Variables used in the *Chelonus* key

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Content

Introduction

In order to create a multi-entry key for determining *Chelonus* species the first step is to identify the variables that can separate the species. Useful variables have to apply to the following conditions:

- A wide range of values for the different species, while the range of values within a species is small
- Data are available for many species. This can be in the form of a published description or figure, complemented with own observations of specimens
- The variable must be relatively easy to estimate, preferably without measuring.

The variables are divided into three categories: morphological characters, surface sculpture and colour.

Morphological variables

Data on morphology of Chelonus species have been collected from keys and species descriptions in all available literature, and additional measurements where made on the figures in these articles. The purpose of this is not only to find the characters which can be used as variables but also to collect data for these species for use in this key.

Useful variables have to apply to the following conditions:

1. Data for this variable must be available for many species. This can be in the form of a description or a figure which can be measured.
2. The variable must be relatively easy to estimate, preferably without measuring. Variables where a small change in viewpoint affects the outcome are unreliable and therefore unwanted.
3. A useful variable has a wide range of values for the different species, while the range of values within a species is small.

The measurements which are based on the published figures are based on the assumption that these figures are realistic reproductions of the species (why else add the figures to the description?). Some figures however seem more like draft sketches where even the left and right side of a symmetrical figure are quite different. It is unavoidable that these measurements contain errors. Also the measurements given in the species descriptions or in keys can contain errors. These can be the result of:

1. An error in measurement (precision). In many descriptions integer values for small numbers (twice, three times,…) are very frequent and suggest estimated values. The error range for ‘twice’ (and not 2.0) should be from 1.5 to 2.5, which would make these values practically useless. For practical use I assume an error of 10% (so ‘twice’ = 1.8 - 2.2)

2. A difference in viewpoint. A small change in viewpoint may significantly affect the measurement values, especially if the object is rounded and there are no elements to align the view with.

3. Unknown measurement methods. Some parts can be measured is different ways, for instance according to Belokobylskij & Tobias (1998), or according to van Achterberg (1988). To be meaningful It must be clear which method is used. The viewpoint used is also important: often it is not stated whether a lateral or frontal viewpoint (or in between?) is used when measuring eye height and width.

To reduce all these possible errors most of the variables are divided into a few broad categories.

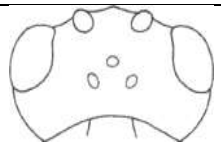
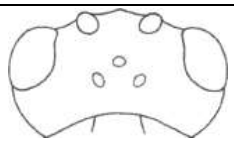
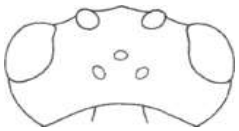
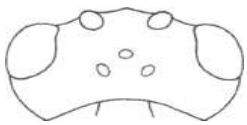
Body length

A main character which is mentioned for almost all species is body length. While the variability can be quite large within a species, there is still a large difference between small, medium and large species. Because the body length can be easily and exactly measured there is no need to divide body length into categories.

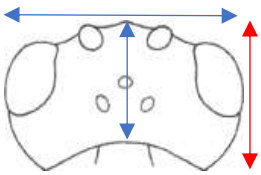
Head dorsal view

The measurements of the head in dorsal view are complicated by the fact that the head is not flat dorsally, so the point of view has an impact on the measurements, especially those in longitudinal direction such as temple and eye length, ocellar triangle length, and depth of excavation at back of head.

Head width : length (maximum width and length)

1	2	3	4
very narrow <=1.6	narrow 1.6 - 1.8	wide 1.8 - 2.0	very wide > 2.0
			

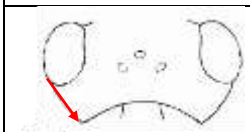
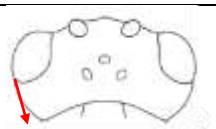
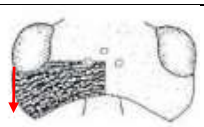
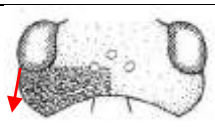
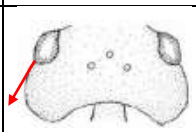
Belokobylskij & Tobias (1998) define the head length as the distance to the mid of the posterior excavation (blue arrow). This makes the width : length ratio dependent on the measure of excavation, which appears to be measured differently by different authors. The ratio of head width : maximum head length (red arrow) seems to be more stable.



The measurements given in the species descriptions are often larger than the measurements based on the figures (using maximum head length). Most of the time it is not stated which measure is used, but the measures are closest to maximum head length. In a description the width is very often 'twice' the length, which is probably a rough estimation. The average width : length ratio based on the figures is 1.78.

