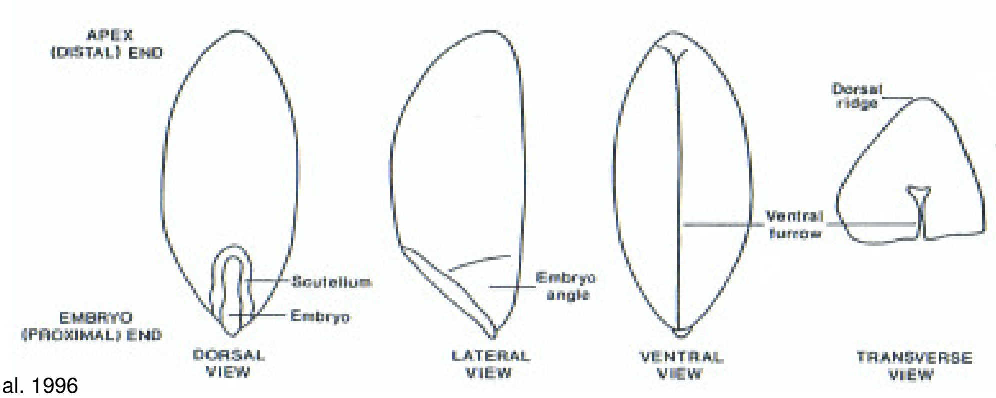
Schematic drawing:



Hervey-Murray 1980

Identification of charred grains of prehistoric wheat species

Important characters of the wheat grain



Hillman et. al. 1996

Procedure

Wheat grains are mostly found in a charred state. In waterlogged sediments however there may be many uncarbonised pericarp- and testa-remains, mostly in a fragmentary state. For their identification a special effort is needed (see e.g. Körber-Grohne 1981; Dickson 1989). We will not treat this here.

When dealing with carbonised grains it is important first to make a note of the state of preservation.

a) preservation good, no distortions or damage visible

b) preservation OK, but some damage

c) grain pop-corn-like, with starch protruding

d) grain fragmented

Secondly, the shape from above (dorsal view), from the ventral side (ventral view), from the side (lateral view) and in cross section should be noted and recorded (see criteria-list) . Additionally, the shape of the ventral furrow, the position of the embryo, structure of the grain's outer surface and finally hairs at the apex of the grain should be observed and noted down. Finally, some well-preserved grains should be measured (length, breadth, height; see meaurement-lines); different indices (ratios) can then be calculated from the measurement data. The individual wheat species generally have a characteristic shape (combination of characters) and also characteristic measurement indices (see below).

For the characteristics of the individual species see the following pages.

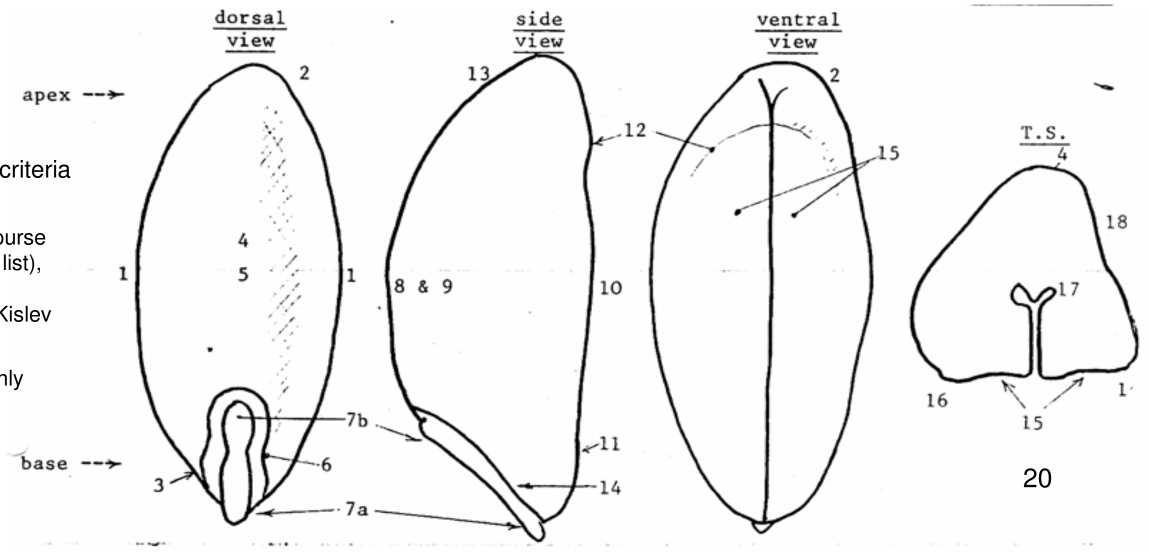
Comment

Although there is a whole series of morphological characters, of which the ones for the identification of wheat grains to species can be summarised here, the actual species identification is often difficult. This has various causes (e.g. Knörzer 1970 p. 33; Hillman et al. 1996; the author's observations):

- The morphological similarities between the grains of the different species are large already.
- Grains of one and the same species can vary greatly in their appearance, for example caused by their position in the ear and/or the spikelet
- The intraspecific and regional variation within a species alter the appearance and dimensions greatly.
- The changes in appearance from charring are large.
- Shapes are changed differently according to the conditions of charring.

In spite of all difficulties it is usually possible to identify wheat grains. Above all, a good state of preservation is needed. It is also very helpful when one also finds chaff remains in a grain sample (especially rachis segments and glumes), for these often provide better diagnostic characters than the grains. If one finds samples of pure grain, identification to species can be difficult (compare this with Jäger 1966, Hajnalova 1978, Knörzer 1970, Dalnoki & Jacomet 2002 and many others). Only some species have a so generally characteristic shape that their certain identification is possible (einkorn, for example, as long as it is one-grained). The separation of emmer and spelt can be difficult, and also there are no (or only very vague) useable characters for the differentiation of the grains of the various species groups of free-threshing (naked) tetraploid wheats (macaroni and rivet wheats) and hexaploids (bread wheats). For the latter see Kislev 1984, and below, individual species.

criteria useful in identifying charred cereal grains



*= most important criteria

Hillman's practical course (unpublished criteria list), Hillmann et al 1996, Jacomet (unp.) and Kislev 1984

criteria concerning only wild cereals omitted

a) grains viewed dorsally (or ev. ventrally):

*1 form in general /asymmetry of the grain
- rather oval-broad
- rather slender

1 sides of grain (parallel-sidedness)
- curved
- straight

*1 widest point of the grain
- in the middle
- in the upper half ("drop-shaped")
- in the lower half

*2 shape of grain apex:
- Strongly attenuated
- attenuated to varying degrees
- Conspicuously rounded

*3 shape of the grain base
- strongly attenuated
- less attenuated

*4 shape of the back of the grain (see also transverse section)
- ridged, often very strongly
- generally rounded; if ridge present, very low

*5 ridge (if present) running down grain (see also 12)
- running down symmetrically
- running down asymmetrically (diagonally)

6 shape of the scutellum
- often constricted in the middle
- rarely constricted in the middle

19 position of the embryo
- in a cavity
- on the surface

21 surface of the grain
- smooth
- longitudinal furrows at the dorsal side) present (impressions of glumes)
- horizontal wrinkles

22 hairs at the grain apex
- >1mm long
- < 1mm long
- course
- delicate

b) grains in side (lateral) view

*8 form of the back of the grain:
- flat
- arched, evenly (uniformly)
- arched, highest point in the centre
- arched, highest point right behind embryo (humpy)

b) grains in side view (continued)

*10 ventral face of grain
- strongly curved (convex)
- flat or partially flat
- concave

*11 embryo end of the ventral face
- flat
- curved outwards for short distance behind embryo

12 ventral compression surface (if present) (also ventral view)
- ending well short of aprex (esp. in the upper grain of each pair; 2-g. einkorn)
- much less of this type

*13 form of apex
- gen. strongly attenuated
- between slightly attenuated and somewhat rounded
- strongly rounded to almost truncate
- truncate

14 angle of scutellum
- extremely shallow (acute)
- quite shallow
- steeper (medium)
- steep
- very steep (almost vertical)

c) grains in ventral view (or ev. in the transverse section)

23 flatness of ventral face

12 ventral compression surface (if present) (also side view)
- ending well short of apex (esp. in the upper grain of each pair; 2-g. einkorn)

16 "corners" of grain (also in transverse section)
- sometimes angled
- always rounded

20 shape of hilum-fold
- eit-tief) (wide)
- g-tief) (narrow)

d) grains viewed in the transverse section (or dorsally/ventrally))

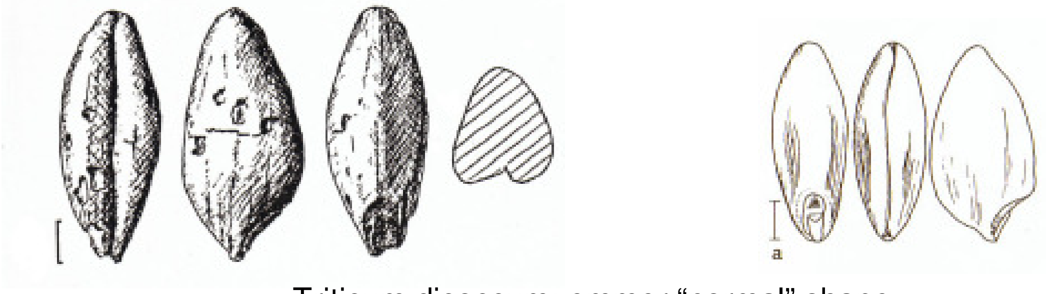
4 shape of the back of the grain
- ridged, often very strongly
- generally rounded; if ridge present, very low

15 eveness of ventral compression surface / ventral compression lines
- uneven, bilaterally asymmetrical
- generally even or only slightly uneven

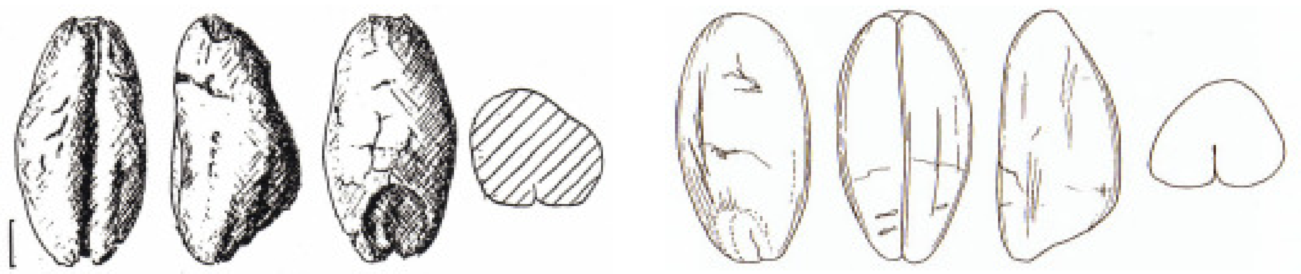
16 "corners" of grain (also in ventral view)
- sometimes angled
- always rounded

wheat grains: comparison of the different species

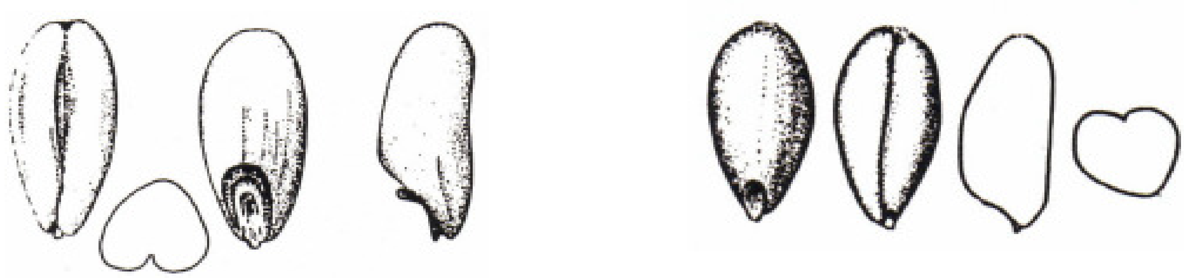
Triticum monococcum: einkorn, « normal shape »



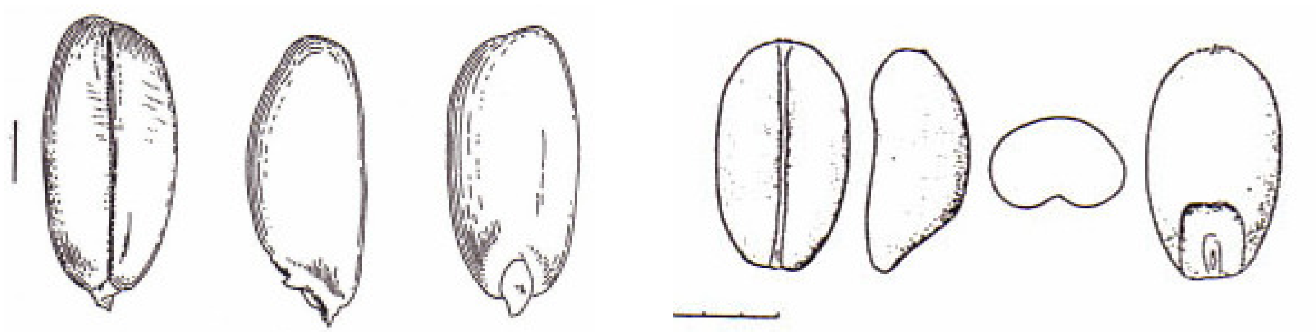
Triticum dicoccum: emmer “normal” shape



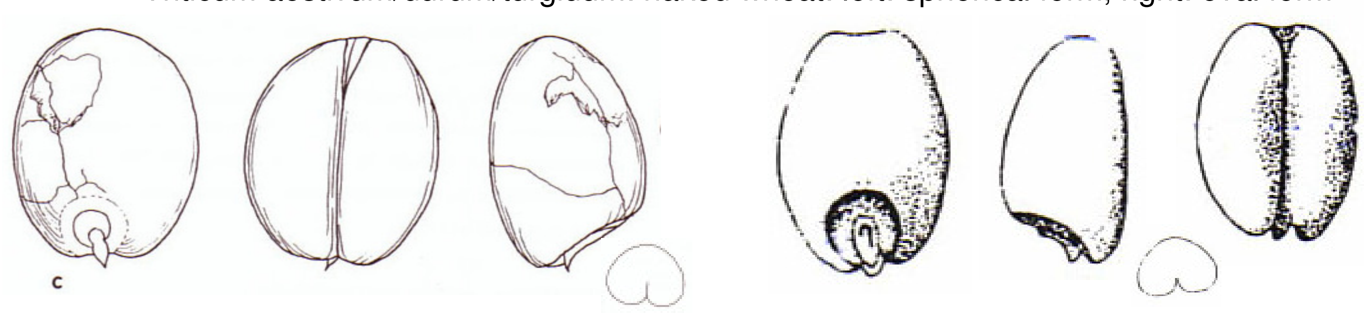
Triticum dicoccum: emmer, drop-shape



Triticum spelta: spelt, left: normal shape, right: drop-shape

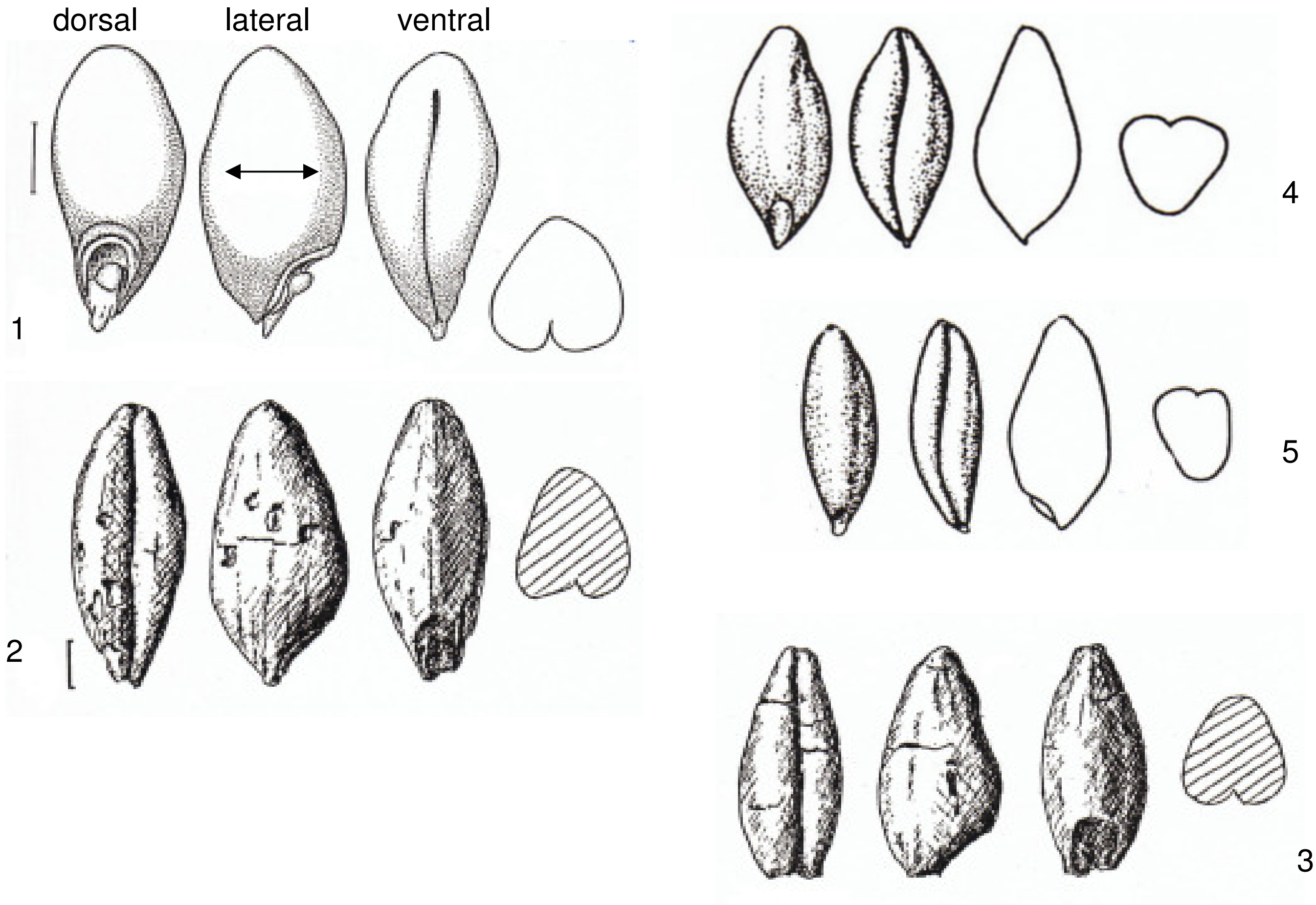


Triticum aestivum/durum/turgidum: naked wheat: left: spherical form, right: oval form

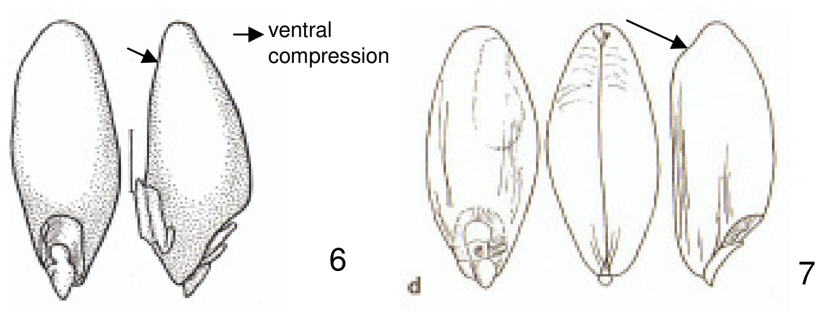


examples from: Knörzer 1967 (LBK, early Neolithic, Germany): Kohler-Schneider 2001 (Late Bronze Age, Austria); Kroll 1975 (Bronze Age, Germany); Hopf 1968 (Neolithic, Germany); Jacomet et al. 1989 (Early-Bronze Age, Switzerland); Van Zeist 1968 (Roman, Netherlands)

Characters and images of (pre)historical finds of einkorn (*Triticum monococcum*): GRAINS



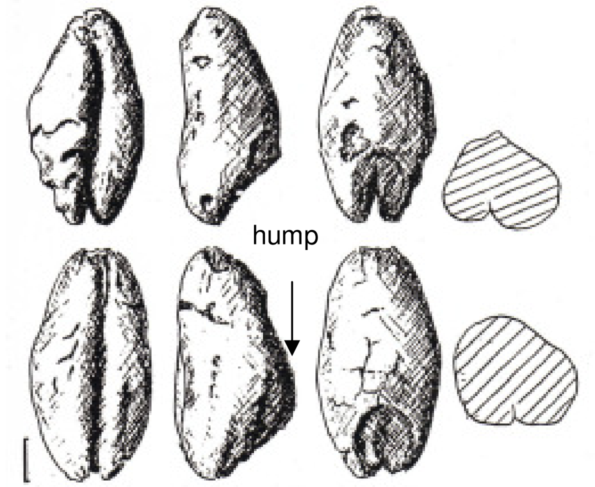
2-grained einkorn



1 and 6: Port-Stüdeli (Switzerland, Neolithic; Brombacher & Jacomet 2003): 2-3: Lamersdrof (LBK, Early Neolithic, Knörzer 1967); 4-5: Ehrenstein (Neolithic, Germany, Hopf 1968); 7: Stillfried (Late Bronze Age, Kohler-Schneider 2001)

Shape in plan (seen from the dorsal side); slim, fairly pointed at the ends.
Shape in side view: high backed, more or less equally rounded on each side. Ventral outline likewise convex. Highest part of the grain usually in the middle. Exception: 2-grained einkorn with flat ventral surface.
In transversal section: not evenly rounded, sometimes apparently with "corners". Dorsal side often almost roof-shaped, however with the highest part rounded off. The sides slightly convex, often also slightly concave. The transition from dorsal to ventral side is often marked with a corner. The ventral furrow is narrow and deep (pressed together).
Positioning of the embryo: slanting/upright (not in a cavity!)
Outer surface structure: often there are two longitudinal furrows on the dorsal side to the left and right of the highest part. These are glume impressions.
Characteristic dimensions and ratios:
L: 4.5-7.1 mm / B: 1.0-3.0 mm (rarely >2.5mm)
H: 1.6-3.1 mm (rarely <2.3mm)
L/B: 1.6-2.58 (rarely <2, mostly more)
L/H: 1.77-2.5 (rarely <2)
B/H: 0.69-1.2 **(mostly <1)**
B/Lx100: 37.8-46.2 (**<50**) ***difference from emmer***!
Variations, identification difficulties:
"Typical" examples of normal, single-grained einkorn have an unmistakeable shape compared with other wheat grains found in central European prehistory. Grains from 2-grained einkorn are more difficult: here there can be similarities with emmer grains. Grains of 2-grained einkorn are much more delicate than those of emmer, and have often a ventral compression ending well short of the apex (esp. the upper grain of each pair). Therefore, they can be identified with ± great certainty, particularly when chaff is also preserved in

Characters and images of (pre)historical finds of emmer (*Triticum dicoccum*): grains

1


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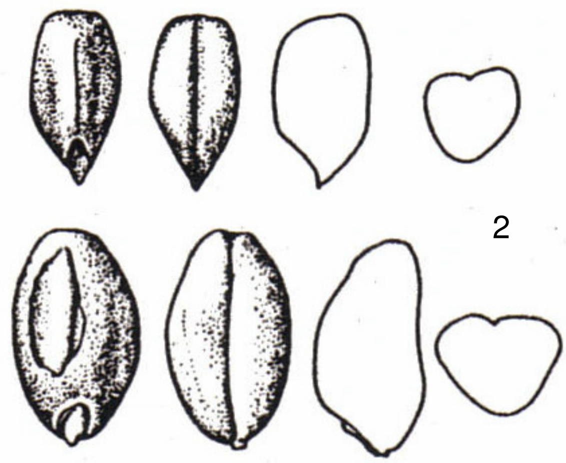

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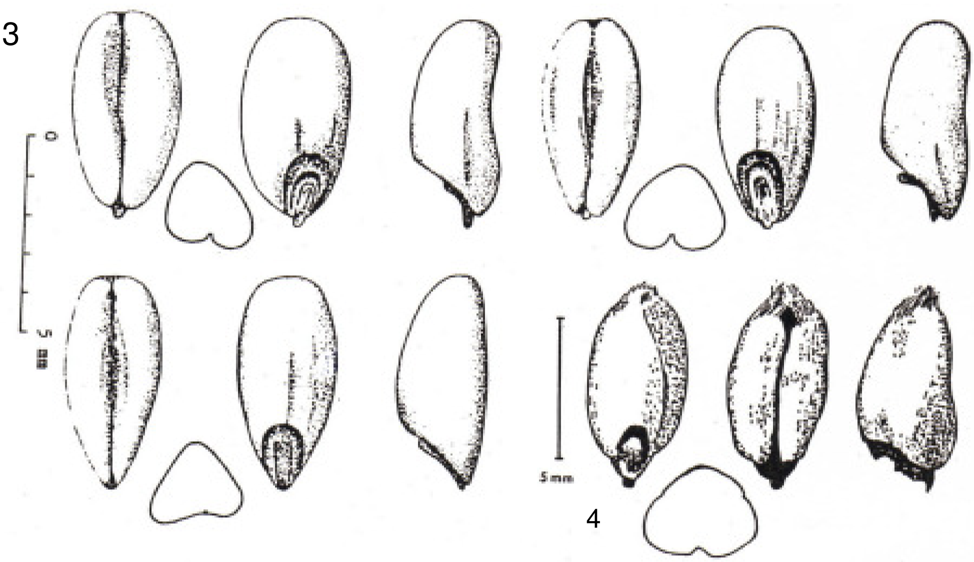
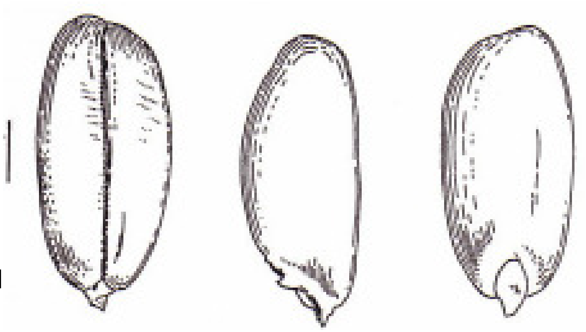


4

1: Lamersdorf (LBK, Germany, Early Neolithic, Knörzer 1967); 2: Ehrenstein (Neolithic, Germany, Hopf 1968); 3: Archsum/Sylt (Bronze Age, Germany, Kroll 1975); 4: Feddersen Wierde (Iron Age; Germany; Körber Grohne 1967)

Shape in plan view (seen from the dorsal side):
Mostly slim, the upper end frequently rather pointed, but often bluntly rounded too; this last goes particularly for the abundantly found drop-shaped grains. At the lower (embryo) end, most grains are pointed.
Shape in side view:
The dorsal outline is often hump-backed; the highest point is often directly above the embryo. The embryo-cavity is often not symmetrically rounded, but twisted. The ventral side is mostly lightly concave to flat.
Shape in section:
Fairly evenly rounded to rather angular; the ventral furrow is narrow and deep (rarely also angled transverse section)
Positioning of the embryo: mostly slanting-upright.
Various surface structures:
Similar to einkorn, and well-preserved examples have visible longitudinal furrows which represent impressions of the glumes.
Characteristic measurements and ratios:
L: 3.5-6.1 mm
B: 1.8-3.2 mm (rarely >3mm, normally less)
H: 1.5-3.4 mm
L/B: 1.57-2.04 (mostly **around 2**)(***difference from einkorn***!)
L/H 1.57-2.5 (mostly **>2** but rarely as much as 2.5: ***difference from einkorn and spelt***).
B/Lx100: 48.33 - 60.38 (normally **around 54**) (***difference from einkorn***).
Possibilities for confusion, identification difficulties:
Delicate grains, for example from the apical part of an ear can be confused with those of 2-grained einkorn.
Grains from one-grained spikelets (from the base and the top of an ear) look very similar to "normal" (1-grained) einkorn.
Differentiation from normal einkorn: emmer grains are wider in relation to their height, that is their B/H ratio is usually >1.
Differentiation from naked wheat forms: Grains of emmer are normally narrower (mostly <3mm wide). From this their L/ B ratio is always distinctly higher (around 2) than in naked wheat, e.g. Triticum aestivum (< 1.7).
Separation from spelt: Emmer grains are on average higher than those of spelt, so the L/H ratio in emmer is 1.9-2.5 (mostly around 2.3), while it is mostly >2.5 in Triticum spelta. Furthermore, spelt grains, particularly when they were charred in the spikelets, can have a very similar shape (see Jacomet et al. 1988, Eptingen-Riedfluh, also Jacomet & Dalnoki 2002).

Characters and images of (pre)historical finds of spelt (*Triticum spelta*: grains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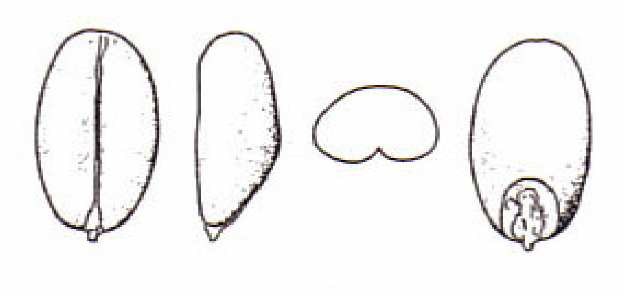
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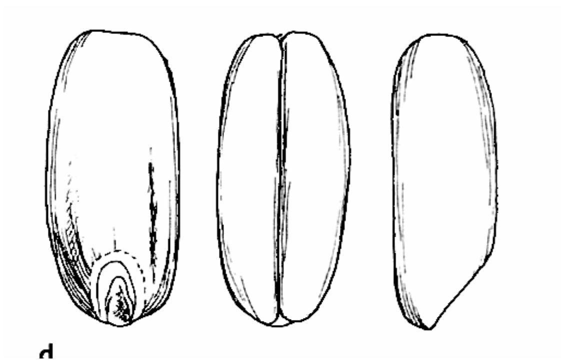

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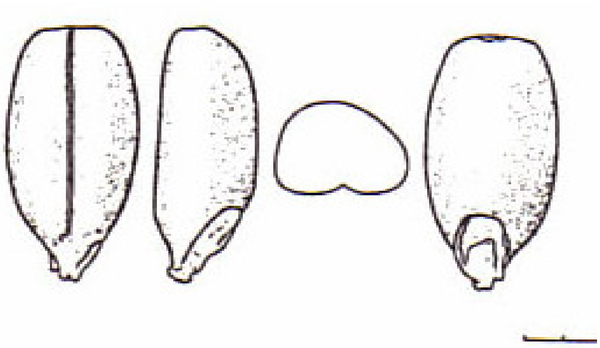
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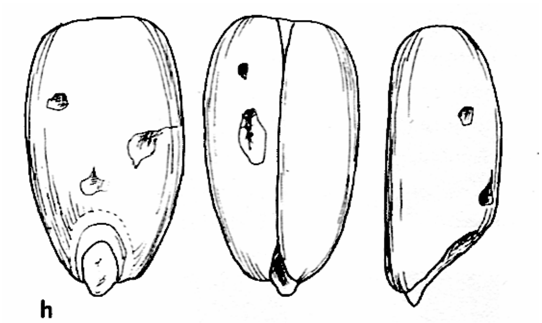

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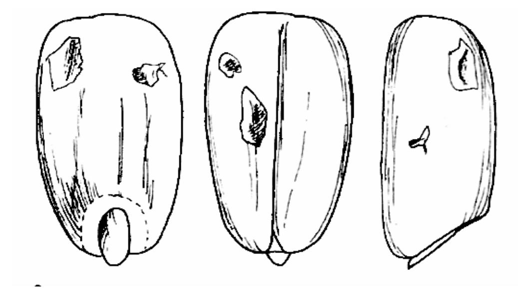
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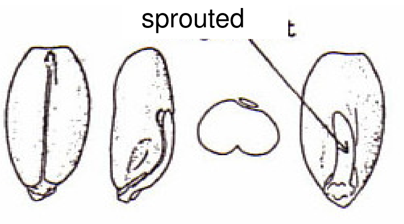


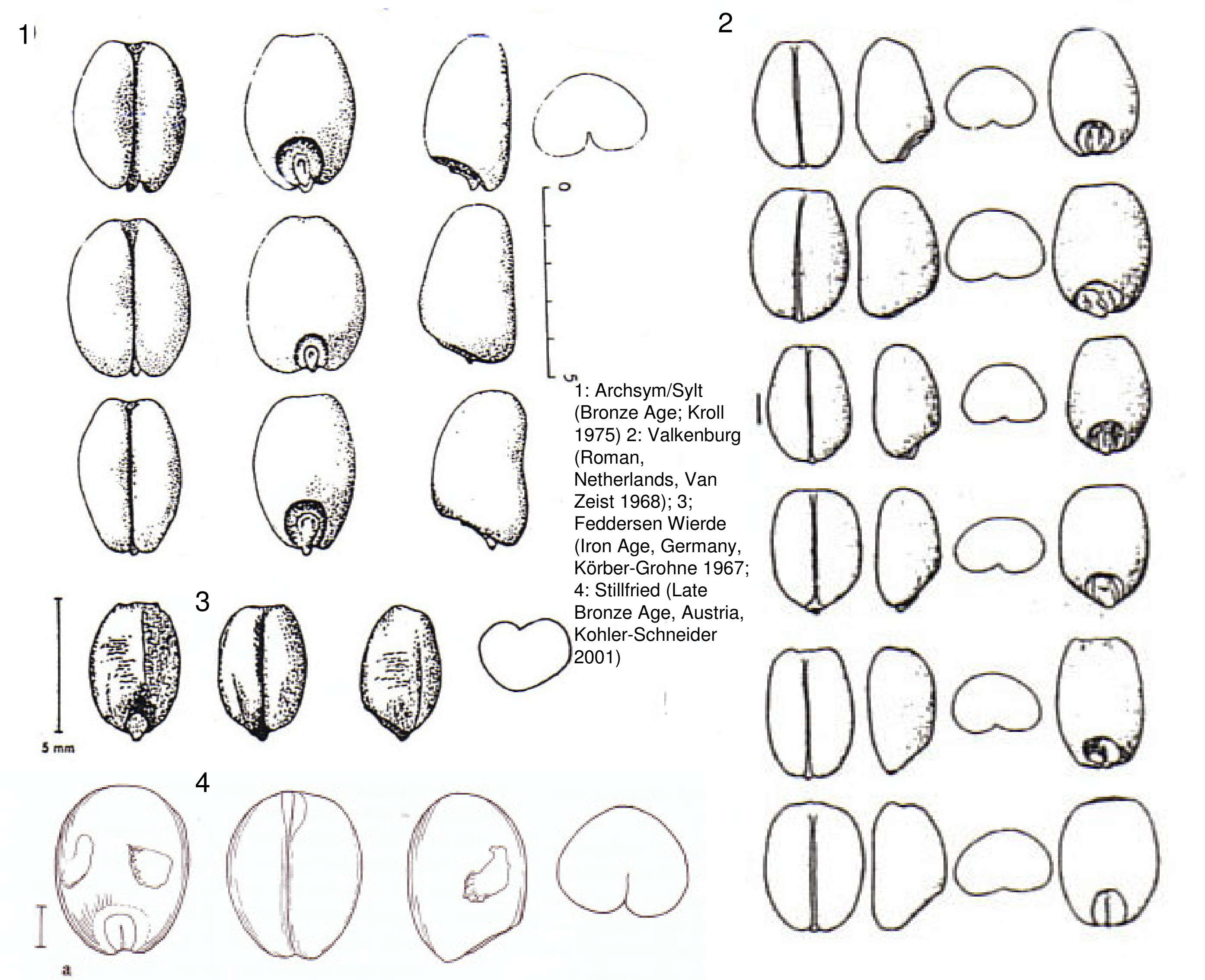
7

1: Zürich-Mozartstrasse (Early Bronze Age, Switzerland, Jacomet et al. 1989); 2-3+7: Valkenburg (Roman, Netherlands, Van Zeist 1968); 4-6: Stillfried (Late Bronze Age, Austria, Kohler-Schneider 2001)

!!! oops!!! grains of the so-called « new glume wheat » may look similar, however somewhat more delicate; see later pages

Shape in plan view (dorsal view):
"typical" grains: oval, often with almost parallel sides. The upper end bluntly rounded, lower end blunt but often relatively pointed. There may be many grains which are somewhat drop-shaped (see figures).
Shape in side view:
Dorsal ridge symmetrically rounded, but very flat (also the drop-shaped spelt grains are rather flat compared with emmer, but higher than the "typical" ones). Ventral surface mostly almost flat.
Shape in section:
Mostly symmetrically rounded. Ventral furrow narrow and deep.
Characteristic measurements and ratios:
L: 4.7-8.4 mm
B: 2.0-4.1 mm
H: 1.7-3.3 mm (rarely >3mm)
L/B: 1.5-2.45
L/H: 2.1-3.09 (in "typical" grains **>2.5**)
B/H: 1.0-1.5
Possibilities for confusion:
See under emmer. Important: when spelt grains became charred while in the ear or spikelet, their shape is quite different from that described in the literature as "typical" spelt. It approaches emmer closely in shape and size ratios, and drop shaped grains are encountered regularly.

Characters and images of (pre)historical finds of naked wheat: grains



1: Archsym/Sylt (Bronze Age; Kroll 1975) 2: Valkenburg (Roman, Netherlands, Van Zeist 1968); 3; Feddersen Wierde (Iron Age, Germany, Körber-Grohne 1967; 4: Stillfried (Late Bronze Age, Austria, Kohler-Schneider 2001)

In the following we don't go into the details of the distinction between tetra- and hexaploid naked wheats (some information on the problematic is given **on the following page**). For those interested see Kislev 1979 and 1984; some of Kislev's observations are added below. The distinction is (at least) difficult (if not impossible).

In the following, by Triticum aestivum s.l. we mean all hexaploid naked wheat varieties (incl. T. cpmpactum), by T. turgidum s.l. we mean tetraploid naked wheat in general (T. turgidum or T. durum). We don't treat here other hexa- or tatraploid naked wheat types because they seem not to play any role in central European (pre)history. For an overview of the taxa see the tables at the beginning of part 2.

We also don't put too much attention to the distinction of the different bread wheat-species (or more likelely: varieties), because the forms and measurements are overlapping, and – in addition - the ploidy-level is *per se* not known.

Shape in plan view (dorsal view):

Slender ("tetraploids") to oval ("T. aestivum-vulgare") to round ("T.compactum"). The upper end bluntly rounded (rarely also pointed: cf tetraploid), lower end blunt-rounded, too. Drop-shaped grains possible (cf tetraploid). The surface is smooth, without furrows. The germ area is deep, the embryo lies like in a cavity.

Shape in side view:

Dorsal ridge (mostly symmetrically) rounded, in tetraploids humpy. Ventral surface from rounded (convex) to flat. Max. height ca. in the middle.

Shape in section:

Mostly symmetrically rounded. Ventral furrow wide and deep.

Characteristic measurements and ratios:

L: 3,4-7,0 mm / B: 2,2-4,7 mm / H: 2,0-4,0 mm

L/B: 1.07-1,73 (the boundary between "T. compactum" and "T. vulgare" is seen around 1,5 (compactum is below, vulgare above)

L/H: 1,1,-2,1

B/H: 1.1-1,3

B/L*100: 54.4-89,3 ("T. compactum" >65-70, "T. vulgare" <65)

Separation of naked wheat grains from other wheat species (Table 9):

Separation from emmer (<u>Triticum dicoccum</u>):

Grains of emmer are mostly distinctly narrower (usually <3mm wide). Consequently their L/B ratio is clearly higher than in naked wheats (mostly around 2) . There are also clear differences in B/L x 100 ratio, which is between 48 and 60 for emmer (average usually around 54) also distinctly lower than in naked wheats (around 54-81).

Separation from "typical" (flat) spelt grains (<u>Triticum spelta</u>):

Critical remarks to the identification possibilities of (pre)historical finds of naked wheat: grains

In the literature of central Europe all naked wheat grains were formerly considered to be hexaploids (Triticum aestivum L., bread wheats in the widest sense). The author, through the study of beautifully preserved finds of naked wheat from lake shore settlements in the sub-Alpine region, became aware that this clearcut arrangement could not be quite so certain (Jacomet & Schlichtherle 1984). Heer had already (1865) recognised the morphologically distinct character of some of the lake-settlement wheats and described these as a separate subspecies, called Triticum vulgare antiquorum ("small lake settlement wheat"). Our conclusion, and also Heer's before as well as that of U. Maier (1996) later, depend mainly on morphological characters of the rachis and glumes (see below). Lastly, distinct similarities with tetraploid naked wheats of the Triticum turgidum-group can be recognised. Also, Kislev (1979 and 1984) has referred to the possible presence of tetraploid naked wheats in the archaeological finds from the near East; he described what was in his opinion a tetraploid find as a new hitherto unknown species (Triticum parvicoccum). The author was therefore interested in which grain characters the tetraploid naked wheats could be separated from the hexaploids (characters see previous page, from Kislev 1984). From that, it appears that the grains of naked tetraploid wheats have a greater similarity to emmer (tetraploid glume wheat) than to hexaploid bread wheats. This however, does not hold for the larger part of the clearly tetraploid "lake-dwelling-wheats", and maybe also not for other finds of that type from other geographical regions and periods which were made in the meantime (e.g. Kühn 1996, Petrucci-Bavaud & Jacomet 2002; Moffett 1991). Therefore we propose **to identify naked-wheat grains in central European contexts as "Triticum "nudum", what means, that it is a tetra- or hexaploid naked wheat** (so T. aestivum s.l./turgidum s.l. (incl. durum's; it hast always to be specified which nomenclature is used)).

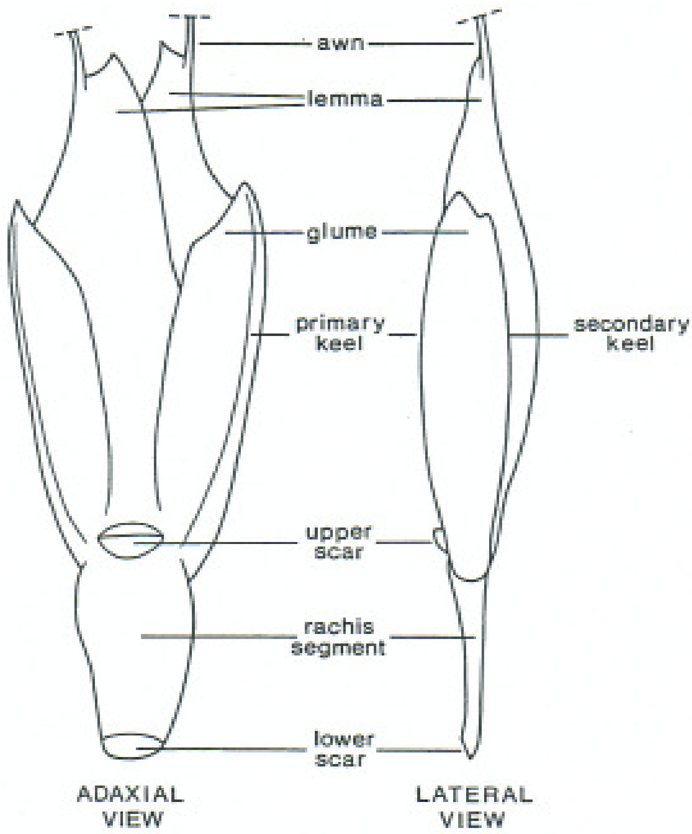
An other critical point is the difficulty to make a differentiation between the different forms of hexaploid naked wheats. From the older literature – in a time, when everybody supposed that all naked wheat found in Europe was a hexaploid – a huge debate concerning the separation of dense-eared forms (cone wheat, Triticum aestivum grex aestivo-compactum Schiem.) and lax-eared forms (Triticum aestivum L. s. str.) is known. Hopf (various publications), van Zeist 1968, Rothmaler 1955 and many others besides give various characters and dimensions as identification criteria (see partly on the previous page). This became obsolete since it is known that also tetraploids can be present in the archaeological material.

Nevertheess, it may be important to note during identifying archaeological naked wheat remains the form of the grains, because it is not excluded that different varieties are present. One can e.g. distinguish between:

- short stubby grains (former T. compactum type)
- long slim grains (former T. vulgare type)
- intermediate shapes

Identification of chaff remains of (pre)historic wheat

The principal diagnostic features of a stylized spikelet of a glume wheat



Hillman et al. 1996

The by- products resulting from grain processing, such as chaff, provide the most important means for the identification of prehistoric wheat species on the basis of morphology (see Fg. 2 in Hillman 1984). These are rachis parts (internodes. rachis fragments) and the glumes (also lemmas and paleas). These parts of the cereal flowering structure provide many diagnostically useful features for the separation of the individual taxa.

The separation of the individual species, is firstly based on morphological characters. Secondly, measurements are used for identification. The characters used in the following section come partly from the literature (Helbaek 1952 a&b, van Zeist 1968, Hopf 1968, Villaret-von Rochow 1967, Körber-Grohne 1967 and Körber-Grohne and Piening 1983, Hillman et al. 1996, Jones et al. 2000, Kohler-Schneider 2001), partly they were worked out by the Basel Lab members (e.g. Zibulski 2001) on the basis of recent and subfossil material.