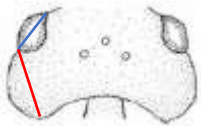
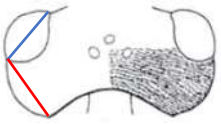
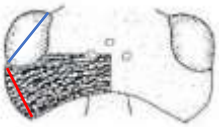
Temples narrowing - widening behind eyes

This variable is often mentioned, and can be expressed as the angle that the temples make behind the eyes. This leads to the following categories:

1	2	3	4	5
strongly narrowing	narrowing	parallel temple not widening	widening w temple >= w eye	strongly w temple >> w eye
				
C. annulatus (P7)	*C. annulipes (P1)*	*C. caradrinae (P7)*	*C. brachyurus (P2)*	*C. pedator (P6)*

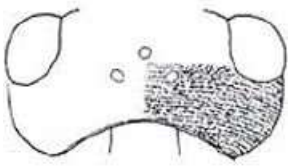
Eye length : temple length (method B&T)

There are different ratios used to describe the relative size of eye and temple. The ratio of eye length and temple length according to the method of Belokobylskij & Tobias (1998) appears to be the easiest to use and is probably also used the most in the literature. The categories are:

1	2	3	4
very short	short	long	very long
<=0.75	0.75 - 1.0	1.0 - 1.25	> 1.25
			
C. 4redator (P6)	*C. flavipalpis (P3)*	*C. caradrinae (P7)*	*C. canescens (P1)*

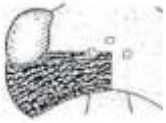
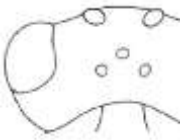
Temple length : transverse eye diameter (method B&T)

This ratio is often used in descriptions, but in the figures there is a large variation between authors. In addition to a difference in viewpoint, the eyes are often narrower in Tobias's figures. The average TL : EW ratio is 2.66 for all figures by Tobias et al., and 1.5 for figures by Papp. Therefore this variable is not used.

	
C. risorius (Papp)	*C. risorius (Tobias & Lozan)*
1.58	1.93

Roundness temple

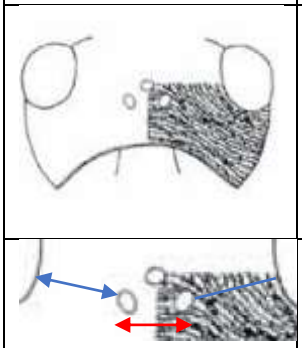
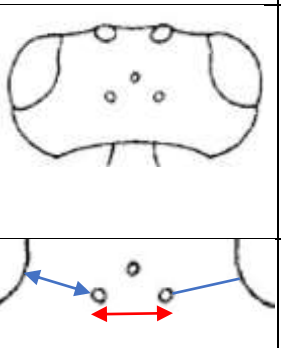
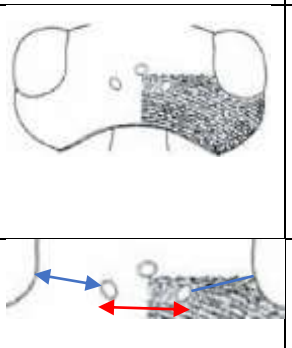
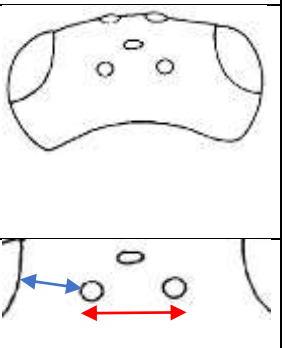
The temple can be rounded or relatively straight. The roundness of the temple is strongly correlated with contracted or widened temples, and also somewhat with the eye length : temple length ratio. The roundness is unrelated to the head width : length ratio.

1	2	3	4	5
very strong	strong	medium	weak	very weak
				
C. 4redator (P6)	*C. flavipalpis (P3)*	*C. caradrinae (P7)*	*C. canescens (P1)*	*C. annulatus (P7)*

Ocelli

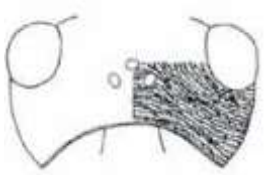
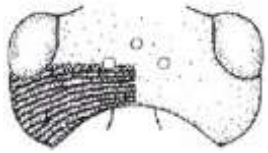
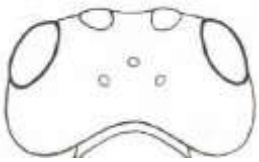
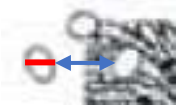
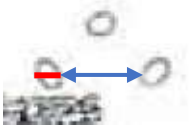
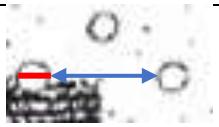
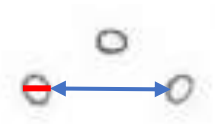
Although there seems to be a difference between Papp and Tobias in how the distances between ocelli and between ocelli and eyes are measured, the differences between species are large, making these potentially useful characters. These variables that can be easily measured and are not much affected by the point of view.

OTW : OOL (ocellar triangle width : distance between ocelli and eye)

1	2	3	4
very short	short	long	very long
<= 1.0	1.0 - 1.3	1.3 - 1.6	> 1.6
			
C. erosus (P3)	*C. longiventris (P4)*	*C. scabrosus (P3)*	*C. larsi (T1)*

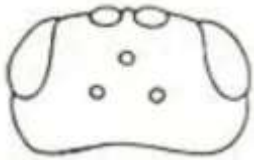
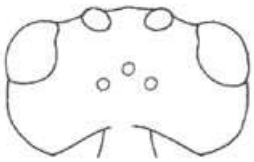
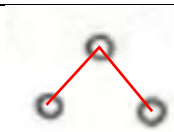
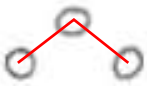
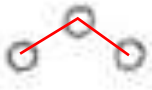
POL : OD (distance between hind ocelli : hind ocellus diameter).