For identification, the following **morphological criteria** should be considered (after Jones et al. 2000):

• the upper scar (scar left by the disarticulation of rachis)

• the primary keel (the level at which it arises, his ascendence)

• the secondray keel (robust or not)

• the angle of glume insertion

• the width of the glume bases in lateral view

• the veini

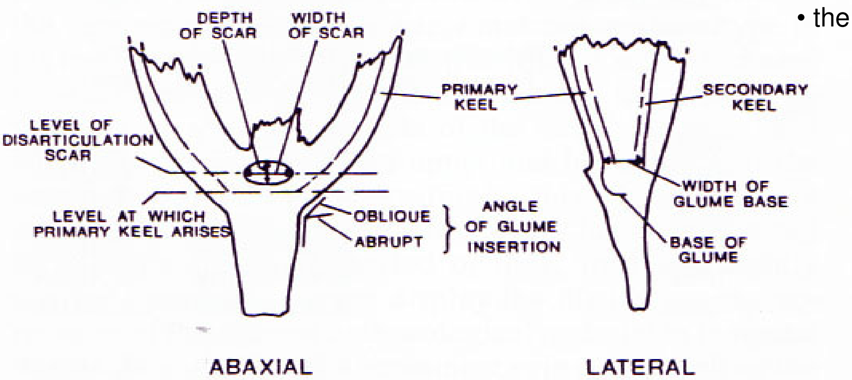
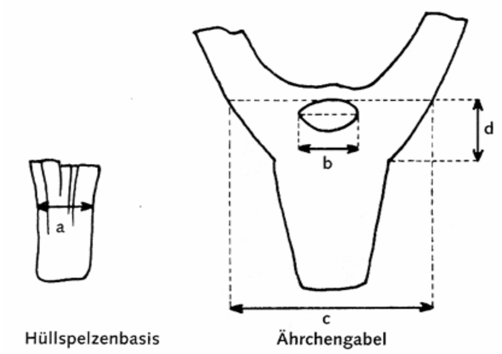


Fig. 5. A diagram indicating some of the terms used to describe spikelet bases in the text Jones et al. 2000



measurements used for the distinction of glume-wheat chaff:

a width uf the glume bse in lateral view

b width of the upper scar

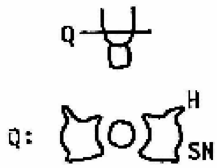
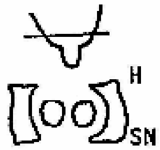
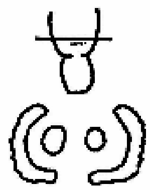
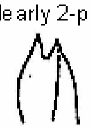
c width of the spikelet fork at the upper margin of the upper scar

d distance between upper scar and the point of glume insertion

Kohler-Schneider 2001

glume wheat chaff: morphological and metrical criteria for distinguishing of rachis remains, spikelet forks and glumes bases of glume wheat: einkorn-emmer and spelt.

Measurement lines see other pages

criterion	einkorn	emmer	spelt
shape of the lower part of the glume (H)	even curvature  internode broad in relation to spikelet width	basal "angle"  internode narrow in relation to spikelet width	Rather even curvature internode rather broad
angle between the glumes breakage pattern of the glumes	small<90°  mostly at the insertion point of the next-higher rachis segment, so fragments of the latter rarely remain	larger  as for einkorn	variable mostly snaps in the region of the middle of the rachis segment, so finds have at least part of the next-higher rachis segment still attached
glume base width (dimension L)	0.45-0.9 mm av: 0.65 mm	0.7-1.1 mm av: 0.92 mm	1.1-1.4 mm ab: 1.28 mm
shape of the lower part of the glume in cross-section	massive, rounded – somewhat rectangular 	rather massive, clearly rectangular, thinner than in einkorn but more massive than in spelt 	rather massive, not so clearly rectangular, much wider and thinner than in emmer 
glume keel: main keel (H) first side nerve (SN) sides (between H & N)	 stands out clearly stands out clearly, visible as an edge mostly without further longitudinal nerves	 stands out rather clearly standing out rather clearly often very clear lengthwise nerves	 not clearly protruding very hard to make out very obvious lengthwise nerves
glume apex	clearly 2-pointed 	first point clear, (extension of the main nerve H), second point mostly indistinct 	no actual points present; upper edge has an S-shaped outline 

composed after: Helbaek 1952A + B, Körber-Grohne 1967, Körber-Grohne & Piening 1983, van Zeist 1968, Villaret-von Rochow 1967 and own studies. Composed by: S. Jacomet. From Jacomet / Brombacher / Dick 1989.

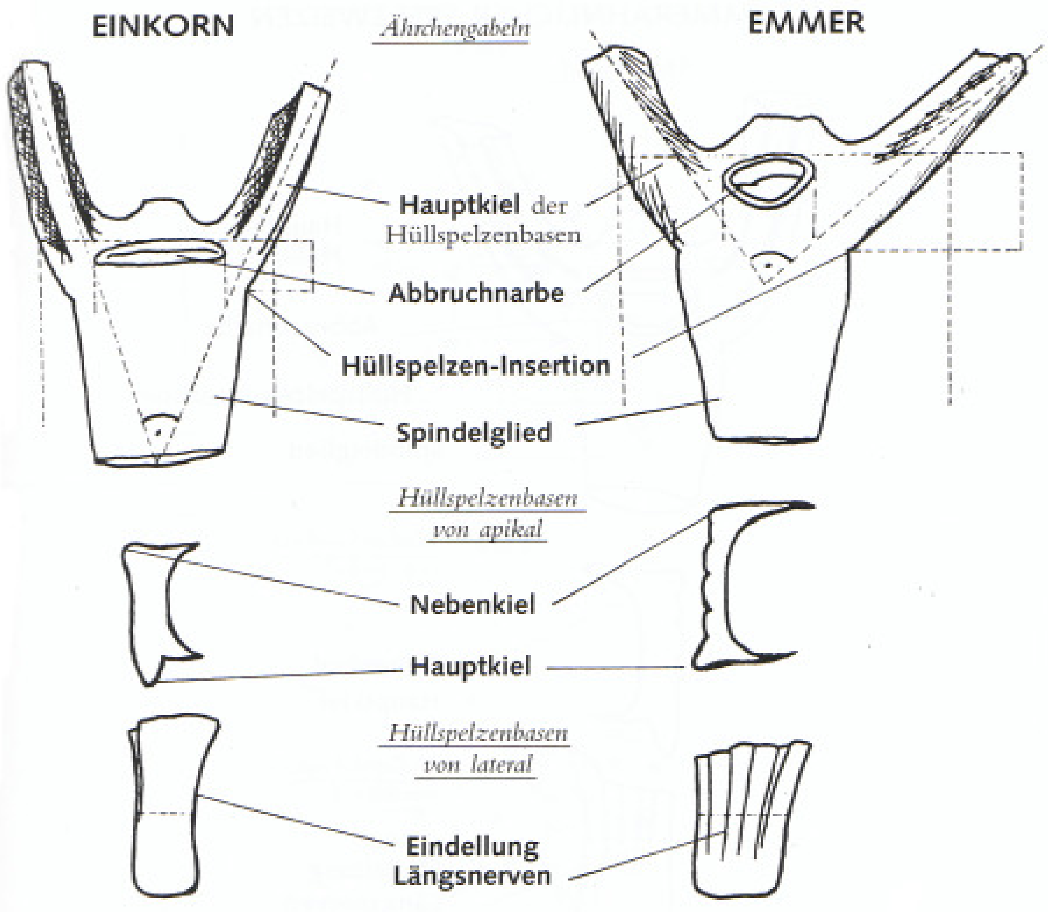
For highly fragmented remains of glume wheat chaff see the work of Zibulski 2001

The following suggest themselves as particularly important measurement points that are diagnostic for species identification (for measurement lines see other pages)

- the basal width of the glumes between the keel and the first side nerve (L) : provides good identification criteria between the species although there is a certain amount of overlap between emmer and einkorn on the one hand, and between emmer and spelt on the other.
- the basal width of the spikelet (Q)
- the maximal width of the rachis (P)
- the ratio Q:P. In emmer this is around 2:1, in einkorn normally <1.5:1.
- the maximal width of the spikelet (R)

Morphological and metrical criteria for the distiction of rachis remains, spikelet forks and glumes bases of glume wheat: **EINKORN AND EMMER**

For english terms see page 67 and 71!



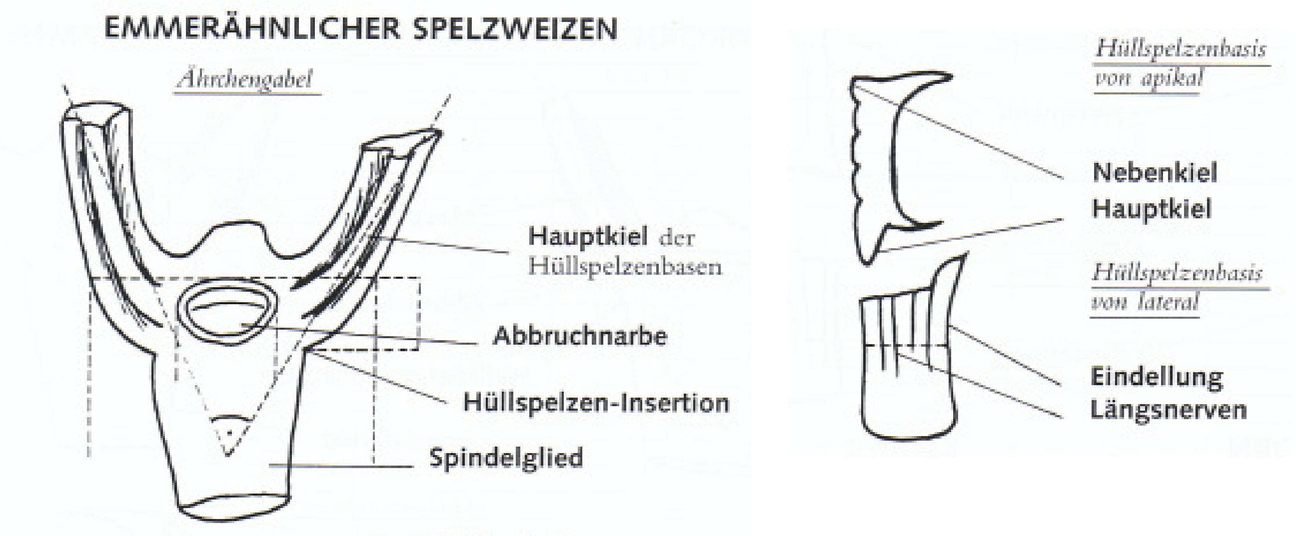
	EINKORN	EMMER
Abbruchnarbe:	breit, linear, flach	eng, rund, tief
Hüllspelzen-Insertion:	ca. in Höhe der Abbruchnarbe	weit unterhalb der Abbruchnarbe
Hauptkiel der Hüllspelzenbasen:	sehr stark ausgebildet und vertikal hervortretend, nahe an die Abbruchnarbe heranreichend	weniger stark ausgebildet und lateral hervortretend, nicht an die Abbruchnarbe heranreichend
Nebenkiel:	deutlich ausgeprägt	weniger deutlich ausgeprägt
Hüllspelzenbasen von apikal:	sehr massiv, Basisbreite niedrig	weniger massiv, Basisbreite höher
Hüllspelzenbasen von lateral:	meist leichte Eindellung, keine Längsnerven	keine (od. leichte) Eindellung oft zusätzliche Längsnerven
Spreizwinkel der Hüllspelzenbasen:	meist relativ klein (kein sicheres Merkmal)	meist relativ groß (keine sicheres Merkmal)
Spindelglieder:	verhältnismäßig breit	verhältnismäßig schmal

Abb. 28: Bestimmungsmerkmale an Ährchengabeln von Einkorn und Emmer (schematisch).

Kohler-Schneider 2001

Morphological and metrical criteria for the distiction of rachis remains, spikelet forks and glumes bases of glume wheat: **new glume wheat**

For english terms see page 67 and 71!



EMMERÄHNLICHER SPELZWEIZEN

Abbruchnarbe: eng, rund, tief (wie bei Emmer)

Hüllspelzen-Insertion: ca. in Höhe der Abbruchnarbe (wie bei Einkorn)

Hauptkiel der Hüllspelzenbasen: sehr stark ausgebildet und vertikal hervortretend (wie bei Einkorn), nahe an die Abbruchnarbe heranreichend (wie bei Einkorn), auffällig U-förmig ausgeweitet

Nebenkiel: deutlich ausgeprägt (wie bei Einkorn)

Hüllspelzenbasen von apikal: sehr massiv (ähnlich Einkorn), Basisbreite höher (ähnlich Emmer)

Hüllspelzenbasen von lateral: leichte Eindellung (wie bei Einkorn), deutliche zusätzliche Längsnerven

Spreizwinkel der Hüllspelzenbasen: meist zwischen typisch Einkorn und typisch Emmer (kein sicheres Merkma auffällig abrupte, U-förmige Insertion der Hüllspelzenbasen

Spindelglieder: verhältnismäßig schmal (eher wie bei Emmer)

Abb. 29: Bestimmungsmerkmale an Ährchengabeln von „emmerähnlichem Spelzweizen" (schematisch).

Tab. 53: Meßwerte von Einkorn (n=10), Emmer (n=10) und „emmerähnlichem Spelzweizen" (n=30) in mm.

		Einkorn	Emmer	Emmerähnlicher Spelzweizen
a	Basisbreite der Hüllspelzen	0,66 (0,5–0,8)	0,9 (0,7–1,0)	0,91 (0,8–1,1)
b	Breite der Abbruchnarbe	0,87 (0,7–1,0)	0,70 (0,6–0,8)	0,85 (0,7–1,0)
c	Basisbreite der Ährchengabeln	1,84 (1,7–2,0)	2,21 (2,0–2,5)	2,12 (1,8–2,4)
d	Distanz Abbruchnarbe/Hüllsp.insertion	0,59 (0,5–0,7)	0,90 (0,7–1,1)	0,74 (0,5–0,9)
b/c × 100	Index	47,2 (40,2–51,6)	31,4 (27,2–35,3)	40,5 (34,5–47,5)

Measurements of einkorn (n=10), emmer (n=10) and new glume wheat (n=30) chaff, in mm

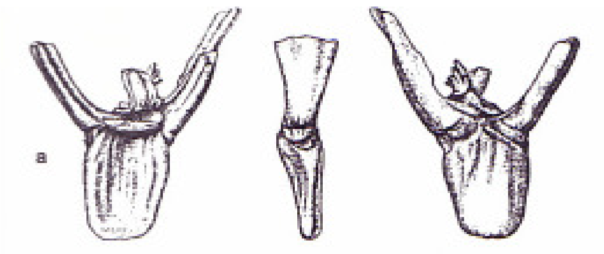
Kohler-Schneider 2001

Morphological criteria for the distiction of rachis remains, spikelet forks and glumes bases of glume wheat: **einkorn, new glume wheat and emmer** (from Jones et al 2000)

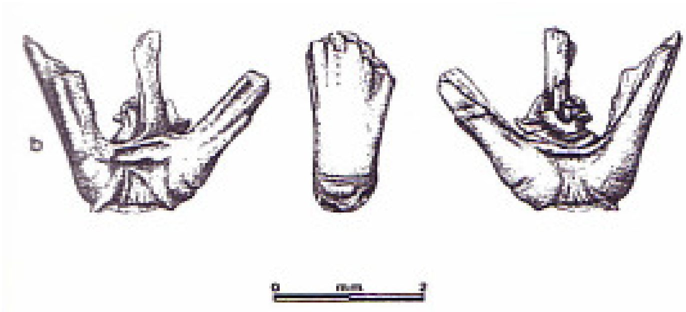
Table 1. Summary of the characteristics which distinguish the new type glume bases from typical einkorn and emmer glume bases from Greece

Einkorn	*New type*	*Emmer*
Scar left by disarticulation of rachis wide and often shallow	Scar left by disarticulation of rachis wide and deep	Scar left by disarticulation of rachis narrow
Primary keel prominent and projecting abaxially	As einkorn	Primary keel usually less prominent and tending to project laterally
Base of primary keel arising at the same level as the attachment scar	As einkorn	Base of primary keel arising below the level of the attachment scar
Primary keel ascends more or less vertically from scar	Primary keel extends laterally before ascending	Primary keel ascends obliquely
Secondary keel robust but rounded	Secondary keel sharply angled, often with a clearly defined 'vein' running along it	Secondary keel angled but less prominent
Glumes inserted into the rachis at an oblique angle	Glumes inserted into rachis at an abrupt angle	Glumes inserted into the rachis at an oblique angle
Glume bases narrow	As emmer	Glume bases wide
Lateral face of glume bases with little or no veining near the base	As emmer	Lateral face of glume bases usually veined near the base

Note that, like all identification criteria, there is considerable variation within as well as between different types which is not apparent from a summary table (see text for more details)

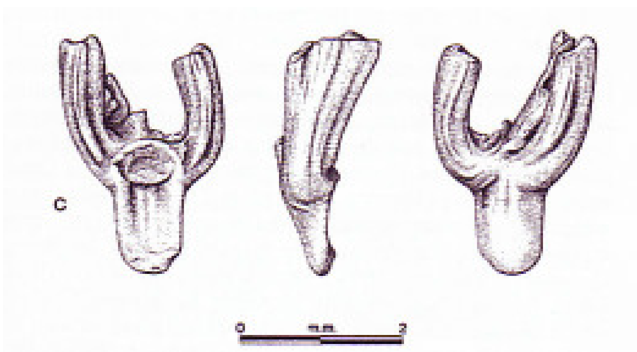


einkorn

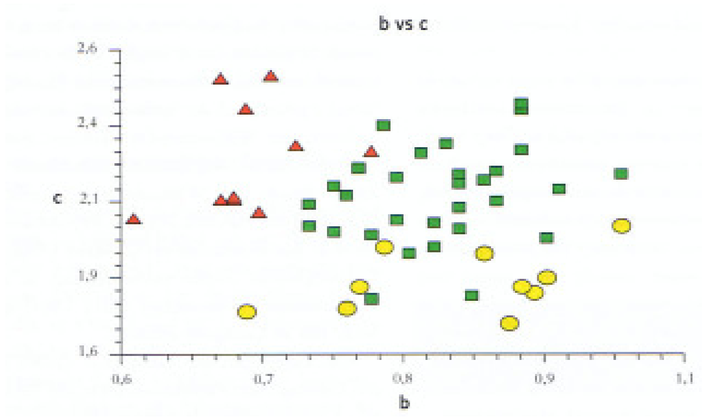


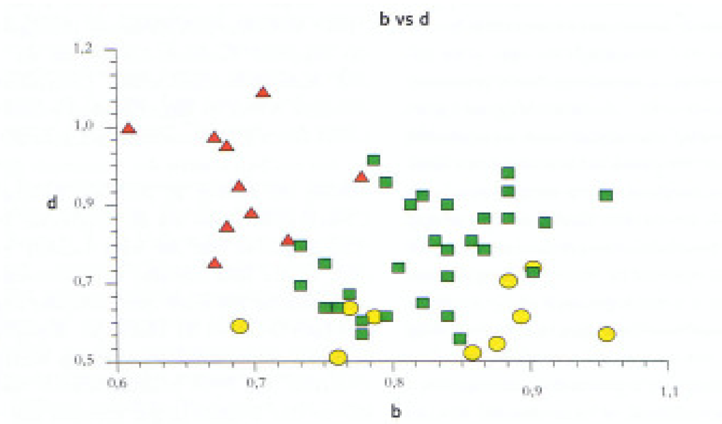
emmer

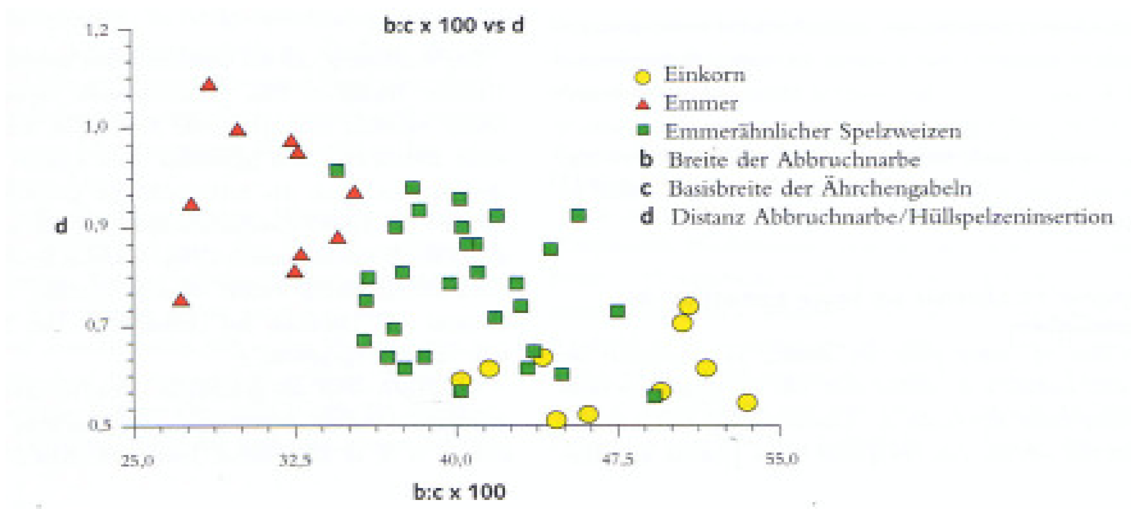
new glume wheat



wheat: measurements of einkorn, emmer and new glume wheat chaff: comparison
Examples from Late Bronze Age Stillfried, Austria





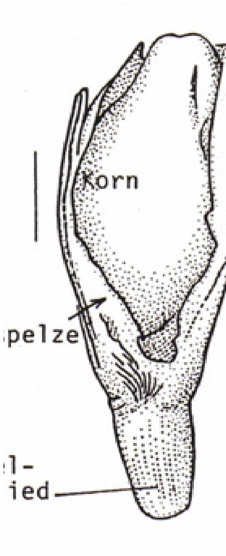


Measurement lines see p. 67

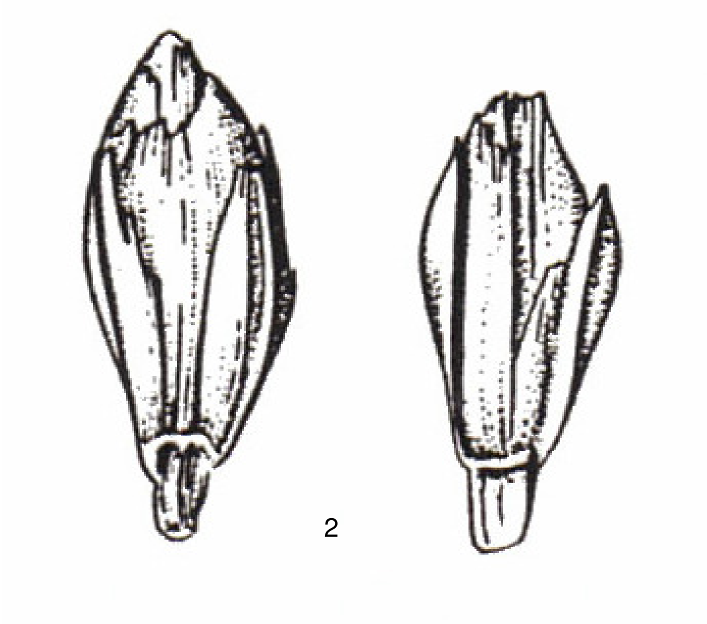
Kohler-Schneider 2001

Images of (pre)historical finds of einkorn (*Triticum monococcum*): spikelets and chaff

spikelets

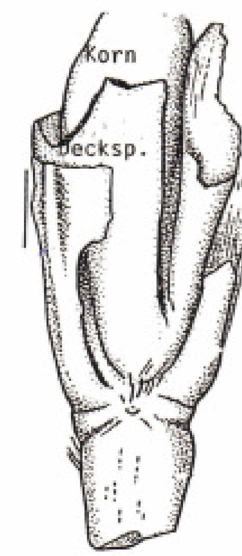


1



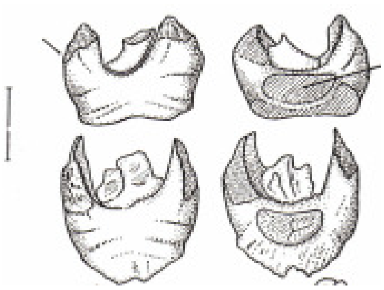
2

2-grained



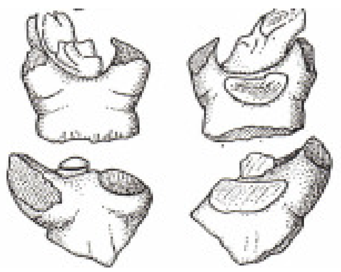
3

spikelet forks, rachis parts

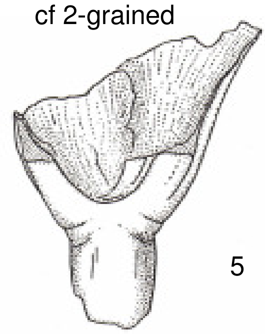


4

subfossil



cf 2-grained



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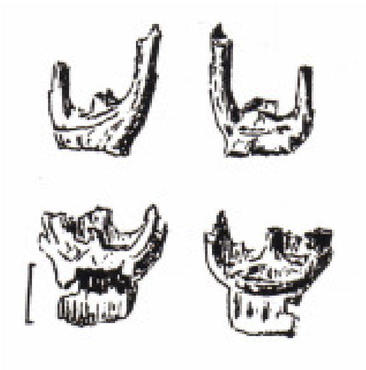

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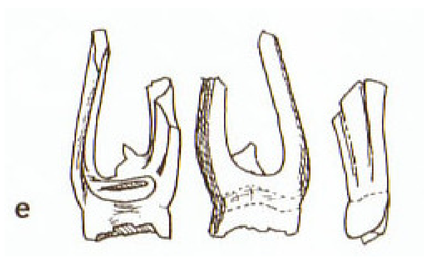

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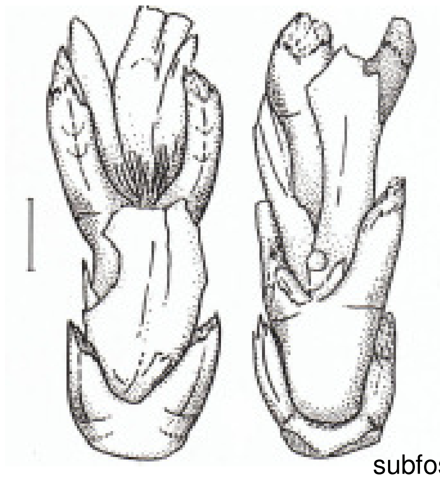
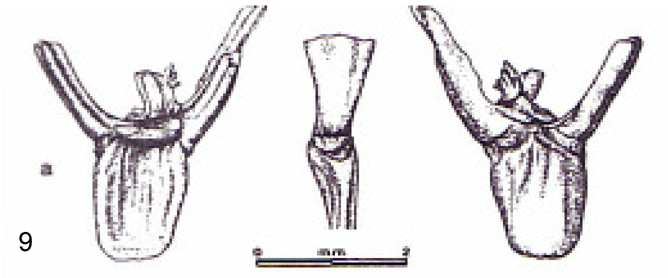


8

subfossil

cf 2-grained



9

1, 3 Port-Stüdeli (Neolithic, Switzerland, Brombacher & Jacomet 2003); 2 Ehrenstein (Neolithic, Germany, Hopf 1968); 4-5, 8: Zürich, Kleiner Hafner (Neolithic, Switzerland, Jacomet et al. 1989); 6 Lamersdorf (Early Neolithic (LBK), Germany, Knörzer 1967); 7 Stillfried (Late Bronze Age, Austria, Kohler-Schneider 2001); 9 Assiros (Bronze Age, Greece, Jones et al. 2000)

Images of (pre)historical finds of the new glume wheat (*Triticum nn*) chaff (spikelet forks) and grains (?)

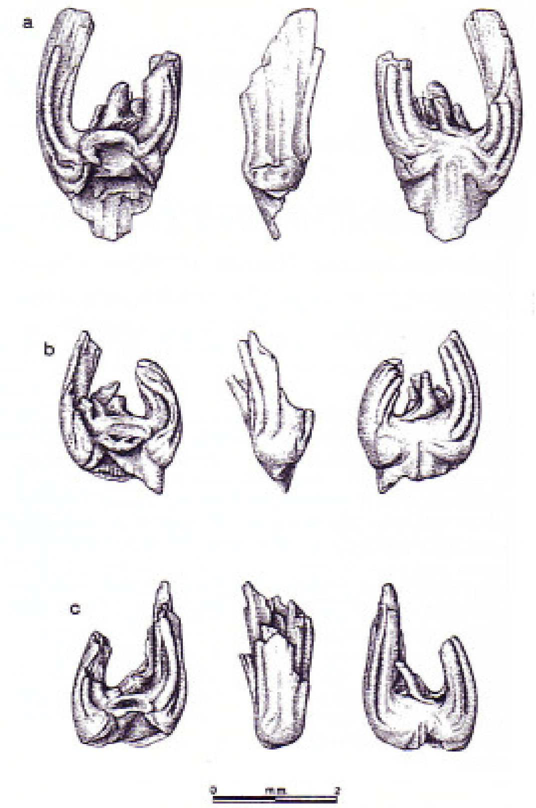


Fig. 2. New type spikelet bases from the Neolithic sites: **a** and **b** Makriyialos, **c** Makri

Jones et al. 2000

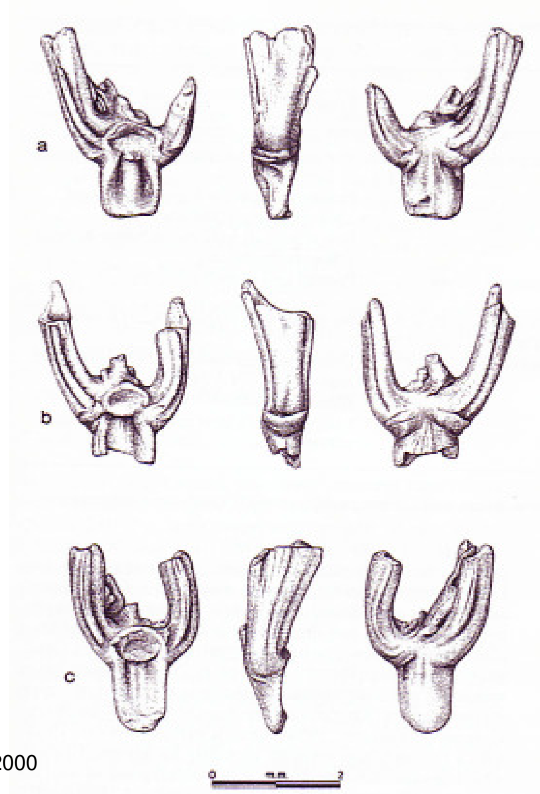
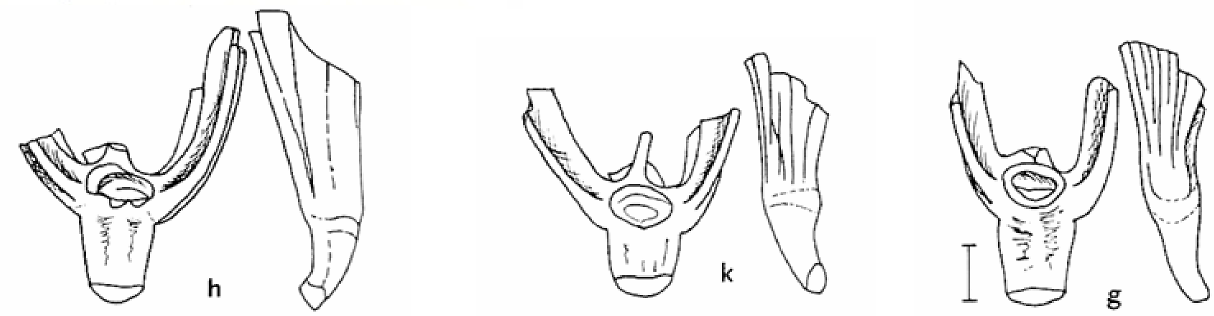


Fig. 3. New type spikelet bases from Bronze Age Assiros Toumba: **a** and **b** sample 4650, **c** sample 4384



Kohler-Schneider 2001: Stillfried, Austria, Late Bronze Age

possible corresponding modern species

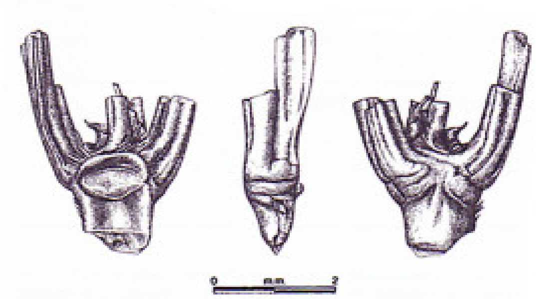
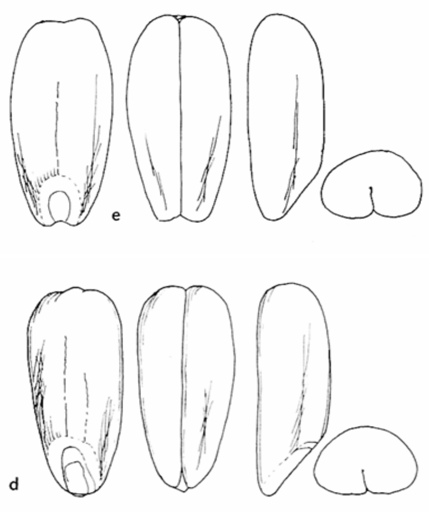


Fig. 6. A modern charred spikelet base of *Triticum timopheevi* Zhuk.

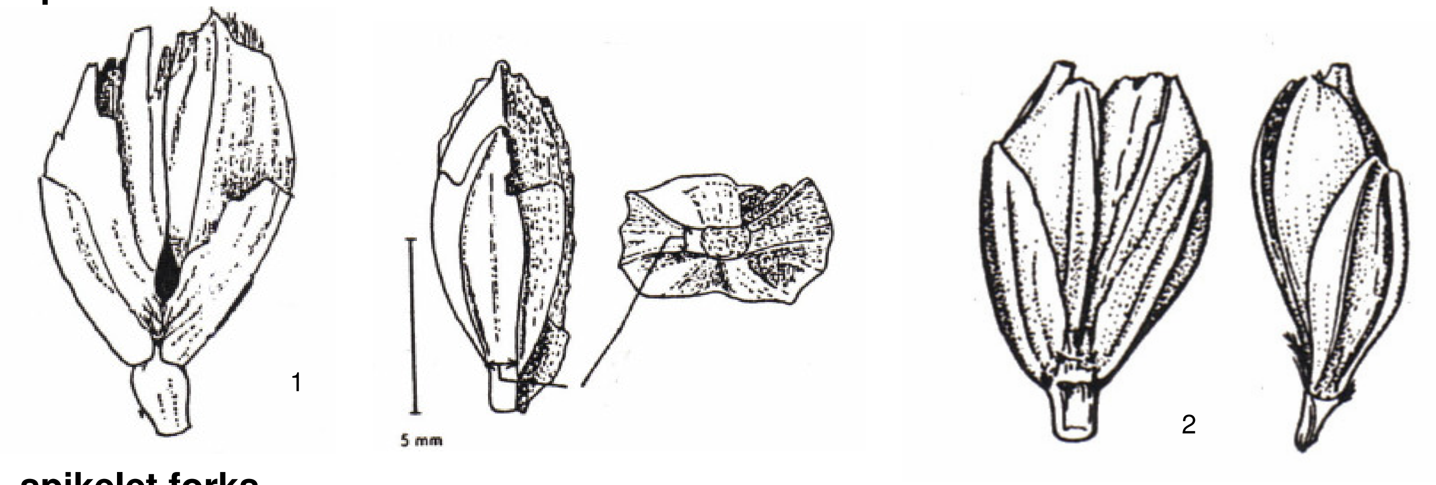


maybe the corresponding grains….

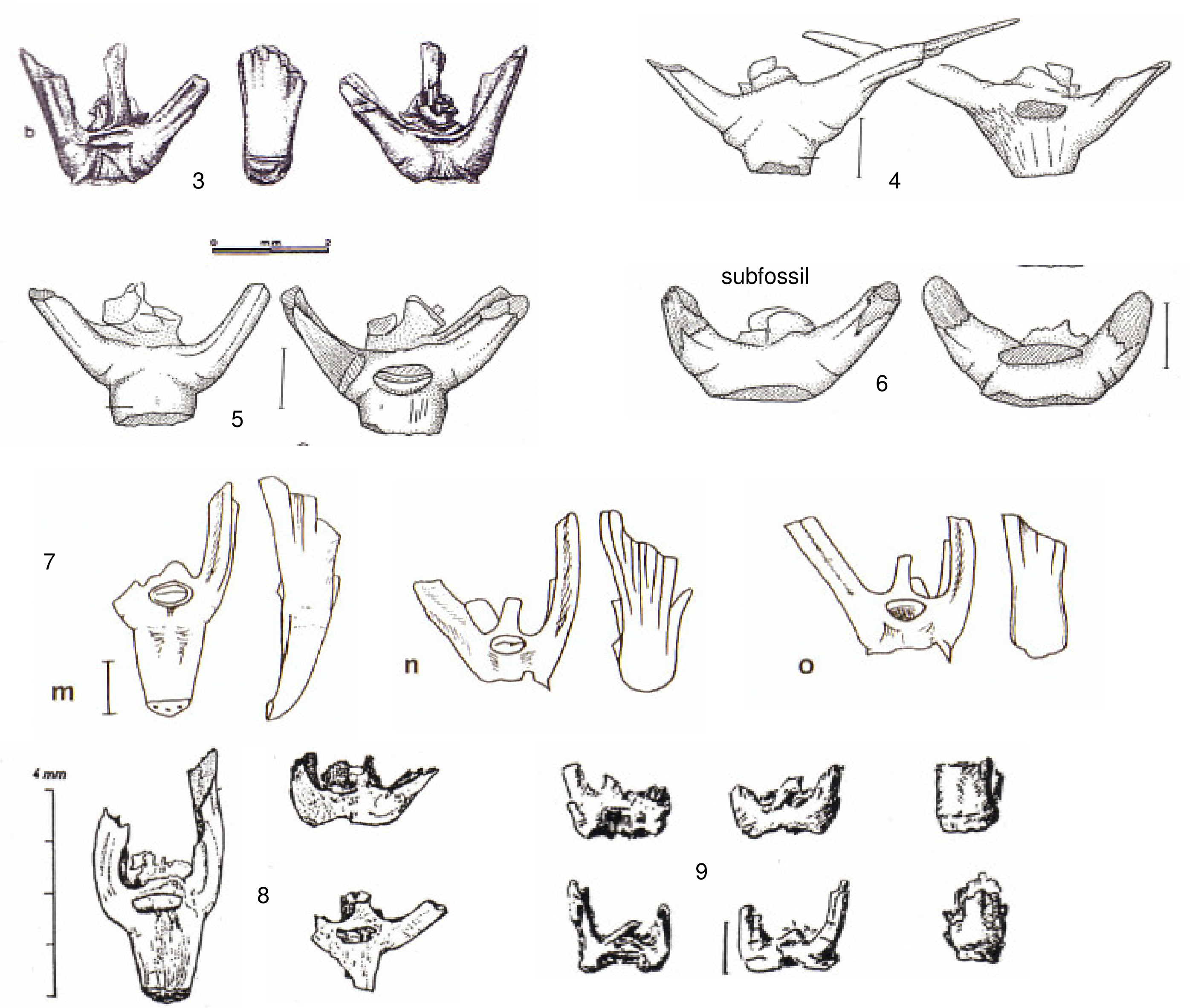
(from Stillfried)

Images of (pre)historical finds of emmer (*Triticum dicoccum*): spikelets and chaff

spikelets



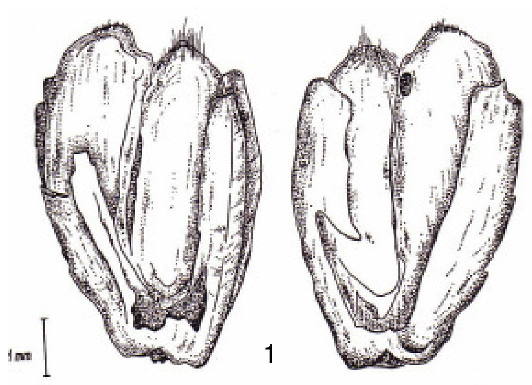
spikelet forks



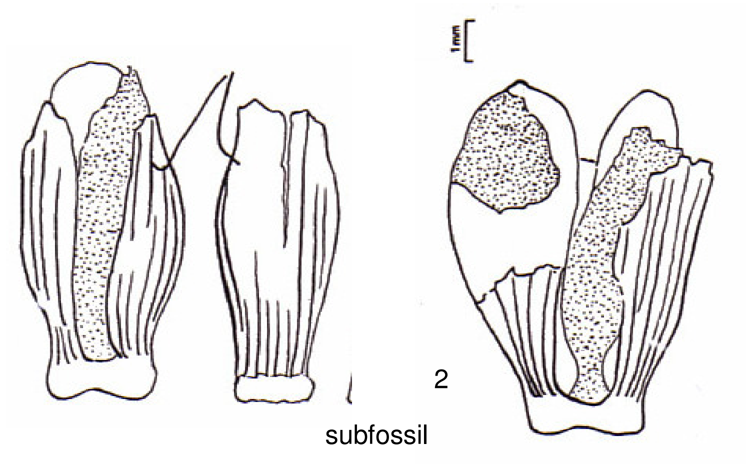
1: Feddersen Wierde (Iron Age, Northern Germany, Körber-Grohne 1967); 2 Ehrenstein (Neolithic, Germany, Hopf 1968); 3 Assiros (Bronze Age, Greece, Jones et al. 2000); 4-6 Zürich, Kleiner Hafner (Neolithic, Switzerland, Jacomet et al. 1989); 7 Stillfried (Late Bronze Age, Austria, Kohler-Schneider 2001); 8: Burgäschisee-Süd (Neolithic, Switzerland, Villaret-von Rochow 1967); 9 Lamersdorf (Early Neolithic (LBK), Germany, Knörzer 1967).

Images of (pre)historical finds of spelt (*Triticum spelta*): spikelets and chaff

spikelets



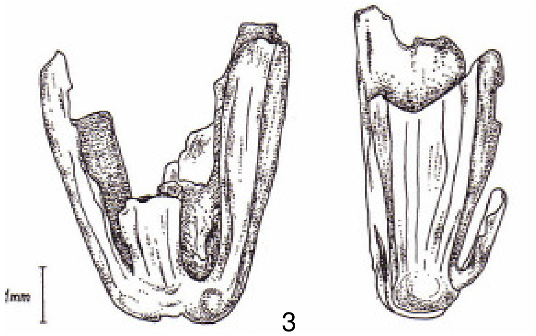
1



subfossil

2

spikelet forks and glume bases



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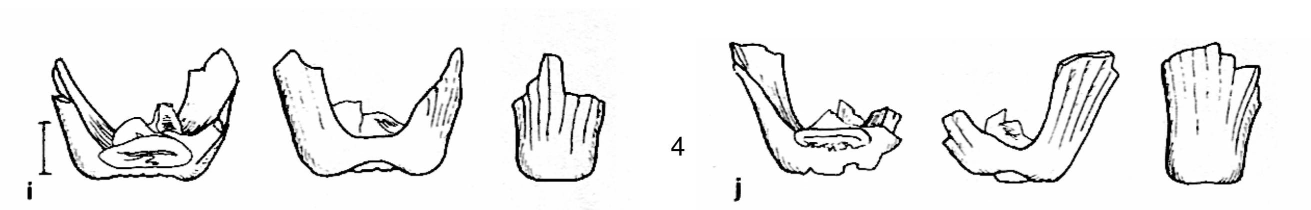

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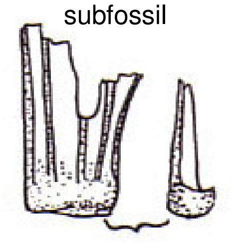
subfossil

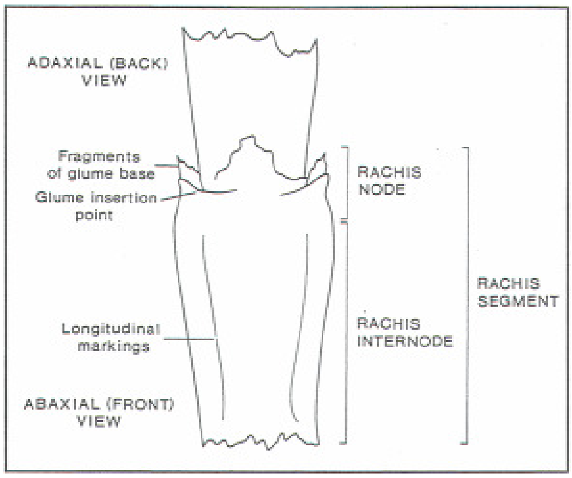
5



6

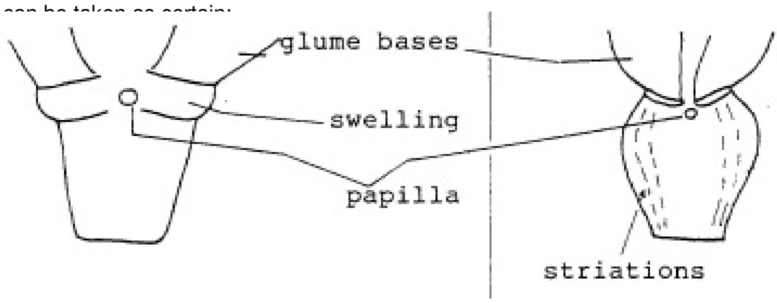
1, 3 Eptingen-Riedfluh (Middle Ages, Switzerland, Jacomet et al. 1988); 2, 5 Welzheim (Roman, Germany, Körber-Grohne & Piening 1983); 4 Stillfried (Late Bronze Age, Austria, Kohler-Schneider 2001); 6 Zürich Mozartstrasse (Bronze Age, Switzerland, Jacomet et al. 1989)

criteria for distinguishing rachis remains of tetra- and hexaploid naked wheat



The principal diagnosctic features of a portion of rachis of a free-threshing wheat. Note the distinction between « rachis segment » and « internode » (from Hillman et al 1996)

Rachis segments are certainly the first things to notice in the identification of naked wheat chaff, particularly their shape and size. The lower part of the glumes, which are mostly broken off, play a smaller role in this (compare glumed wheats). In the case of Neolithic cereals from lake shore settlements, however, it has been noticed that the lowest parts of the glumes often remain attached to the rachis (author's observations, see also e.g. Jörgensen 1975).
All naked wheat rachises were formerly, in the central European literature, without exception considered to belong to the hexaploids (see also grains). They were also placed in Triticum aestivum s.l. although some researchers, among them Heer in the early days, noted variations in the shape. In particular it struck Heer and for example Jörgensen (1975) in the case of Neolithic wheat material from the 'lake villages' of the sub-alpine region that the rachis segments showed unusual swellings underneath the glume attachment points. Jörgensen (1975) described the Neolithic rachis segments from Thayngen-Weier like this: "I have not seen such marked thickenings in extant collections of bread wheat and club wheat. Perhaps this feature is connected only with certain varieties of the species, or is strengthened in fossil material by carbonisation".
The presence of these swellings on the often apparently straight course of the side edges, the absence of a clear longitudinal striation in most cases and characters of the glumes (see below) already led the author to voice considerable doubt in the general classification of Neolithic naked wheat rachis segments as hexaploids (cf. Jacomet & Schlichtherle 1984; see also Maier 1996). All the characters mentioned above fit much better with naked wheats of the tetraploid group (Triticum durum/turgidum). Characters for the differentiation of rachis segments of the two naked wheat groups was taken from the works of Schiemann (1948), Percival (1921) and Hervey-Murray (1980), and consequently the author has made various studies of recent material. In the same period also G. Hillman developed such criteria which finally were published in 2001 (see next page).
The following criteria can be taken as certain:

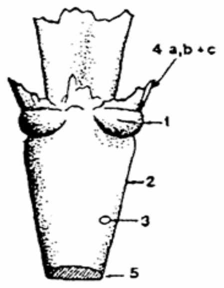


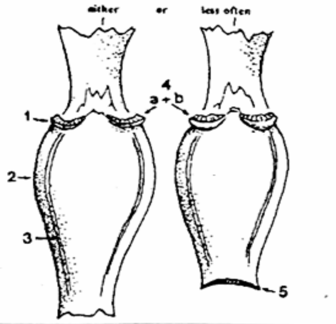
Tetraploidea type Triticum turgidum, T. durum	**Hexaploidea** type Triticum aestivum s.l.
sides straight	sides curved
striations absent	striations usually obvious
thickenings (swellings) under the glume base	no thickenings (swellings) under the glumes
glume parts often remaining attached to the rachis fragments	glume parts always broken off
maximum width in upper part	maximum width just above the middle

The naked wheat rachis segments are of very different lengths (as are the ears, see the following pages). Almost all workers up to now concerned themselves with the question whether specific bread wheat types could be distinguished from club wheats (Triticum "compactum") (Villaret-von Rochow 1967, Jorgensen 1975). Jorgensen (1975), on the basis of extensive studies with recent material, came to the conclusion that this was not possible, for the club wheat dimensions lay completely within the variation of the bread wheats (in the strict sense). In charred material only pieces >4mm could be assigned to bread wheat s. s. with any certainty, and then with reservations.
In naked wheat rachis material it is suggested on the basis of the author's results, to use the following groupings:
tetraploid naked wheat type (turgidum type):
a1) long rachis segments >4mm (lax-eared type)
a2) short rachis segments <4mm (dense-eared type)
hexploid naked wheat type (aestivum type):
b1) long rachis segments >4mm (lax-eared type)
b2) short rachis segments <4mm (dense-eared type)

criteria for distinguishing rachis remains of tetra- and hexaploid naked wheat (Hillman 2001)

***T. DURUM* GROUP** (including *T. turgidum, T. turanicum* and *T.polonicum*	***T. AESTIVUM* GROUP** (including *T. compactum*) + *T. sphaerococcum*





1. shape of rachis node immediately below point of glume insertion

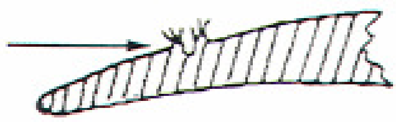
Node often with a conspicuous rounded lump beneath each glume-insertion, with or without a thin fissure across the hump. (This feature is poorly developed in some small-eared pyramidal central Anatolian *durums*.)	Node with either (a) no lumps at all, and merely a narrow ridge below glume insert; or (b) weakly developed lower halves of lumps, in which the upper halves give the impression of having collapsed.