The ratios involving the diameter of the ocellus are problematic as the small size of the ocelli results in a relatively large measurement error. In spite of this, the ratio POL :OD seems to be fairly constant within species (for which there are multiple figures).

1	2	3	4
POL:OD <= 2	2 - 3	3 - 4	> 4
			
			
C. erosus (P3)	*C. elongatus (P7)*	*C. humilis (P2)*	*C. parcicornis (P15)*

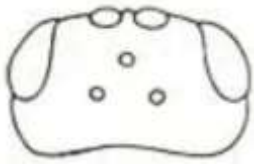
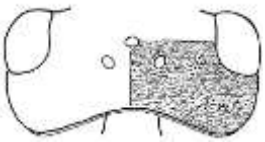
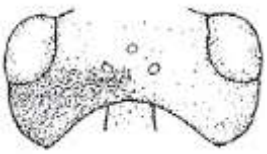
Ocellar triangle shape (ocellar triangle width : length / angle between ocelli)

As can be expected there is a very strong correlation between ocellar triangle width : length ratio and the angle between ocelli. These characters can therefore be combined. Tobias gives higher values than Papp for both W:L and angle, suggesting that his viewpoint is more posterior than Papp's. However, the differences between species are larger than these observer variations.

1	2	3	4
W:L <= 1.8 <= 95°	1.8 - 2.1 90° - 110°	2.1 - 2.4 100° - 120°	> 2.4 > 110°
			
			
C. pappi (T22)	C. canescens (P1)	C. latrunculus (P1)	C. dolosus (T17)

Excavation of head

The figures of *Chelonus* display a large variation in the extent of excavation of the posterior side of the head, relative to head length. However, there is also quite some variation within figures of one species, and between authors: The maximum excavation in figures by Papp = 31% (*C. seticornis*), while figures by Tobias show a larger excavation for 9 species. This may also be related to a different viewpoint used by these authors.

1	2	3	4
<15% very shallow	15-25% shallow	25-35% deep	>35% very deep
			
C. pappi (T22)	C. subsulcatus (P8)	C. seticornis (P2)	C. dolosus (T17)

Differences between male and female

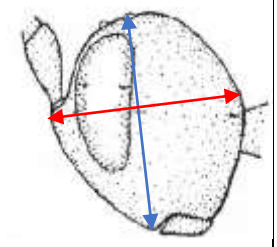
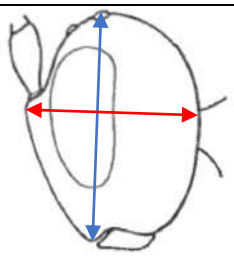
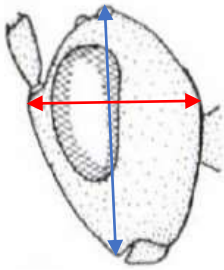
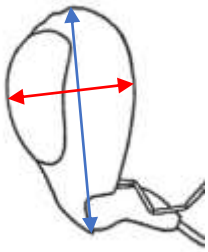
Of all the figures of the dorsal view of the head there are 103 of female and only 35 of male specimen. This lack of male figures probably indicates that the ♂ and ♀ are similar, and there is no need to show both sexes. There are 17 species where there are figures for both male and female specimen by the same author. In these figures there are indeed no significant differences. In the key it is therefore assumed that there are no differences between male and female in head morphology (antennae excepted).

Head lateral view

Head height : length

Head height is measured as the distance from the hind ocellus to the lower side of the clypeus, and the head width perpendicular to this line from below he scapus to the back of the head.

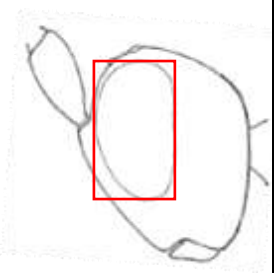
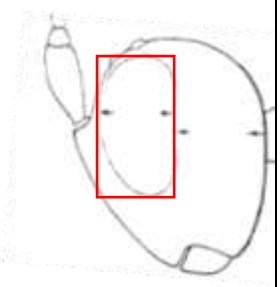
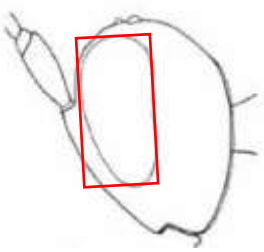
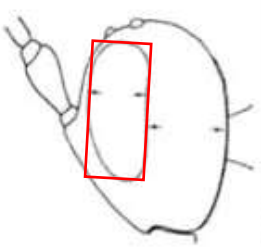
For only 12 species the ratio head height : head length is specified in the description. Using the figures, we can estimate this ratio for 48 species. This character seems to be quite constant when comparing figures for the same species. An exception is C. predator where Papp 1995 shows a completely different head shape than Papp 1997b and Tobias 1986. Remarkably, all figures with a very long head are from Lozan or Tobias and Lozan, which show the whole body in lateral view. Perhaps this way of representing the species does not show the head in realistic proportions.