2. Shape of rachis internode – in lax-eared forms only. (In dense-eared forms of either ploidy, there is insufficient room for internode shape to be properly expressed.)

Rachis internodes forming ± straight-sided trapeziums, with only a slight incurved narrowing immediately below the node, even in extremely lax-eared tetraploids such as *turanicum* and *polonicum*.	Rachis internodes conspicuously shield-shaped, with a strongly curved widening of the upper third of the internode, and a more steeply curved narrowing just below the node.

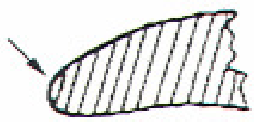
3. Presence/absence of longitudinal lines near the outer edge of the convex (abaxial) race of rachis internodes.
(This feature has so far proved the most reliable of all those listed here.)

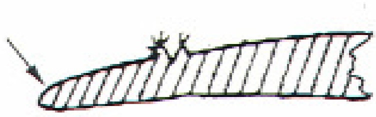
No trace of lines, except those resulting from occasional wrinkles due to shrinkage if the ears were cut while still green.	Clear longitudinal lines present, often bearing hairs. The lines often have the following form in T.S. Ridge often with hairs (The lines are just as conspicuous in compact/ dense-eared forms.)



5. Roundness of rachis edge in transverse section.

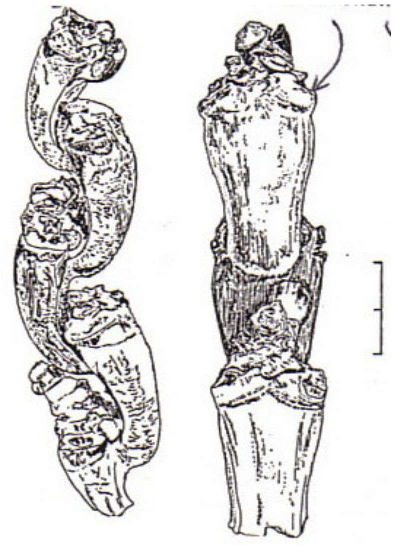
Rachis edge in T.S. generally rounded.	Rachis edge in T.S. generally attenuated.

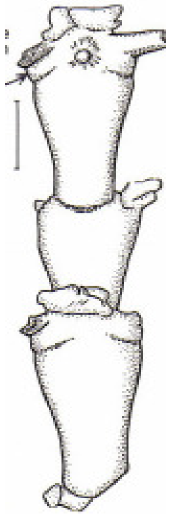




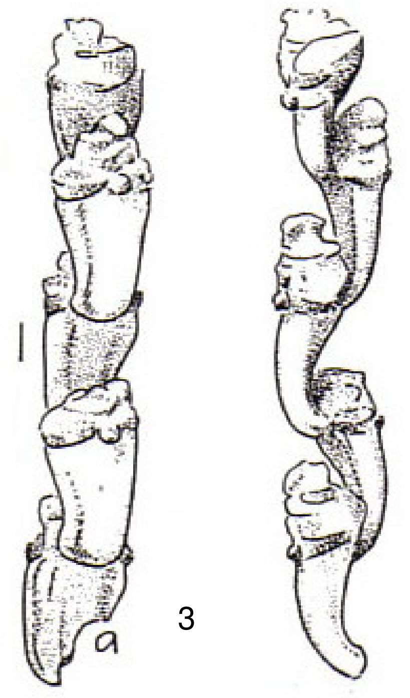
images of (pre)historical finds of naked wheat : rachis remains

Tetraploid 4n





2



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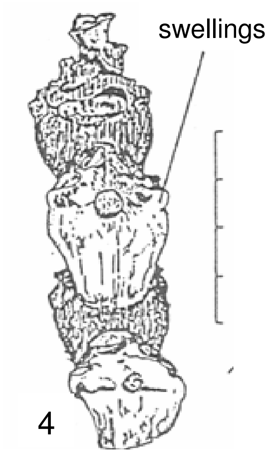

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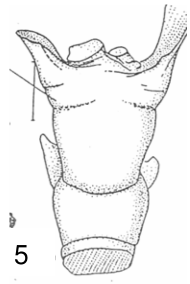
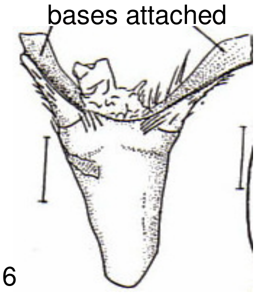


5

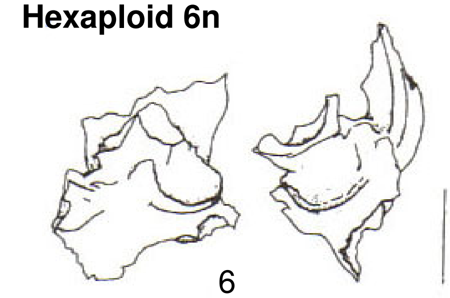
often glume bases attached



6

1-3, 6: rather long internodes (« lax-eared »), 4-5 short internodes (« dense-eared »)

Hexaploid 6n



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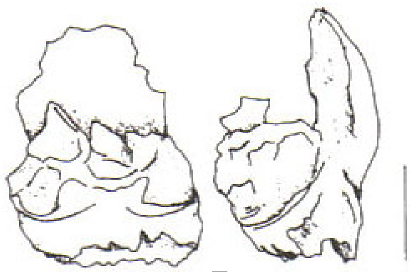

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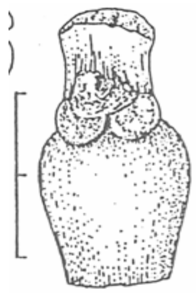

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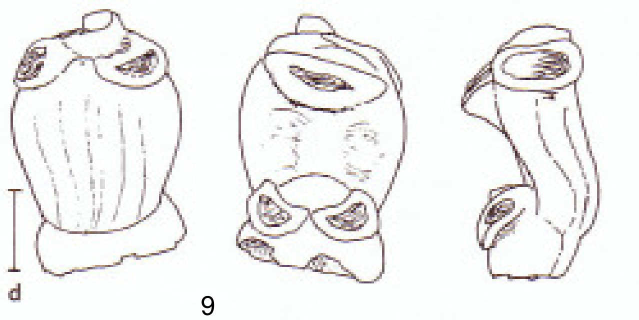


9

1, 4 Burgäschisee-Süd (Neolithic, Switzerland, Villaret-von Rochow 1967); 2, 3, 5 Zürich, Kleiner Hafner (Neolithic, Switzerland, Jacomet et al. 1989); 6, 7 Therwil Baslerstr. (Iron Age, Switzerland, Jacomet, not published); 8 Yverdon Avenue des Sports (Late Neolithic, Switzerland, Schlichtherle 1985); 9 Stillfried (Late Bronze Age, Austria, Kohler-Schneider 2001)

Naked wheat glumes

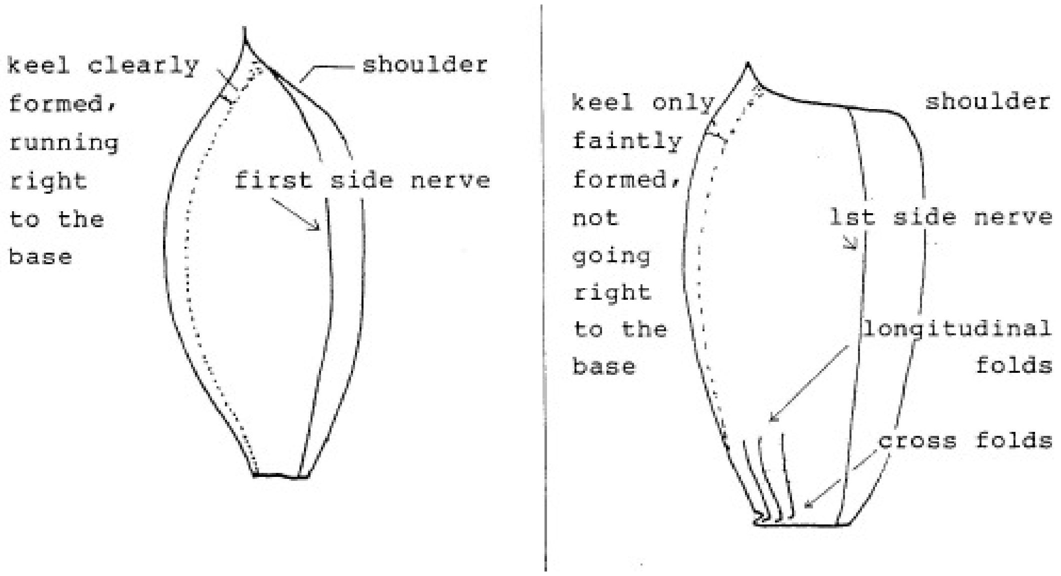
Glume fragments of naked wheat taxa are generally found infrequently. However they play a very important part, for example in the material from the waterlogged settlements in the sub-alpine region, where often whole ears or at least parts of them are found. It is therefore important to consider the glume characters of naked wheats in detail. Their shape can be taken from the figures below.

Morphological characters, of which particularly to be noted are:

- course and height of the main keel
- apical end of the main keel
- shouldering of the glume
- presence of nerves on the glume
- state of the glume base

The glumes also offer some important differential characters for the separation of hexaploid from tetraploid naked wheats.

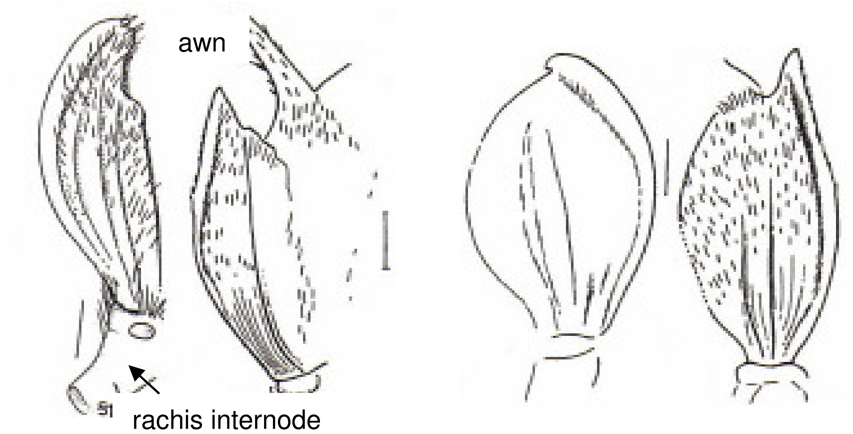
Tetraploidea (T. turgium, T. durum)	**Hexaploidea** (T. aestivum s.l.)
not shouldered, or only slightly	clearly shouldered
No longitudinal folds at the base	clear longitudinal folds at the base
No crosswise folds at the base	crosswise folds present at the base



For identification the following groups had better be used:

a) tetraploidea type
b) hexaploidea type
c) not exactly identifiable

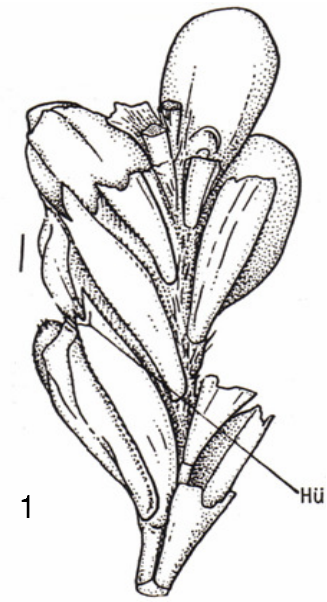
measurements for other parts of the ear: see on former pages



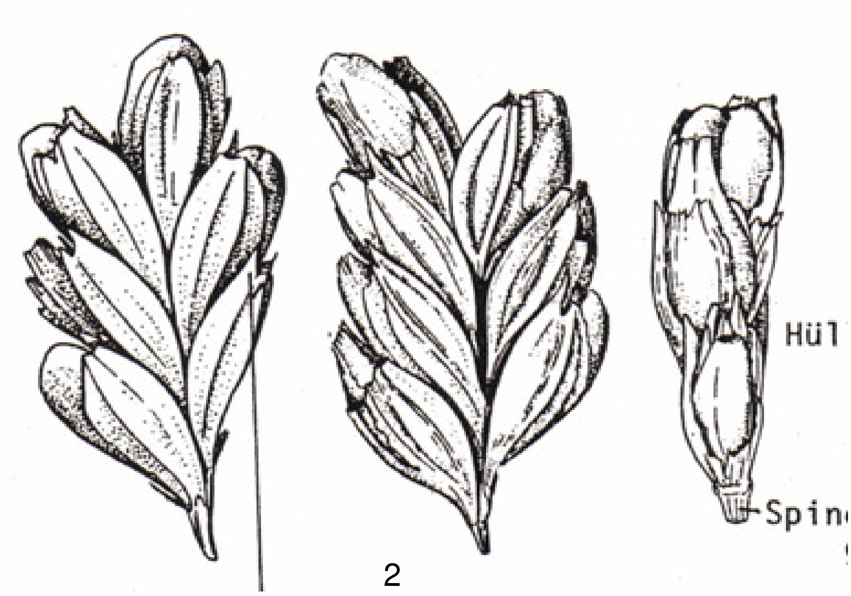
some examples of Neolithic 4n-naked wheat glumes: Zürich Kleiner Hafner (Switzerland, Jacomet et al. 1989)

Images of (pre)historical finds of different wheats: ear-parts (very rare!)

einkorn



1



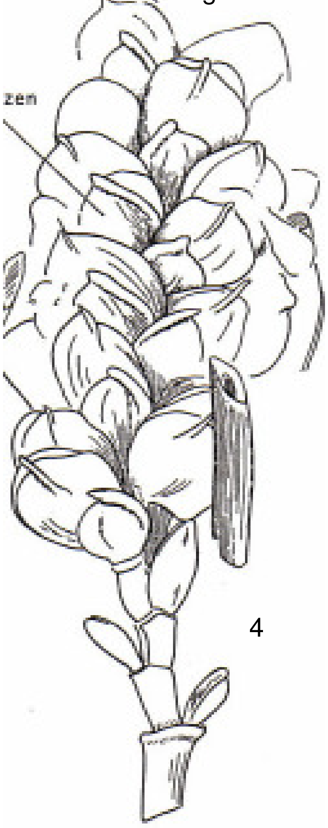
2

tetraploid naked wheat

lax-eared type

3

dense-eared type
with smooth glumes



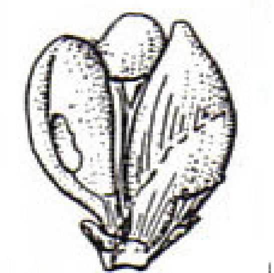
4

dense-eared type
with hairy glumes

5

spikelet

6



1 Port Stüdeli (Neolithic, Switzerland, Brombacher & Jacomet 2003); 2, 6 Ehrenstein (Neolithic, Germany, Hopf 1968); 3-5: Zürich Kleiner Hafner (Neolithic, Switzerland, Jacomet et al. 1989);

Barley (*Hordeum*): General morphology

Origin: Wild grass with 2n=14 chromosomes (Hordeum spontaneum C. Koch), growing wild in the Near East in the Fertile Crescent area

Morphological considerations
•spikelets 1-flowered,
•glumes awn-like,
•lemma and palea with very long awns.

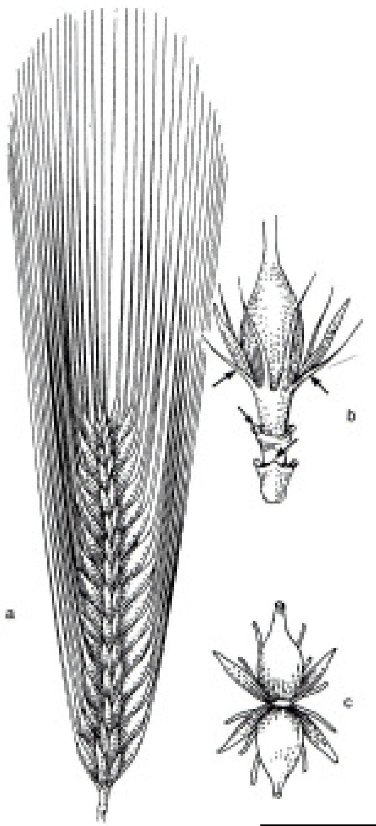
Taxonomy of the domestic forms (see also table at the beginning of part 2, for modern grouping see Zohary & Hopf 2000**):**
Two main criteria for separation:
•number ob fertile spikelets per rachis segment
•hulled or naked

Based on this on can distinguish between:
•**two-rowed barleys:** (Hordeum spontaneum and H. distichum L.) with only one fertile spikelet, the central one, per rachis segment; the 2 outer (=lateral) ones are sterile. There are naked and glumed (hulled) forms.
•**many-rowed barleys (also: 6-rowed)** (Hordeum vulgare L.) with 3 fertile spikelets per rachis segment. There are:
►**dense-eared forms** (the "classical" six-rowed forms, var. hexastichum)
►**lax-eared forms** (the so called 4-rowed barley, var. tetrastichum; in the literature also known as "lax-eared six-rowed")
Of both there are **hulled** and **naked** (var. nudum) forms.

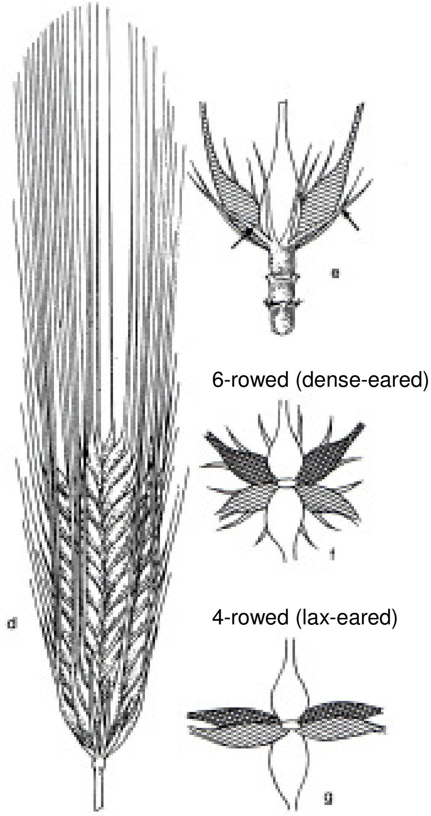
The genetic differences between the various forms are slight (see e.g. Salamini et al. 2002).

Further useful literature:
Charles 1984, Bouby 2001

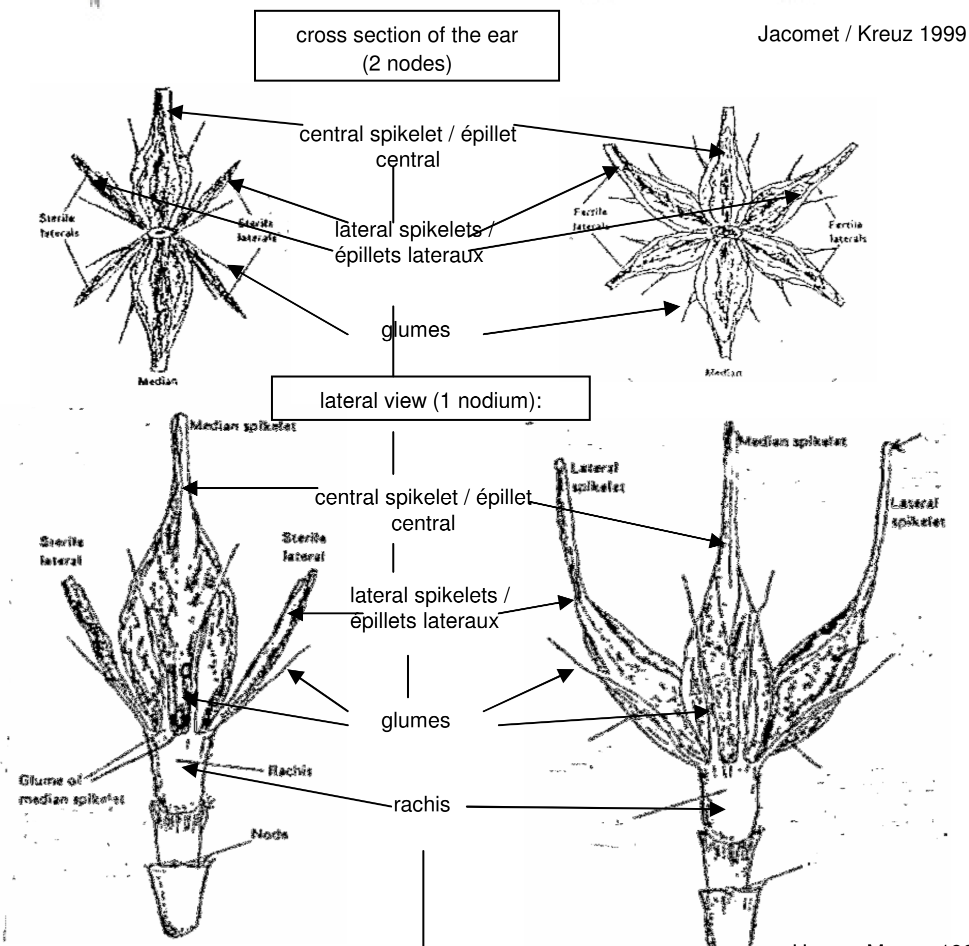
2-rowed



six-rowed (or: many-rowed)



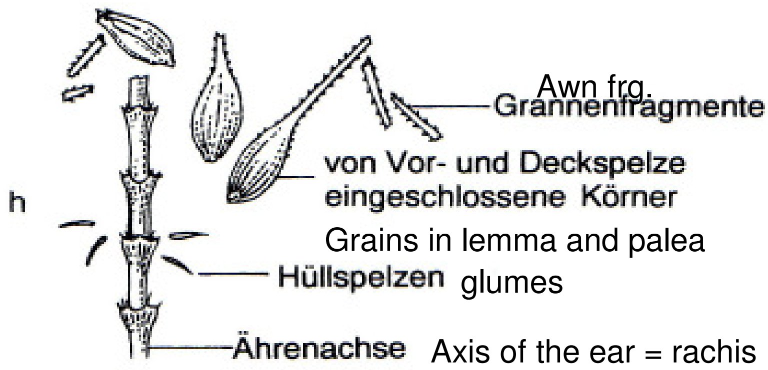
Jacomet / Kreuz 1999



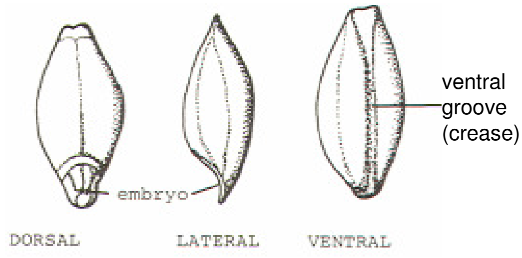
Hervey-Murray 1980

Barley (*Hordeum*): The finds and their main morphological criteria

after threshing / hulled form



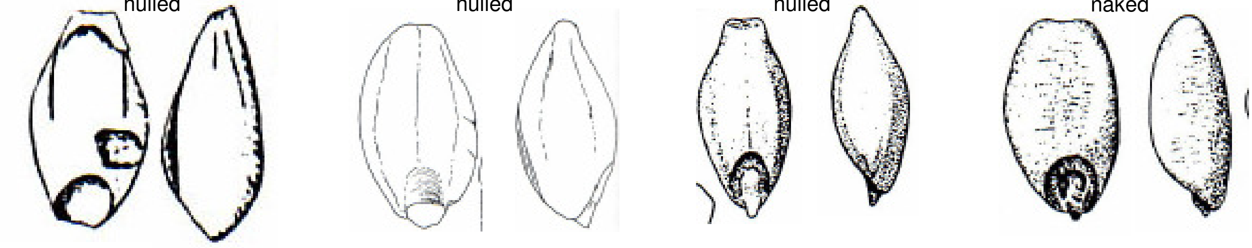
grain:
central 6-row or 2-row grain, husks removed



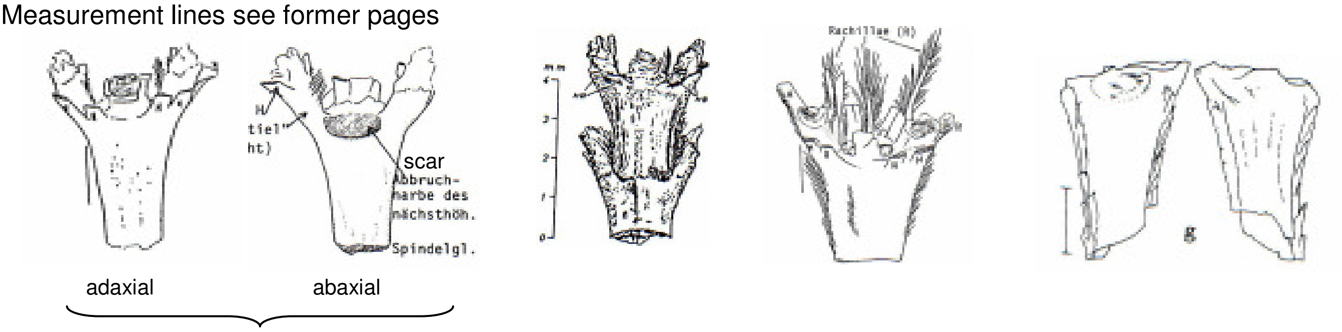
Charles 1984

Grains (and lemma):

- Shape seen from the dorsal or ventral side: spindle-shaped, more or less pointed / tapering at the top and bottom.
- Shape seen from the side (lateral view): spindle-shaped too, relatively flat. Highest part more or less in the middle. For differences to wheat see the figures on the next page
- in hulled barley the lemma (and palea) is closely attached to the grain, and its basis provides useful characters for the distinction of the forms (see next pages)
- Special characteristics: see under the various taxa, see next pages
- Measurement lines see former pages



Rachis segments:
Shape various (see the various taxa, next pages When preservation is good, the narrow glume attachments can be seen at the top (H on the 2 left figures below). From the front one can see 4 (the 2 of the middle floret and another (=the front) of the lateral florets), from the back 2 (the rearmost of the 2 lateral florets). In contrast to wheat the rachis is very straight (in lateral view; see comparison on the **next page**).
Measurement lines see former pages

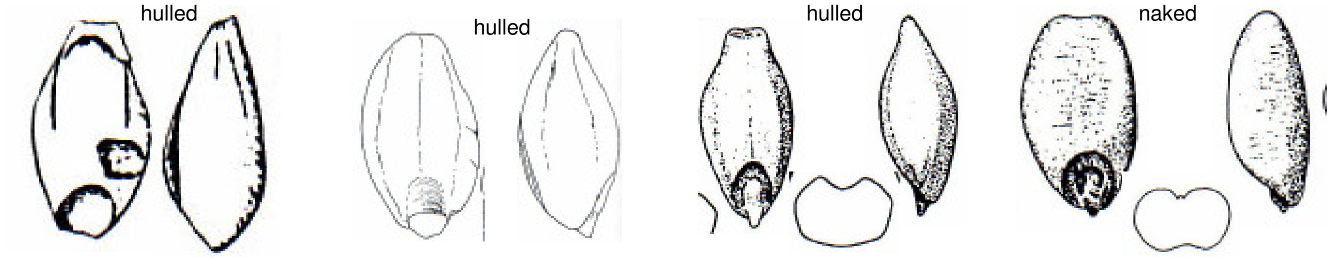


The identification of barley remains is difficult and particularly confusing for beginners because there are so many varieties. We shall deal with **two** levels of approach:
a) separation of two-rowed from multi-rowed forms (H. distichon from H. vulgare)
b) separation of multi-rowed forms from each other:
b1) lax-eared or dense-eared
b2) hulled or naked
The most important identification characters are summarised in the tables on the next pages

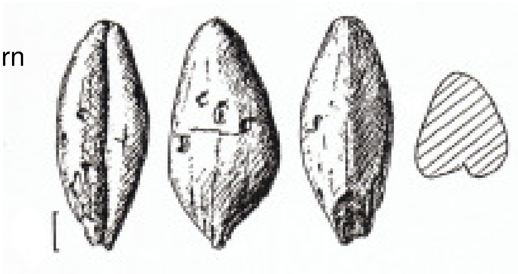
Barley- and wheat-remains: a comparison

grains

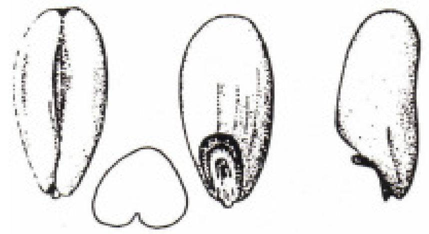
barley



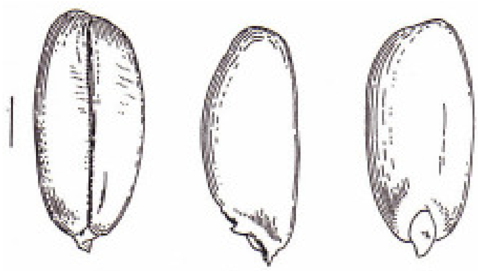
einkorn



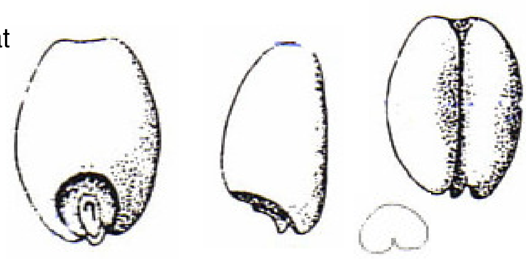
emmer



spelt

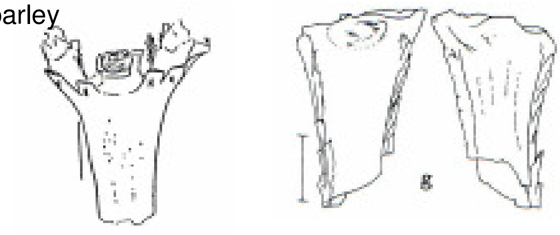


naked wheat

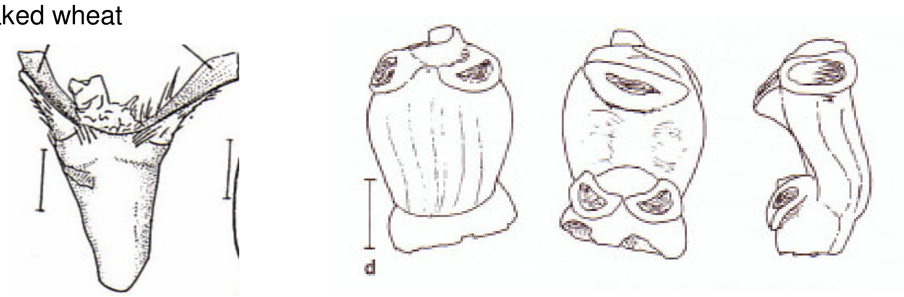


rachis remains

barley



naked wheat

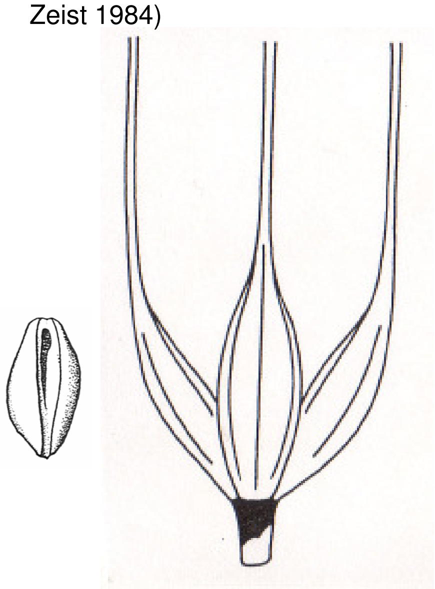


Barley: Differences between six-rowed and two-rowed barley

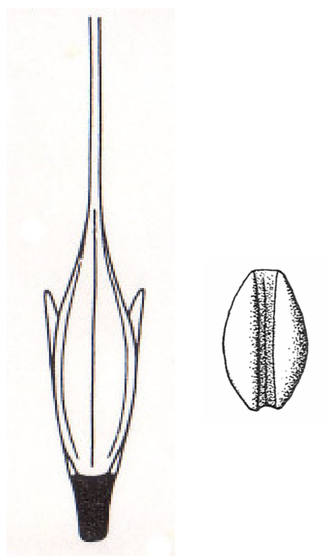
part	many-rowed barley	two-rowed barley
EARS	3 fertile spikelets per rachis segment	1 fertile spikelet per rachis segment = middle spikelet. Both side ones are stunted.
SPIKELETS depression in lemma base	Lax-eared forms (4-rowed): small fold. Dense-eared forms (6-rowed): horseshoe shaped.	horseshoe shaped
GRAINS	straight and twisted grains present (particularly in lax-eared forms). Proportion of twisted : straight grains theoretically 2:1. maximum width of grain: at centre	only straight grains present Maximum width of grain: somewhat below the centre of the grain
RACHIS SEGMENTS bases of the side florets	well-formed bases of the side florets	bases of the side florets somewhat stunted

These criteria can be used for charred material

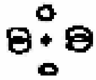
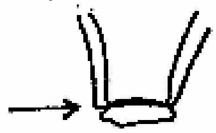
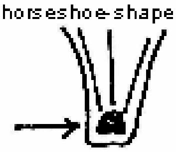
six-rowed (many-rowed) barley: asymmetrical grain from one of the lateral spikelets and the 3 fertile spikelets of one node of the rachis (Bouby 2001 and Van Zeist 1984)



Two-rowed barley: straight grain of the central spikelet and the one fertile and the 2 reduced spikelets of one node of the rachis (Bouby 2001 and Van Zeist 1984)



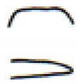
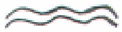
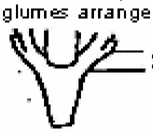
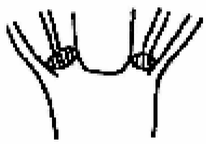
Differences between dense- and lax eared forms of six-rowed (multi-rowed) barley

part	dense-eared = 6-row	lax-eared = 4 row
EARS	spikelets arranged in threes (seen from above)  (seen from side) 	spikelets arranged in threes (seen from above)  (seen from side) 
SPIKELETS depression in the lemma base	slim, furrowed: intermediates! 	horseshoe-shaped 
GRAINS; shape	rounded = short and wide L/B index <1.8; there are intermediates!	slim-oval L/B index > 1.8
Twist	twisting of the side grains not clear	many twisters present in finds. Theoretical ratio twisted: straight 2:1 (2). Does not actually occur.
RACHIS SEGMENTS; shape:	wide in ratio to length; wide base (0.6-1.3mm) (3).	slim, sharply tapering at the base; narrow base (width 0.4-1.1 mm (3). Length/breadth (base) 3.4 to 2.9 (3). According to author's measurements of modern material: > 3 or scarcely less than 3.
length:	1.3-2.4 (1). Own observations on modern material: the variation across one ear is very great! The above counts are only for the middle part of the ear.	length 2.3-3.45 mm (1)
hairs on edges:	pronounced. according to (2) this character is irrelevant.	slightly hairy (4)
side spikelets on "stalks"	stalk very much reduced, hard to see	stalk clearly visible; high attachment points of the rear glumes of the side florets (see Table 4)

There are no "stalks" on the side spikelets of hulled barley!

Zusammenstellung aus Jacomet et al. 1989, nach 1 Villaret-von Rochow 1967, 2 van Zeist 1968, 3 Piening 1981, 4 Helbaek 1952 a und b, 5 Kroll 1975, 6 Körber-Grohne & Piening 1980

Criteria to disinguish naked and hulled forms of barley (six rowed forms)

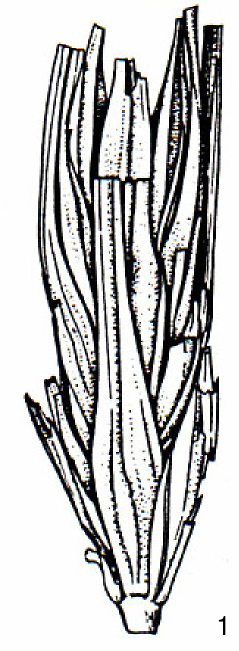
part	naked barley	hulled barley
SPIKELETS	RACHILLA absent	RACHILLA present
GRAINS		
end of grain	rounded or notched (seen from above) 	shape: (5,6) flat/straight seen from above. boat-shaped in side view. 
cross section	round 	flat-sided 
ventral furrow	wide 	shallow, v-shaped 
structure of outer layers	wavy cross-rippling 	smooth
attached lemma / palea remains	normally none; when present, without "hump" (7)	normally present; particularly palea remains on the ventral (lower) surface, lemma remains on the dorsal (upper) surface. "humps" obvious on the lemmas! (7)
According to the author's observations the presence or absence of the "humps" on the lemmas is a problematic character, for the formation of the hump changes with the degree of charring of the find. Besides, lemma remains can remain attached to grain also in the case of naked barleys (see text).		
RACHIS SEGMENTS glume bases attached to the rachis segments	parts of the lemmas and paleas present, rachilla still attached (somewhat higgledy-piggeldy appearance)	all glumes/lemmas/paleas broken off, with the exception of the lemma bases. Rachilla broken off ("clean appearance")
Problematic This character works in cases where an ear broke up in an uncharred state and the parts charred separately. When the ears and consequently their parts charred when joined together and only then broke up, this character can only be used with caution, as the author's charring experiments showed. Also, the separation of lax-eared forms is less difficult than for dense-eared types.		
"Stalks" of the side florets (real stalks in the sense of (3).	present 4-rowed (lax eared) forms: side florets clearly stalked, the rear glumes arranged thus:  6-rowed (dense-eared) forms: presence of stalk not clearly visible	absent 

Zusammengestellt nach Angaben aus der Literatur (Villaret- von Rochow 1967, van Zeist 1968, Piening 1981 und mündliche Mitteilung, Helbaek 1952A + B, Kroll 1987 und Körber-Grohne & Piening 1980) und eigenen Beobachtungen an Vergleichsmaterial.
Zusammenstellung: S. Jacomet.

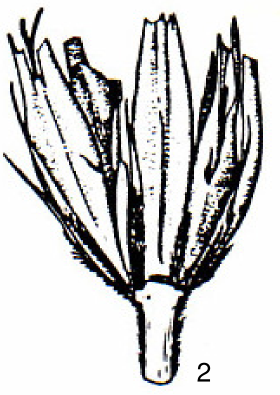
images of (pre)historical finds of of six-rowed barley (*Hordeum vulgare*): **naked**

ears, spikelets and rachis parts

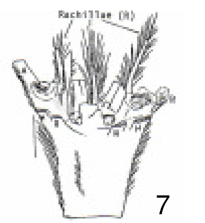
2, 3 and 5: lax-eared, with long internodes; 4, 6,7: dense-eared, with short internodes



1



2



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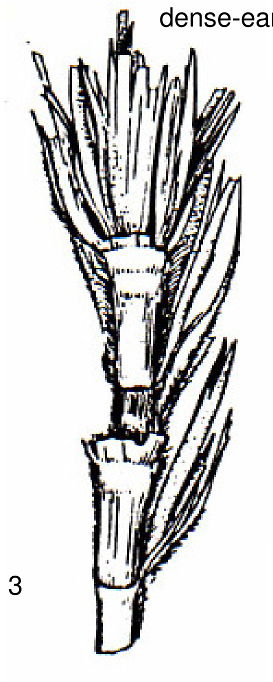

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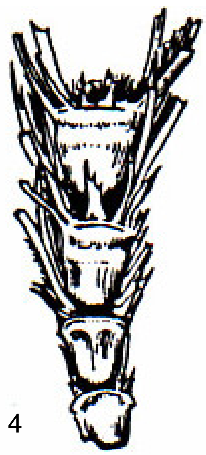
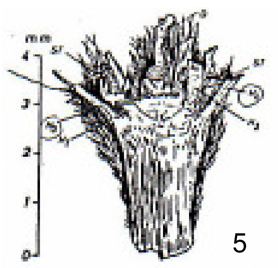


4

ear-base: short internodes!