1	2	3	4
very short <=1.25	short 1.25 - 1.4	long 1.4 - 1.55	very long > 1.55
			
C. mucronatus (P2)	C. lugubris (P1)	C. nigritulus (P6)	C. rostratus (T15)

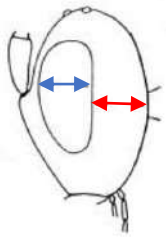
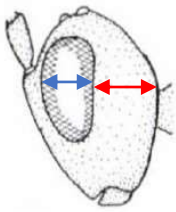
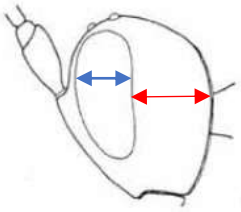
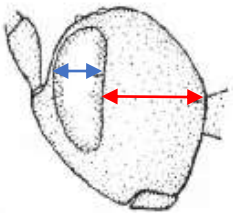
In addition to an elongated head, C. rostratus also has an elongated rostrum and palpi.

Eye height : length

It is not always clear whether eye height / eye length (width?) ratios are measured using a lateral or a frontal view. Belokobylskij & Tobias (1998) show these measurements in lateral view, but in descriptions the eye height and width are often combined with face width, which must be measured using a frontal view. The data here are therefore mostly based on the figures, the data from the descriptions are taken to be measured using frontal view.

1	2	3	4
very short <=1.8	short 1.8 - 2.0	long 2.0 - 2.2	very long > 2.2
			
C. annulatus (P1)	*C. olgae (P7)*	*C. scabrosus (P3)*	*C. flavipalpis (P3)*

Temple length : eye length

1	2	3	4
very short <=1.1	short 1.1 - 1.3	long 1.3 - 1.5	very long > 1.5
			
C. longiventris (P4)	C. lugubris (P1)	C. pellucens (P3)	C. mucronatus (P2)

Temple widening or narrowing ventrally

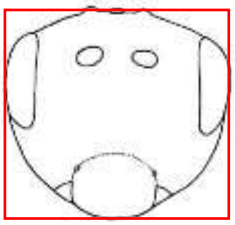
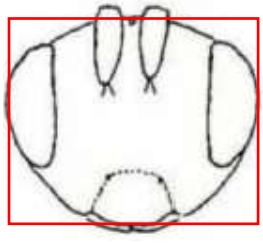
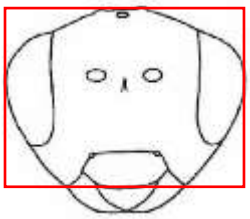
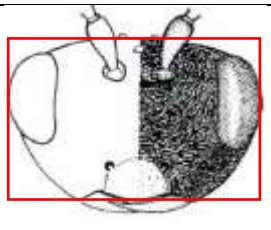
Because of the rounded shape of the eye and the lack of distinct reference points to measure temple width at, the given descriptions for temple widening or narrowing ventrally are very uncertain. Measuring the figures using fixed points at 50% and 75% of eye length from top of eye gives reasonably standardized data, but here the position where the temple width is measured depends on the eye length. It seems best not to use this character.

Head frontal view

The frontal view of the head is less frequently shown in figures than a dorsal or lateral view. That is strange as there are many distinctive characteristics which are also easily measured. To standardize the measurements of the figures, the figure of the frontal view of the head is first straightened. The image is rotated so that the lower edges of both eyes are on a horizontal line.

Head width : height

The head height is measured from the top of the head, on or above the front ocellus, to the lower edge of the clypeus. The ratio 'head width : head height' varies from 1 to more than 1.5 with an average about 1.25.

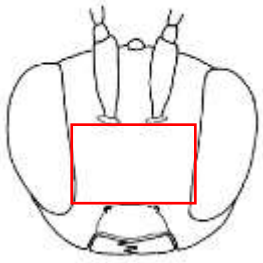
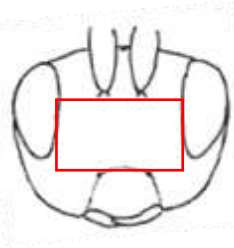
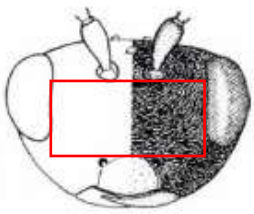
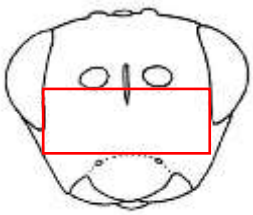
1	2	3	4
very narrow <=1.2	**narrow** 1.2 -1.3	**wide** 1.3 - 1.4	**very wide** > 1.4
			
C. kopetdagicus (T14)	*C. hofferi (TL4)*	*C. nigellus (T9)*	*C. depressus (P4)*

Face width : height

The face width : height ratio is given for many (83) species in descriptions. This suggests that it is an important variable. The face is measured from the antennal foramen to the top of the clypeus, and the width is the distance between the eyes at the middle of the face. When measuring face width : height from figures, the difficulty is that the antennal foramen is not always drawn, most often only

the antennal radicle and scapus are shown. In that case the top of the face starts at the lowest point of antennal radicle.