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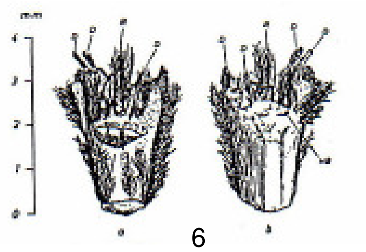
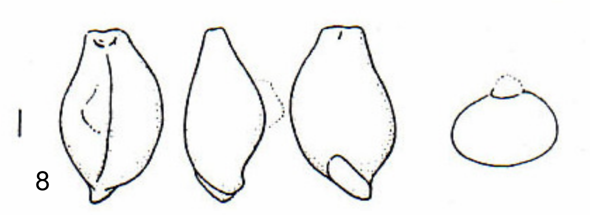


6

grains: mostly rather slender forms



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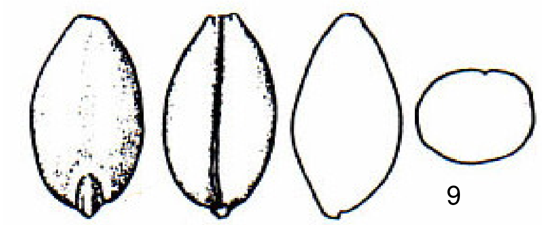
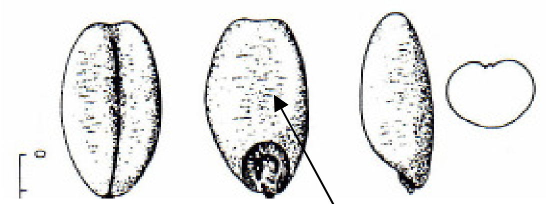
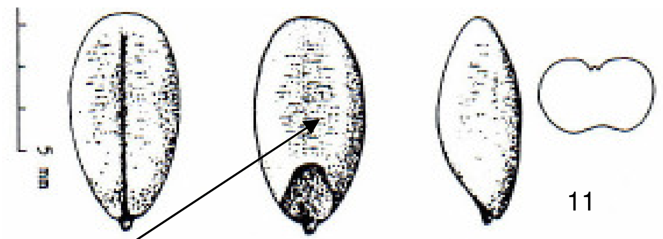


9

asymmetrical and diostorted (above) grains: lax-eared

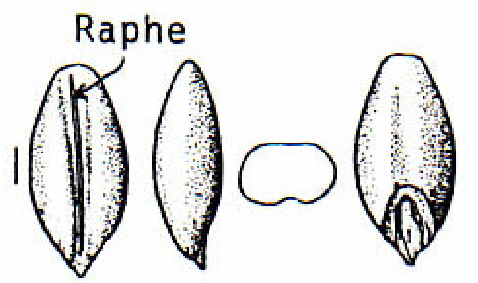


10

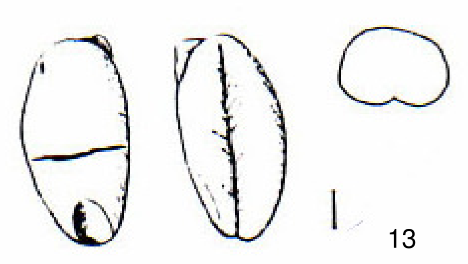


11

typical wrinkles on the grain-surface



12

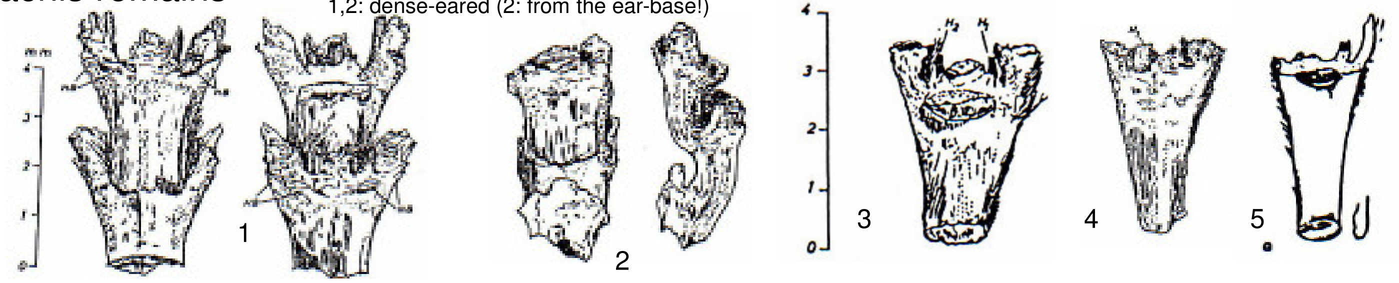


13

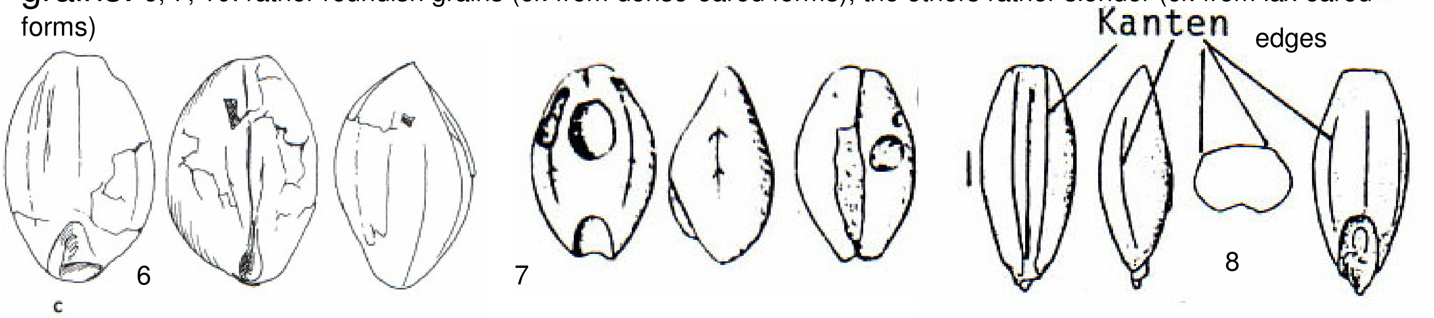
1-4,9: Ehrenstein (Neolithic, Germany, Hopf 1968); 5-6: Burgäschisee-Süd (Neolithic, Switzerland, Villaret-von Rochow 1967); 7-8: Zürich kleiner Hafner (Neolithic, Switzerland, Jacomet et al. 1989; 10-11: Archsum (Bronze Age, Northern Germany, Kroll 1975); 12: Valkenburg (Roman, Netherlands, Van Zeist 1968); 13: Augst (Switzerland, Roman, Jacomet et al. 1988).

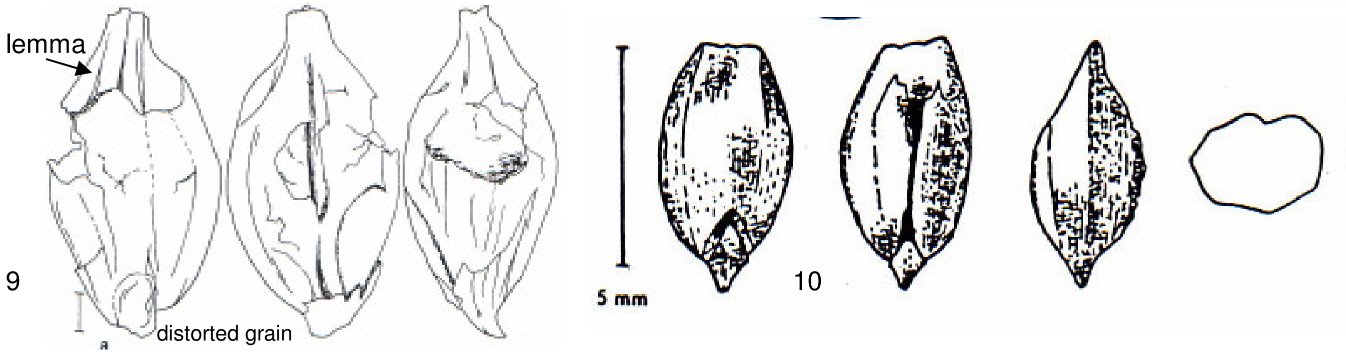
images of (pre)historical finds of of six-rowed barley (*Hordeum vulgare*): **hulled**

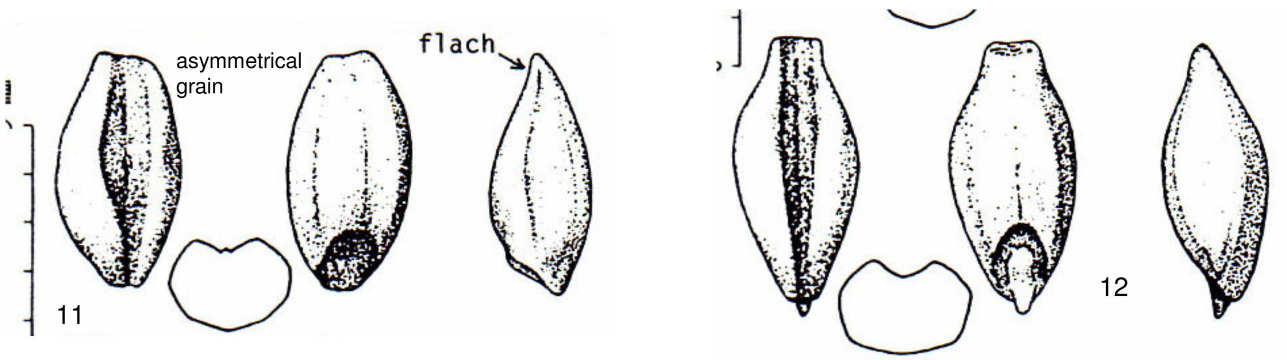
rachis remains

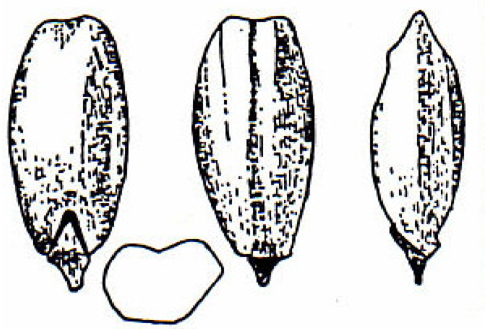


grains: 6, 7, 10: rather roundish grains (cf. from dense-eared forms), the others rather slender (cf. from lax eared forms)





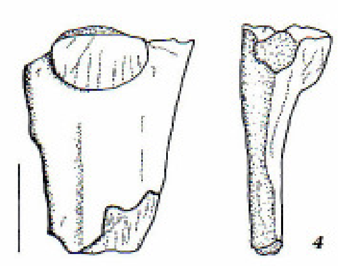


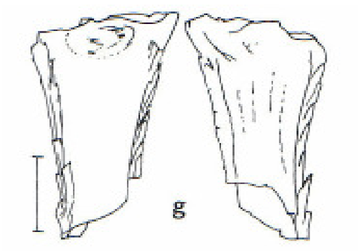


1-4: Burgäschisee-Süd (Neolithic, Switzerland, Villaret-von Rochow 1967); 5, 10 and 13: Feddersen Wierde (Iron Age, Northern Germany, Körber-Grohne 1967); 6, 9: Stillfired (Late Bronze Age, Austria; Kohler-Schneider 2001); 7: Augst (Switzerland, Roman, Jacomet et al. 1988); 8: Valkenburg (Roman, Netherlands, Van Zeist 1968); 11-12: Archsum (Bronze Age, Northern Germany, Kroll 1975)

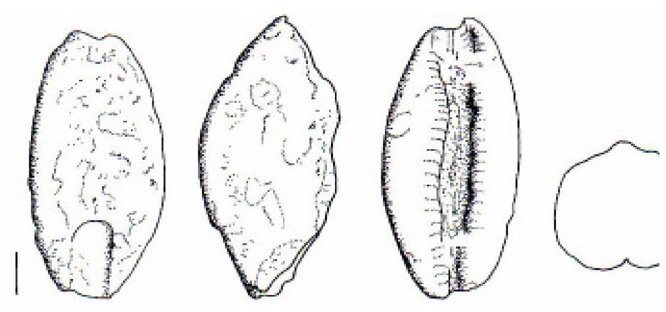
images of (pre)historical finds of of barley (*Hordeum vulgare/distichon*): **various**

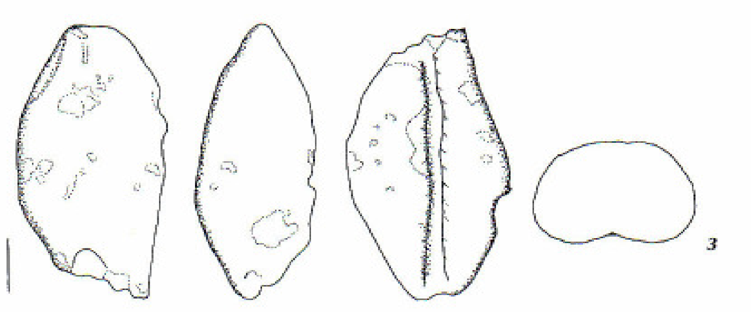
badly preserved rachis remains from dry sites, **not to decide which form** (left: Augst, Roman, Jacomet & Petrucci-Bavaud 2004, right: Stillfried, Late Bronze Age, Austria, Kohler-Schneider 2001)



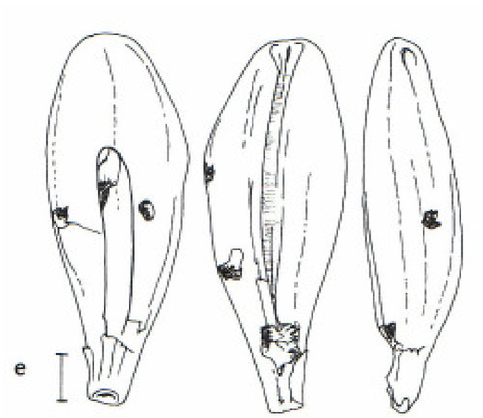


Badly preserved grains of barley from dry sites, **not to decide which form**! *(*Augst, Roman, Jacomet & Petrucci-Bavaud 2004)

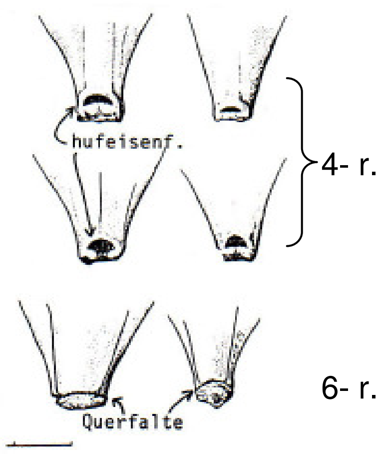




Sprouted barley-grain, slender, distorted (lax-eared, 4-rowed barley) (Stillfried, Late Bronze Age, Austria, Kohler-Schneider 2001)



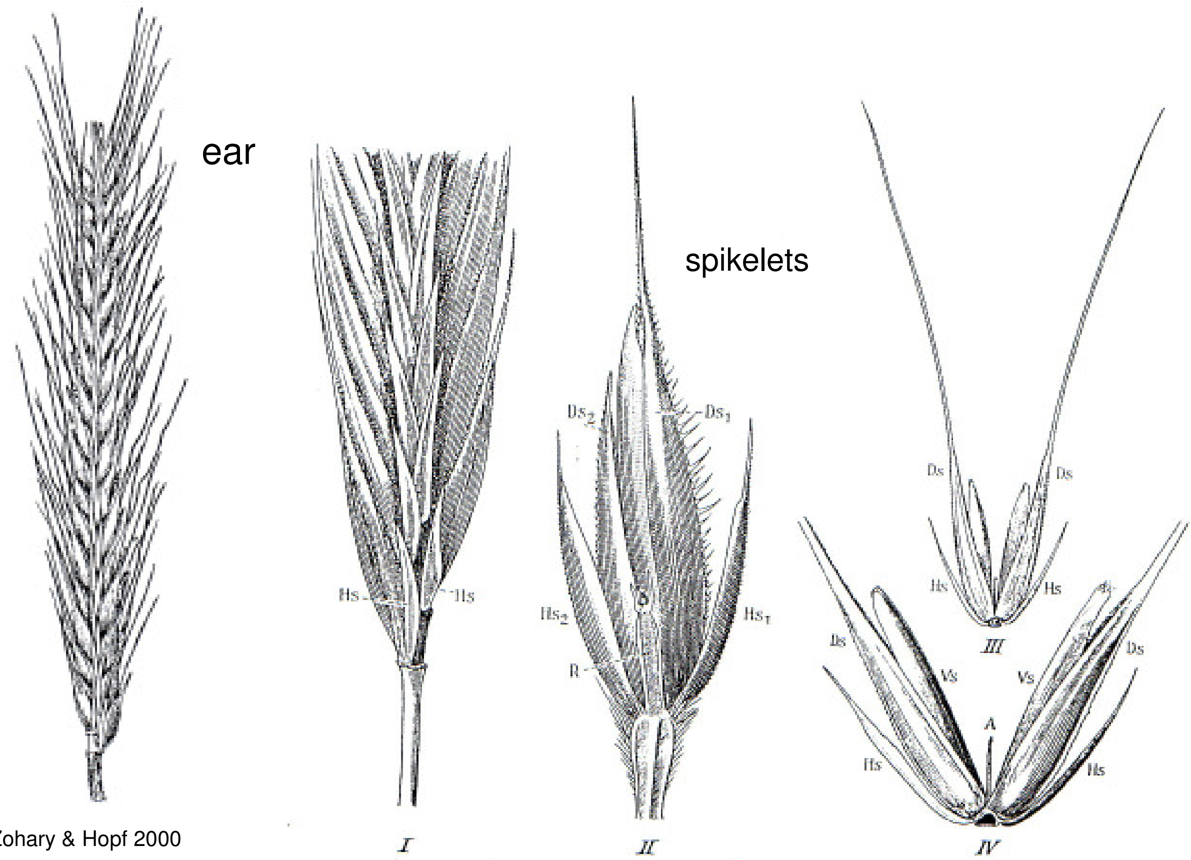
lemma bases:



Valkenburg (Roman, Netherlands, Van Zeist 1968)

for the identification of 2-rowed barley see Bouby 2001

Rye (Secale cereale L.)



Zohary & Hopf 2000

Secale cereale (from Troll, 1954,1957). **I lower part of the ear**; *Hs* glumes (narrow). **II apex of the ear** with rudiment of the rachis (R) und a fertile spikelet, *Hs1*, H*s2* glumes of the uppermost spikelet, *Ds1, Ds2* the lemmas of the uppermost spikelet (only 1 grain developed in Ds1). **III, IV spikelets in adaxial view**: *A* axis of the spikelet (rachilla); *Hs* glumes; *Vs* palaea's; *Ds* lemma's (both fertile). Rye spikelets have 2 fertile florets.

Identification of rye-grains

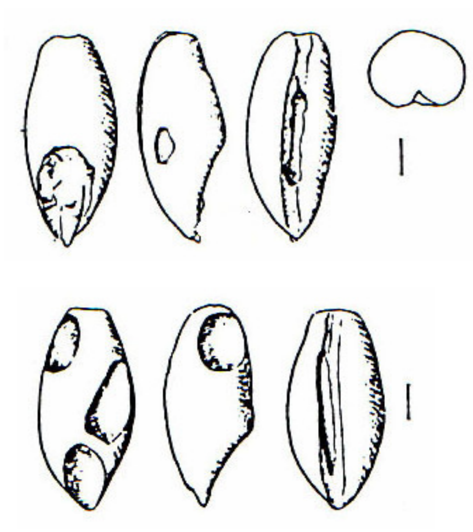
shape in dorsal view: oval, rather often with almost paerallel sides. Upper end truncate (to rounded). Lower (embryo) end strongly attenuated. Scutellum mostly very long.

Shape in lateral (side) view: Ventral face from rather convex to flat. Back evenly arched to rather flat. Upper end suddently truncated.

Transverse section: mostly rounded. Hilum fold deep, reaching the apex of the grain.

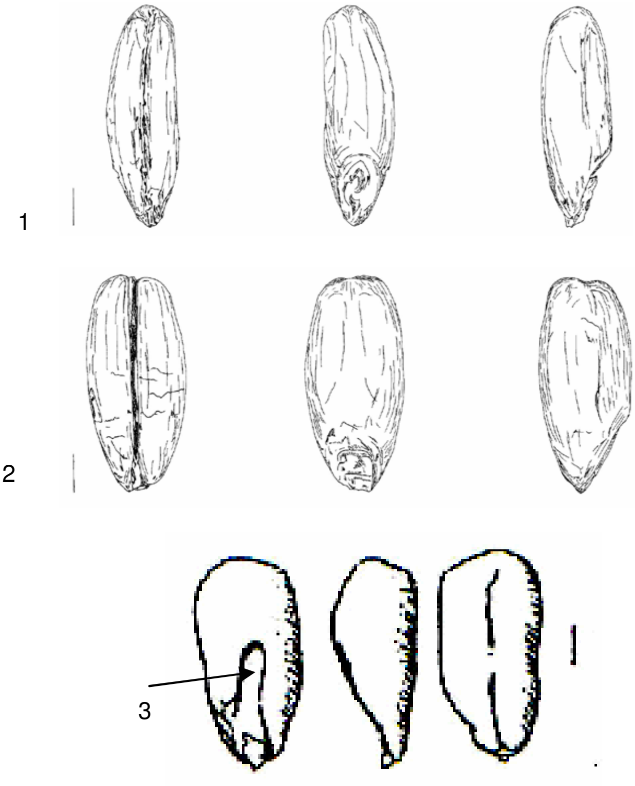
Rye grains are usually easy to distinguish from wheat and barley grains by the truncated apex and the long scutellum.

Rye is a naked cereal, therefore the glumes don't leave a trace on the grain surface which is usually smooth and shiny.



two rye grains from Roman Augusta Raurica, Switzerland (Jacomet et al. 1988)

rye (Secale cereale): archaeological finds and identification criteria of the rachis remains)



rye grains: 1,2: from medieval Basel-Rosshof, Switzerland (Kühn 1996). 3: from Roman Augusta Raurica, Switzerland (Jacomet et al. 1988). 3: sprouted (arrow)

measurements and indices of rye grains from Roman Augusta Raurica (37 grains):

L: 5,1 mm (3,9-6,0 mm)

B: 2,4 mm (2,0-2,9 mm)

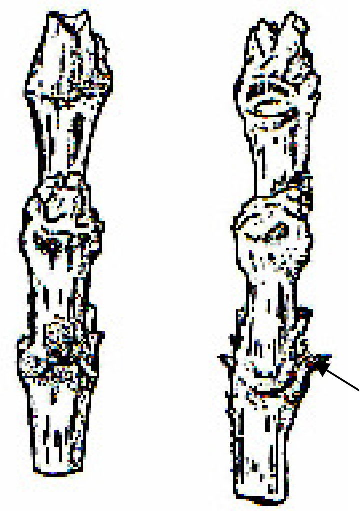
H: 2,2 mm (1,6-2,7 mm)

L/B: 2,14 (1,54-2,48)

L/H: 2,41 (1,62-3,56)

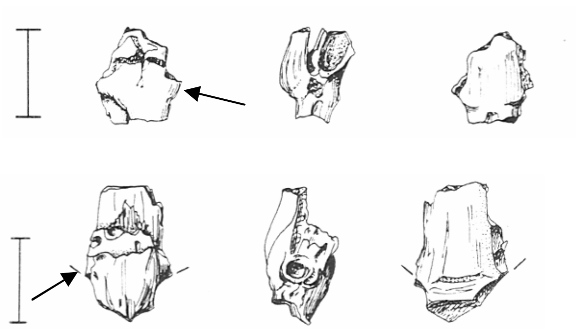
B/H: 1,13 (0,84-1,5)

Rachis remains of rye



Dorestad NL (Van Zeist 1968)

Basel-Rosshof, medieval (Kühn 1996)

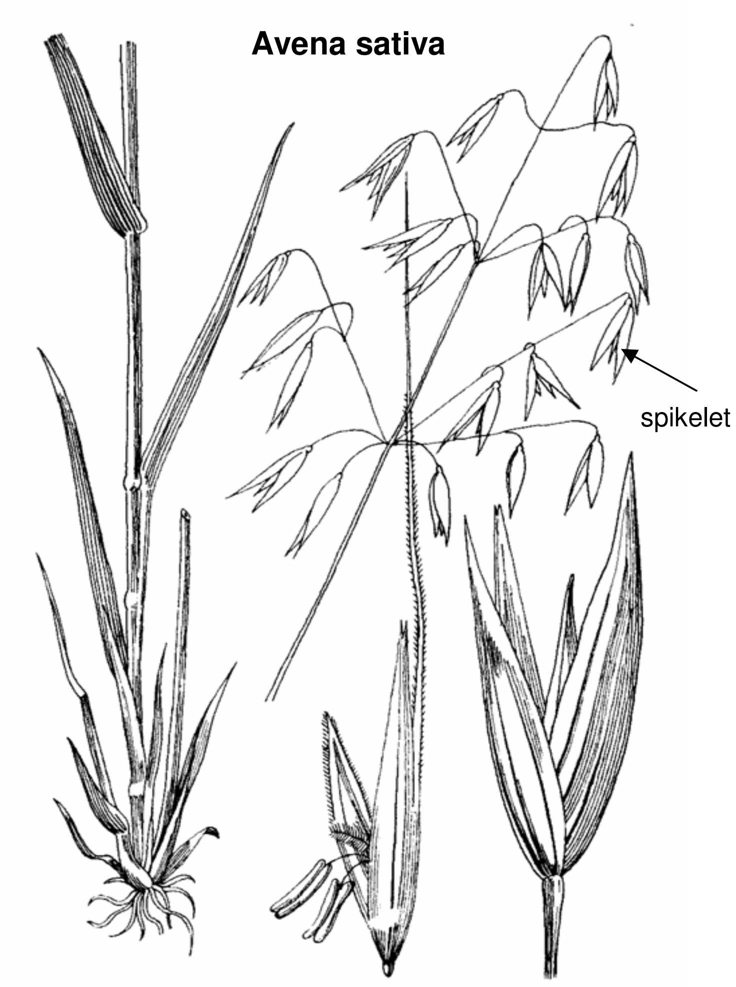


Basel, Reischacherhof, early Medieval (Jacomet & Blöchliger 1994)

→ glume bases

Identification critieria: sides straight. The bases of the narrow glumes are visible at the side in the region of the node.