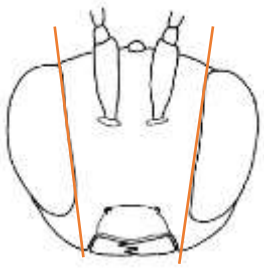
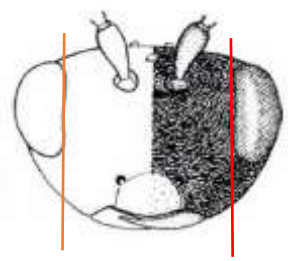
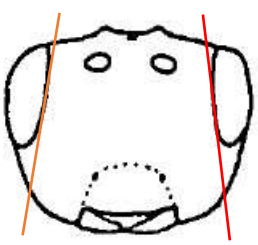
The average face width : height ratio in figures is 2.0. This corresponds with the data given in de species descriptions: for 37 species it is 2 or about 2, although 1.8 and 1.5 are also frequently noted. This character appears to correspond with the face width : eye width ratio.

1	2	3	4
very narrow <=1.6	narrow 1.6 - 1.9	wide 1.9 - 2.2	very wide > 2.2
			
C. subsulcatus (P8)	*C. ()*	*C. depressus (P4)*	*C. dolosus (T17)*

Eyes converging ventrally

This character shows whether the inner eye margins converge or diverge ventrally, making the face wider or narrower ventrally. It is sometimes used to differentiate between species. Difficulties in measuring this character are that the inner margin of the eyes is sometimes convex, and also the height of the face varies, sometimes the top of the clypeus is above the lower margin of the eyes, and sometimes below it. This affects the point where the angle (converging or diverging) of the eye margin can be measured.

To standardize this measure: The only fixed points are the intersections between the top face line and the eye rim, and the mid face line and eye-rim. The bottom face line may not intercept with the eye, so cannot be used. The angle of the line between the top face corner and the mid-point is used to determine whether the eyes are converging or diverging. Of course, this only measures the eye rim bordering the top half of the face. If the eyes are converging the angle is positive, if diverging negative. For simplicity, and because by far the most species have the inner eye margins more or less parallel, we only use the categories ‘distinctly converging ventrally’, ‘about parallel’ and ‘distinctly diverging ventrally’.

1	2	3
distinctly converging > 4° converging	about parallel	distinctly diverging > 4° diverging
		
C. subsulcatus (T14)	*C. depressus (P4)*	*C. macrellips (TL)*

Eye height : width

The eye height is measured from the highest to the lowest point of the eye, the eye width is the largest width perpendicular to this line.

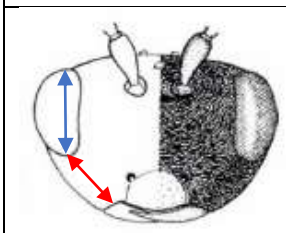
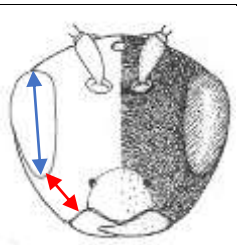
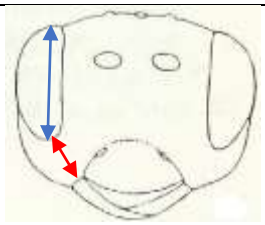
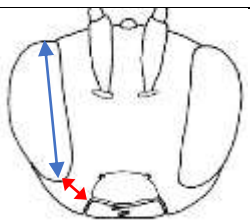
Nearly all figures with the frontal view of the face show a height : width ratio of the eye between 2.1 and 2.7 (with 3 outliers). In the species descriptions more than half of values are lower than 2.1, with a minimum of 1.3! It is hardly ever stated how the height and width are measured (perhaps latero-frontal view?), but as this eye height or width is often also compared with face width, one can assume that it is from a frontal view. Sometimes the text and figures of the same author do not correspond, as with Tobias 1999 for *Chelonus nigellus*: 'Longitudinal eye diameter 1.6 times transverse one, twice gena height, 0.77 times face width', while his figure shows eyes with a height : width ratio of 2.4. Given the small range of this ratio in the measured figures, and the uncertainty of the available data, it seems best not to use this character.

Eye height : malar space length

The ratio 'eye height : malar space length' is also often used. Sometimes it is not clear whether a lateral or frontal view is used in descriptions or keys, but as both van Achterberg (1988) and Belokobylskij and Tobias (1998) show malar space to be measured in frontal view, this is assumed to be the case. While Belokobylskij and Tobias use the shortest distance from mandible to eye, van Achterberg uses the vertical distance from the top of the mandible to the bottom of the eye.

For the figures the shortest distance between the top of the mandible and the eye is used for malar space length. Measured this way, the ratio ranges from 1.2 to 5.2, with 2.1 as average. Only 5 measurements are above 2.5, and 1 above 3.5 (*C. subsulcatus*, 5.1). In the descriptions these values are somewhat higher, but it is difficult to compare, as the values are given as 1.5, 2, 2.5 or 3. In the 8 species which have both a description and a figure, the values calculated from the figures are on average lower.

Eye height : malar space length:

1	2	3	4
very short EH:MSL <= 1.6	short 1.6 - 2.2	long 2.2 - 2.8	very long > 2.8
			
C. depressus (P4)	C. microphtalmus (P1)	C. ripaeus (T4)	C. subsulcatus (P8)

Eye height : face width

Another character used is the ratio 'eye height : face width'. This character combines the shape of the eye and of the head. The range of values for this ratio from the figures is 0.5 to 1.1. As this ratio is mostly determined by eye height, it overlaps with 'eye height : malar space length' (see also the four figures above for eye height and face width).

Malar space length : mandible base length

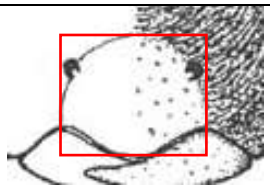
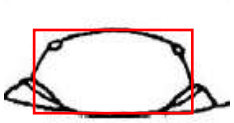
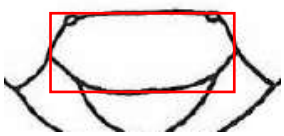
This ratio is often used in descriptions, but from figures it is very difficult to reconstruct. The mandibles bases are often very small and the left and right mandibles differ in width.

Clypeus

Next to the figures of the complete head in frontal view there are also figures of just the clypeus. This suggests that this part can be distinctive. The clypeus width : clypeus height ratio is a measure of the shape of the clypeus, and the face height : clypeus height shows the size of the clypeus relative to the face.

Clypeus width : height

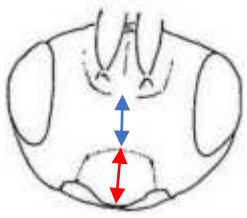
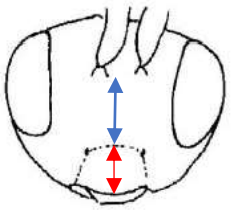
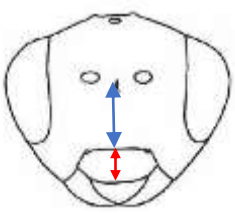
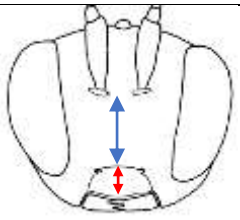
The clypeus can be almost as high as wide or more than twice as wide as high. In most species the clypeus is clearly separated from the face, making is easy to measure. The width of the clypeus is measured at its widest point, usually just above the mandibles. The height is measured in the center from the top to the lower border. The ratio varies between 1.2 and 2.4, with an average 1.7. The figures and descriptions agree very well for almost all species with both description and figure.

1	2	3	4
quadrangular CW:CH <= 1.5	semicircular 1.5 - 1.75	transverse 1.75 - 2.0	very transverse > 2.0
			
C. microphtalmus (P1)	C. minutus (P16)	C. mucronatus (T14)	C. nigellus (T9)

Face height : clypeus height

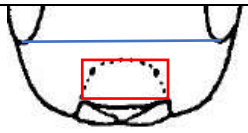
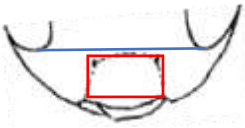
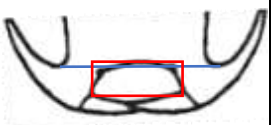
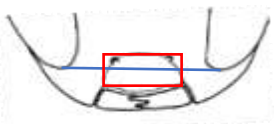
This ratio for the figures varies between 1.0 and 2.2, with an average 1.5. The same applies for the descriptions, with the remarkable finding that all of the 12 values above 1.7 are ‘exactly’ 2 (one clearly erroneous 4 excepted). Apparently more detail than this was assumed not relevant, while in the figures there is quite some variation in this range.

Because of this, and because this ratio is affected by both the shape of the clypeus and the shape of the head making it fairly difficult to see differences without measuring, this a less useful variable.

1	2	3	4
very small FH:CH <= 1.25	small 1.25 - 1.5	large 1.5 - 1.75	very large > 1.75
			
C. minifossa (LT2)	C. rostratus (Lo1)	C. nigellus (T9)	C. subsulcatus (P8)

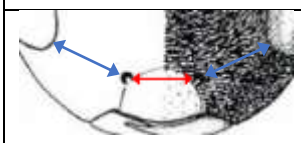
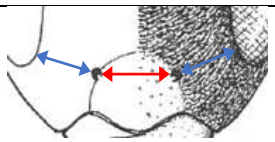
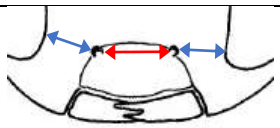
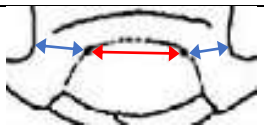
Clypeus extending above bottom of eyes

One aspect that has not been used, but which is easily determined and seems to vary distinctly between species (based on the figures) is the position of the clypeus relative to the bottom of the eye. In some species the clypeus extends above the lower border of the eyes, in many it is somewhat above or below it, and in others the clypeus is distinctly below the lower border of the eyes.