Oat (Avena species)



In contrast to wheat, barley and rye, oat has its spikelets in **panicles**.

In European archaeological contexts usually 4 different Avena-species may be present:

Avena sativa, the domestic oeat

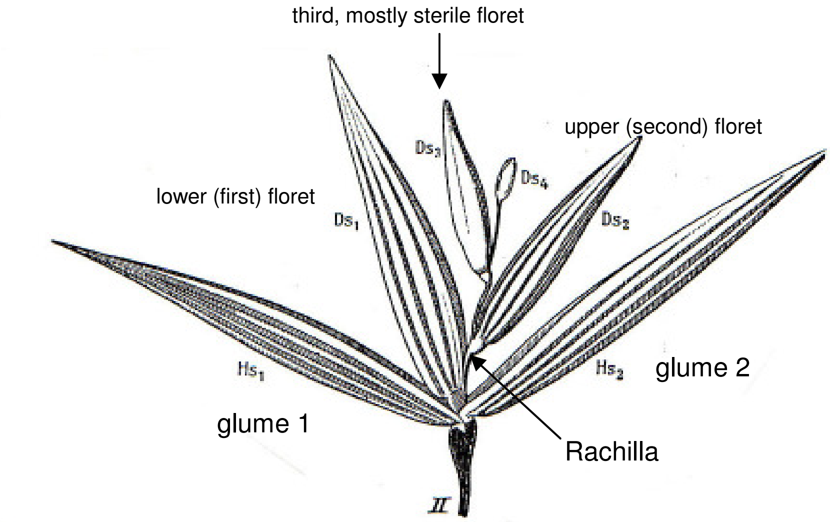
Avena strigosa, weedy and cultivated

Avena fatua, a weed

Avena sterilis, a weed

They are not easy to distinguish in the archaeobotanical record. For the grains, this is rather impossible. If good preserved parts of the florets (esp. the lemma and parts of the rachilla) are present, it may be possible.

spikelet



the spikelets of A. sativa have usually two fertile florets (ev. 3)

Ds1 = lemma of the first floret (the first grain)

Ds 2 = lemma of the second floret (the second grain)

from Troll 1954/1957

Oat (Avena L.): Identification criteria

(after Pasternak 1991 an there cited literature as well as Ruas & Pradat 2001)

Morphological feature / plant part	Avena sativa	Avena strigosa	Avena fatua
surface of the lemma	smooth, without hairs	smooth, at the basis and the rachilla occasionally a bit hairy	rough (grob gekörnelt), densely hairy. Base of the lemma and Rachilla with dense and rough hairs
awns on the lemma	lemma of the first floret occasionally with awn, lemma of the second floret without awn.	all lemma‘s with awn	all lemma‘s with awn
Disarticulation scar of the first floret	broad, close to the lemma-base	narrow, often tapering (attenuate), in some distance of the lemma-base	olique, horsehoe-shaped, with bulge at the edge
Disarticulation scar of the second floret	narrow, close to the lemma-base	see first floret	see first floret
Rachilla (spikelet axe)	That of the first floret broad and short, that of the second floret long and thin (fine)	That of the first floret narrow, at the upper end a bit broadened and often „gekniet“. That of the second floret is always very thin.	thin
Size of the grains	First grains large, second grains smaller (like A. strigosa). Max. heigt in the center.	Smaller than the first grains of A. sativa, equal size than the second grains of A. sativa	Similar to those of the other species. Rather very slender. Apex a bit attenuated, max. height below the center.

Identification key for hulled oat-grains

(Text and figures from Pasternak 1991: Schleswig, Germany, Medieval).

1 lemma without awn

2 Rachilla broad and short, disarticulation scar broad and near to the lemma-base: *Avena sativa,* 1. grain without awn

2* Rachilla long and thin, disarticulation scar narrow and near to the lemma-base : *Avena sativa,* 2. grain

1* lemma with awn

3 Rachilla broad and long, with bristle hairs and horseshoe-shaped at the end, disarticulation scar horseshoe-shaped, too: *Avena fatua,* 1.-3. grain

3* disarticulation scar not horseshoe-shaped

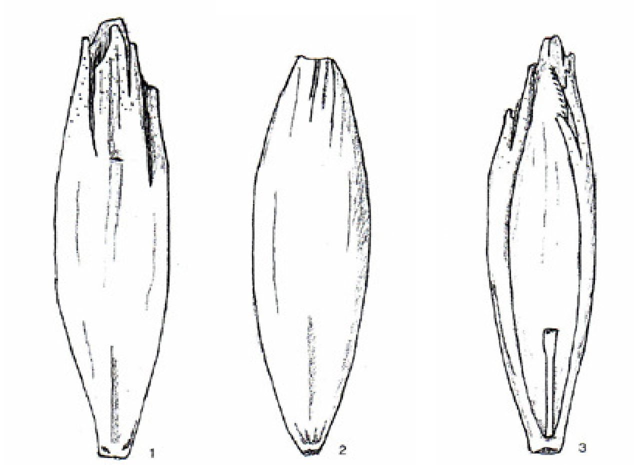
4 Rachilla broad and short, disarticulation scar broad and near to the lemma-base: *Avena sativa,* 1. grain, with awn

4* Rachilla long and narrow, disarticulation scar narrow, in some distance of the lemma-base

5 Rachilla narrow, at the upper end broadened, often gekniet, and occasionally somewhat hairy: *Avena strigosa,* 1. grain

5* Rachilla very thin (like a filament): *Avena strigosa,* 2. grain

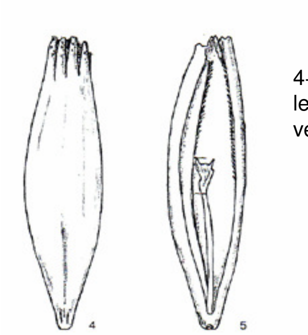
Difference of *Avena sterilis* from the other mentioned species: the first grain is formed like in *Avena fatua*. The disarticulation scar however is longish-oval and not horseshoe-shaped. Te second grain of *Avena sterilis* is very similar to the second grain of *Avena strigosa,* and when an awn is lacking also to that of *Avena sativa*. It is not possible to distinguish it surely from the latter species. The glumes are plus/minus hairy.



1 A. sativa: 1. grain, with awn at the dorsal side

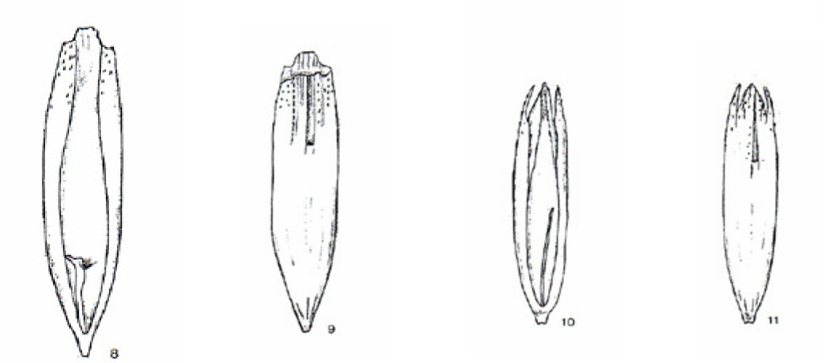
2 A. sativa: 1. grain, dorsal side without awn

3 A. sativa: 1. grain, ventral side



4+5: A. sativa: 2. grain: left: dorsal side, right: ventral side

8-11: A. strigosa



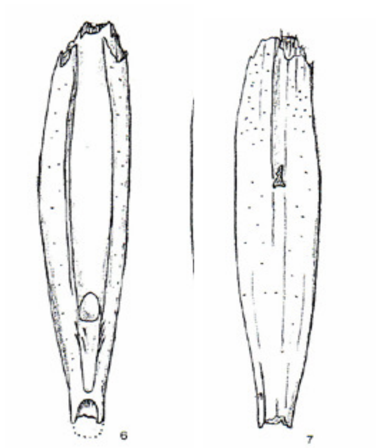
1. grein, ventral side

1. grain, dorsal side

2. grain: ventral side

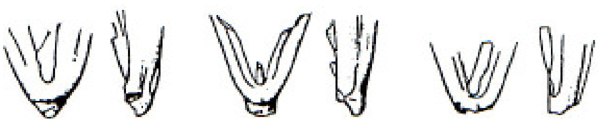
2. grain, dorsal side

6-7: A. fatua

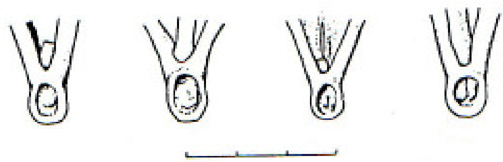


6: ventral; 7: dorsal side

floret-bases of Avena sativa



and Avena fatua



Valkenburg und Dorestad NL, Roman (Van Zeist 1968)

oat (Avena L.): **flower base morphology**: examples from a medieval site in France compared with modern specimen (from Ruas & Pradat 2001)

FIG. 54

Lemmes actuelles d'*Avena sativa* vues en face ventrales : **a** premier fleuron ; **b** deuxième fleuron.

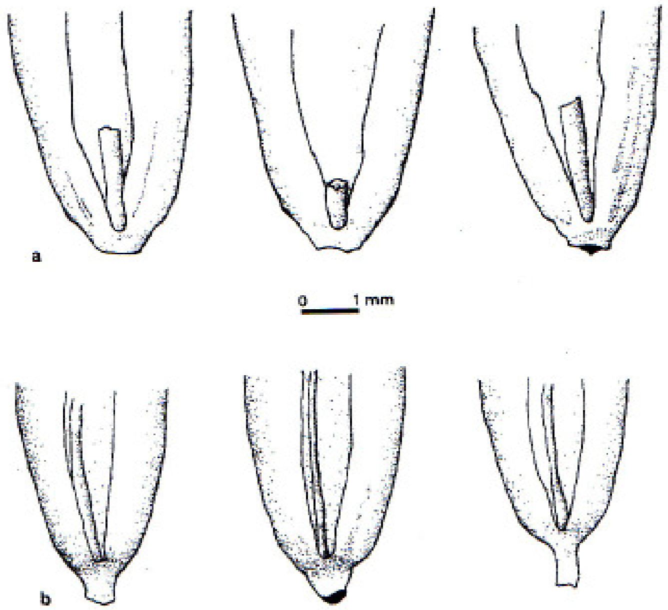
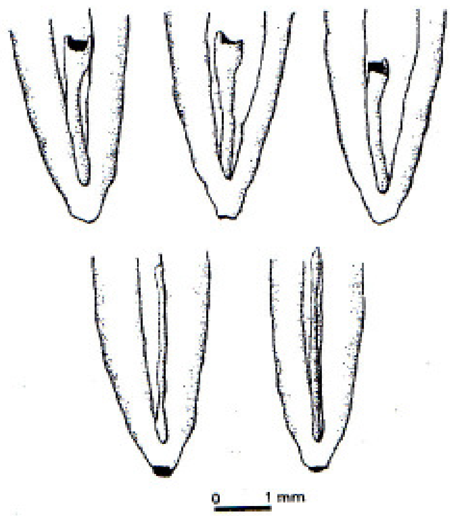


FIG. 55

Lemmes actuelles d'*Avena strigosa* (face ventrale).



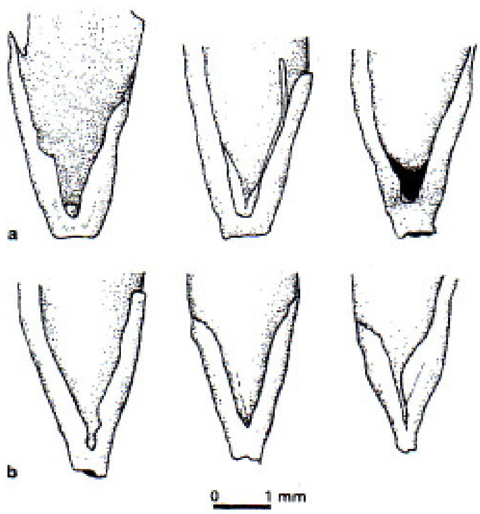


FIG. 56

Lemmes carbonisées d'avoines : **a** *Avena sativa*, site de Gaudines (IXe-Xe s.) ; **b** *Avena strigosa*, site de Péran (Xe s.).

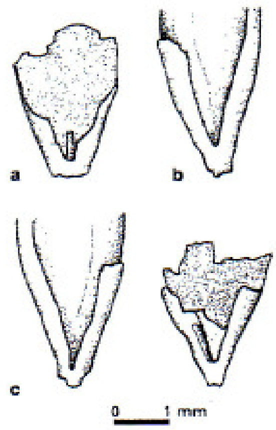
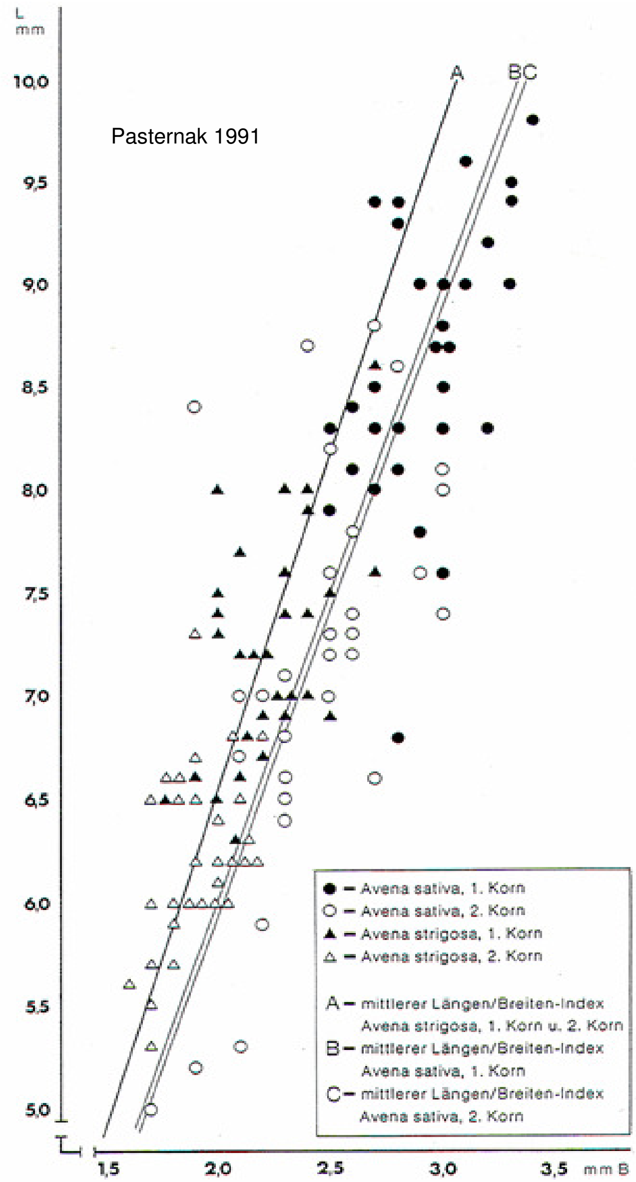


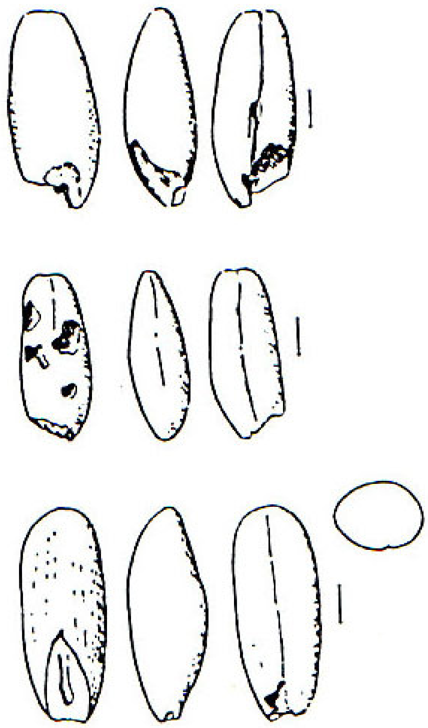
FIG. 57

Le Teilleul. Lemmes carbonisées d'avoines extraites de la fosse 2209 : **a** *Avena sativa* ; **b** *Avena sativa/strigosa* ; **c** *Avena strigosa*.

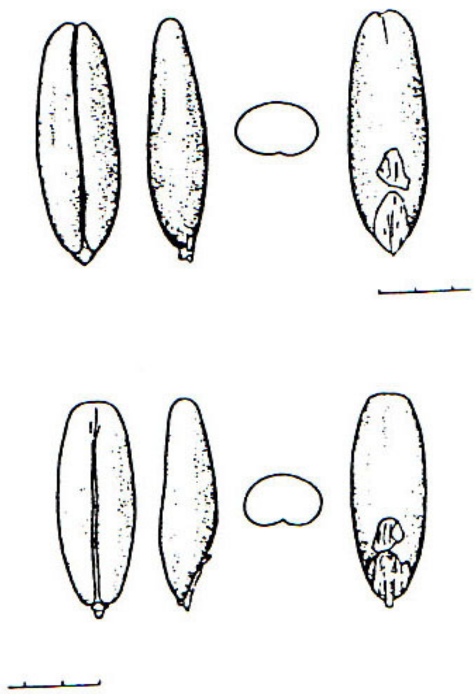
oat (Avena L.): **Grain morphology and sizes**



oat grains from Augst (Roman, Switzerland, Jacomet et al. 1988)



oat grains from Dorestad (Roman, Netherlands, Van Zeist 1968)



Dorsal view: Oat-grains are slender, the widest point is in the middle (esp. in A. sativa; in A. fatua also in the lower half). Sides maybe straight or slightly curved. Scutellum is rather long. Apex is rounded.

In lateral view the grains are rather flat, both sides are evenly arched and slightly convex. Apex rounded.

Zu den **Messwerten**: es wurden bespelzte Haferkörner gemessen. Die Körner wurden von Spelzbasis bis Kornende gemessen. *Avena sativa* hat im Mittel die größeren Körner, es wird allerdings deutlich, daß die ersten Körner von *Avena strigosa* und die zweiten Körner von *Avena sativa* in denselben Größenbereich fallen. Daraus folgt, daß eine Trennung der beiden Arten in entspelztem Zustand mit ausschließlich metrischen Methoden nicht möglich ist. Zwar hat *Avena strigosa* geringfügig schmalere und deutlich kleinere Körner, die große Streuung der Maße von *Avena sativa* verhindert jedoch eine Trennung der beiden Arten.

Millets

In the millets, the spikelets contain 1 floret. The inflorescences are panicles (in Setaria italica with very short branches!)

Broomcorn millet
Panicum miliaceum

Part of the panicle with spikelets

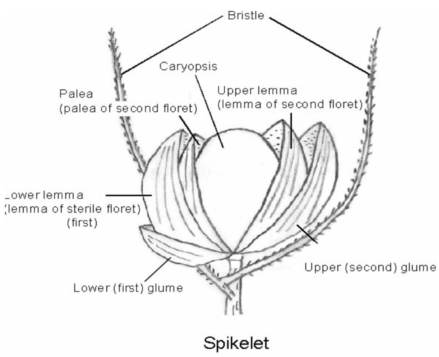
floret

Zohary&Hopf 2000

Italian millet
Setaria italica

Part of the panicle with spikelets

Spikelet of Setaria italica



Nasu et al., in press (Vegetation History and Archaeobotany)

A spikelet in the millets consists of 1 sterile and 1 fertile floret. The lemma of sterile floret (lower lemma) ist still visible, the palea of the first floret is atrophied to very small and scarious organ and sometimes lost. The lemma and palea of the second floret are well developed and enclose the grain cloesely.

Millets

Broomcorn millet: *Panicum miliaceum* L., Italian millet: *Setaria italica* (L.) P.B.

In the following literature characteristics of the domestic millet species can be found: NETOLITZKY 1914, KROLL 1983, KÖRBER-GROHNE 1967, KNÖRZER 1971 und WASYLIKOWA 1978 (see also Nasu et al., in press). The most important identification criterie are:

• **The surface structure of the lemma and palea**:

Panicum miliaceum: surface smooth, with some longitudinal stripes. Cells longish-rectangular.

Setaria italica: surface with papillae.

• **The shape and size of the grains**: KROLL 1983

P. miliaceum: oval; in carbonised state 1.3-2.2 mm long;.

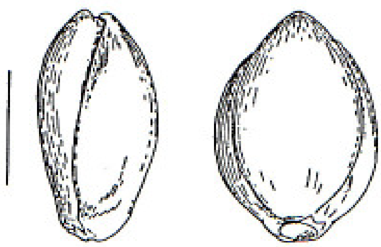
S. italica: roundish; in carbonised state 1.1-1.7 mm long

• **The shape of the scutellum** (embryo-cavity) in **naked grains**:

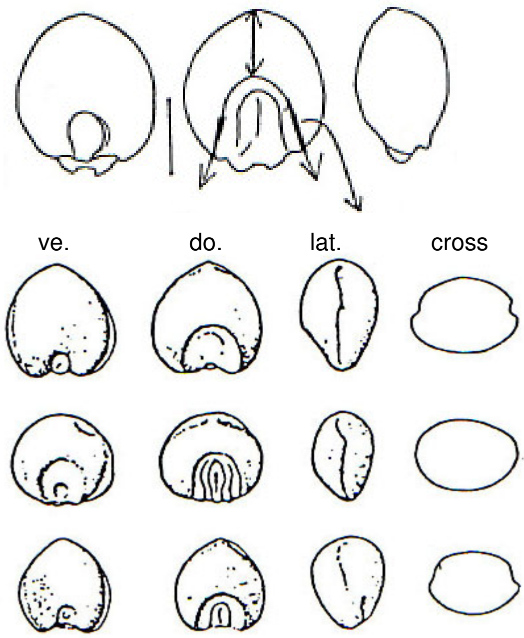
Panicum miliaceum: very broad scutelleum with divergent edges versus the base. Reaches in maximum the half of the grain length. (In *Echinochloa* = *Panicum crus-galli*: scutellum a bit narrower than in P. miliaceum and reaching 2/3 of the grain length. Edges plus minus parallely).

Setaria italica: Scutellum narrow, reaching min. 2/3 of the grain length, edges parallely.

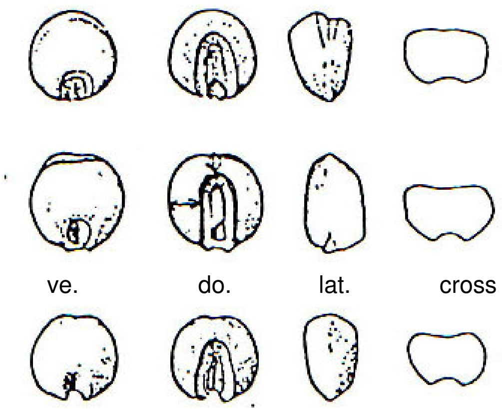
Panicum miliaceum: grain with lemma and palea: Bronze Age, Zürich-Mozartstrasse, Switzerland (Jacomet et al. 1989)



Naked grains of *Panicum miliaceum* (from several sites)



Naked grains of *Setaria italica* (from several sites)



Carbonised grains of broomcorn millet from Late Bronze Age Stillfried (Austria, Kohler-Schneider 2001)

A-h: Rispenhirse *(Panicum miliaceum),* **a-g:** Körner von ventral, dorsal und lateral; **a,b,c,h:** Körner mit Spelzenresten (Kohler-Schneider 2001).

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