1	2	3	4
far below <= -20 %	below -20 - 0 %	above 0 - 20 %	far above > 20 %
 C. macrellips (TL)	 C. rostratus (Lo1)	 C. karadagi (T5)	 C. subsulcatus (P8)

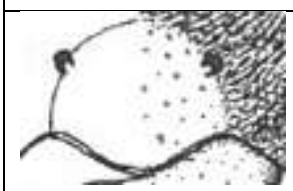
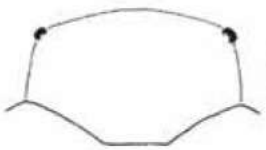
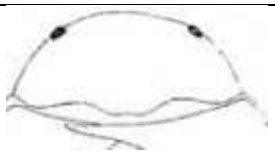
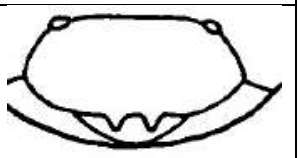
Distance between tentorial pits : distance between pits and eyes

A variable that is frequently used is the ratio of the distance between the anterior tentorial pits and the shortest distance between tentorial pits and eye. There is a good agreement between the data from the figures and the data given in the descriptions. This indicates that this variable can be measured unequivocally.

1	2	3	4
very small <= 1.0	small 1.0 - 1.3	large 1.3 - 1.6	very large > 1.6
 C. depressus (P4)	 C. microphthalmus (P1)	 C. subsulcatus (P8)	 C. frontalis (TL4)

Shape of lower margin clypeus

The shape of the medial part of the lower edge of the clypeus is also often mentioned in descriptions. The different shapes are:

1	2	3	4
convex	truncate	slightly excised, sinuous	two teeth
 C. microphthalmus (P1)	 C. cesa (P7)	 C. bimaculatus (P7)	 C. lukasi (TL3)

Antennae

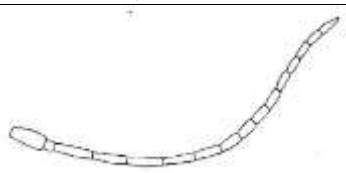
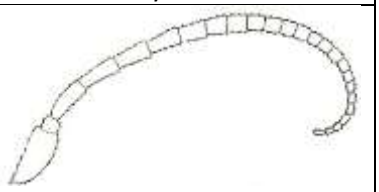
While there are few pictures of antennae, the antennae are important in discriminating the different species and several variables are given in the descriptions. The most important variable is the number of antennal segments, but the length : width ratio of the third segment and of the penultimate segment are also frequently used, as well as the antennal length compared to body length. The shape of the antenna is also important, where some are widened beyond the middle and other are filiform. In contrast to the rest of the head the antennae are often very different between male and female species (as in most Hymenoptera).

Number of antennal segments

The number of antennal segments is a main variable for identifying Chelonus species. Many female species have a fixed number of 16 segments ('Microchelonus'), and males have usually more segments than females. Because antennal segments can be easily counted, there is no need to divide the species in categories with different ranges of segments.

Antenna widened beyond middle

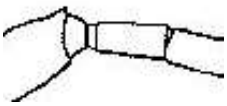
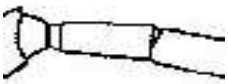
The antenna can be shaped differently between species. It can be widened and flattened beyond the middle, with the segments there shortened, or the antenna can be gradually thinning towards the apex. A widened antenna occurs almost exclusively in females, while males almost always have a filiform antenna. The categories are:

1	2	3
filiform, not widened	slightly widened	clearly widened
		
C. temporalis (T4)	C. pseudobasalis (TL4)	C. oculator (A1)

Length : width ratio of antennal segment 3 (1st flagellar segment)

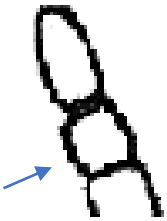
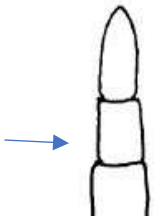
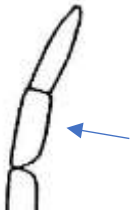
For half of the species the length : width ratio is given as '3'. Also 2.5 and 4 are frequently given in the descriptions, less frequently 2 and 3.5. Extreme values are 1.6 and 5. Only 11 figures of antennae could be found to measure this ratio. The values of these figures range from 1.9 to 4.6. For the 8 species where this value is given in both description and figure the values seem to agree well.

Most of the information on length / width of antennal segments is only given for females. However, there is no general correlation between male and female length : width ratio's. Male antennae are always longer than female antennae, but this can be the result of either more antennal segments or of longer segments. For males this information is therefore often not available. Because of the difficulty in measuring this ratio and (because of this?) the lack of detail in the available data, this variable is reduced to 3 categories:

1	2	3
short l:w < 2.6	medium 2.6 - 3.6	long > 3.6
		

Length : width ratio of penultimate segment

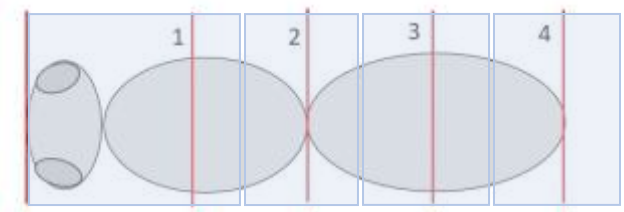
The differences between species appear larger when the length : width ratio of the penultimate segment is compared. The shape of this segment can range from square (l:w <= 1) to elongate (l:w = 2.7). The are 17 figures showing the penultimate segment of the antenna. In the descriptions thee values 1, 1.5 and 2 are very often used. The categories are based on these values:

1	2	3
short l:w < 1.25	medium 1.25 - 1.75	long > 1.75
 C. koponeni (T5)	 C. subsulcatus (P8)	 C. temporalis (T13)

Length of antenna : length of body

The length of the antennae is expressed either as a fraction of body length, but more often it is compared to the length of head, mesosoma and metasoma, as 'head + 0.5 mesosoma', 'head + mesosoma', 'head, mesosoma + 0.5 metasoma' and 'head + mesosoma + metasoma' (=body length). To combine these data into one variable I measured the length of head, mesosoma and metasoma in 10 figures of the dorsal view of the whole body of different species. The ratio's for the length of these body part are very similar, where head : mesosoma : metasoma = 14 : 38 : 48. These relative measures can roughly be expressed as:

	category	*length*	*% of body length*
1	head + 0.5 mesosoma	very short	33 (< 40%)
2	head + mesosoma	short	50 (40 - 60%)
3	head + mesosoma + 0.5 metasoma	long	75 (60 - 85%)
4	head + mesosoma + metasoma (= body length)	very long	100 (> 85%)



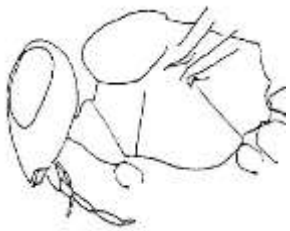
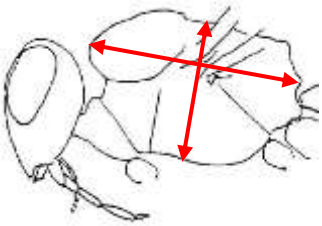
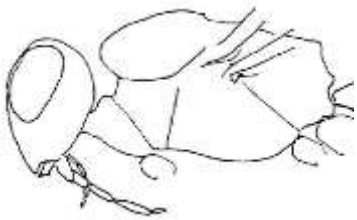
Mesosoma

There are few morphological characters which are frequently mentioned for the mesosoma. Most often the ratio of mesosoma length : mesosoma height is given. The propodeum also has a few morphological features which are used: the size and shape of the lateral and median teeth and the presence of transverse or longitudinal carinae. A distinctive character which is not often mentioned is the prepectal carina (ventrally visible just behind the front coxae), which can sometimes be lamelliform.

There are almost no separate data for males and females, so it is assumed that the mesosoma of male and female are identical.

Mesosoma length : height

In lateral view the mesosoma can be somewhat compressed to more elongated. This is measured by taking the ratio of mesosoma length and mesosoma height. The values vary from 1.2 to 1.8, with 1.5 as the most common value. There are not many figures showing the mesosoma, but the available figures correspond well with the given values. The (lack of) level of detail in the data, and for ease of use, this character is divided in 3 categories:

1	2	3
short l:h < 1.4	medium 1.4 - 1.6	long > 1.6
		

Transverse carina on propodeum

There are no figures published of the transverse carina, and all the information on the transverse carina is given as ‘absent’, ‘weak’, ‘well developed’, ‘strong’. Often it is just stated that the transverse carina is present. The qualifications can be grouped in the following categories:

	category
1	absent
2	weak, indistinct
3	‘present’
4	well developed, distinct, strong, clear, sharp?

Lateral teeth of propodeum

The same applies to the size of the lateral teeth of the propodeum. This character may be variable as different authors sometime have very different opinions on the size of the teeth. Here we have a comparable set of categories:

	category
1	very small, very weak
2	weak, small, short
3	'present'
4	well developed, distinct, strong

Lamelliform prepectal carina

The prepectal carina (on the ventral side, behind the front coxae) is sometimes raised to form a thin lamella. It is sometimes named as 'anterior margin of acetabulum' [Th], or 'fore acetabulum' [P1, P2]. The presence of this lamelliform prepectal carina is rarely stated, perhaps because it does not occur in most species, and is only mentioned in descriptions of species where it does. To qualify as 'lamelliform' it must be clearly more lamelliform than the postpectal carina which is the carina just before the mid coxae (?). The prepectal carina can be bidentate and/or reflexed.

Chelonus bidentulus, 'Acetabulum of first leg in postero-frontal view' (Papp 1995)

For this character there are only two categories, prepectal carina 'indistinct' or 'lamelliform'. If it is not mentioned in the text, it is assumed to be not lamelliform. So far this carina is lamelliform in 6 species.

1	2
indistinct	lamelliform
	 C. bidentulus (P8)

Legs

Many variables have been measured on Chelonus legs, but only few are measured often enough to be useful. Except for the hind femur, there are not many figures which can add data to the dataset. The measurements are all made on the hind leg. There are few datapoints and figures for both males and females. Sometimes the values are different, but there is no consistent pattern and the differences do not stand out above the variation within a sex. Therefore it is assumed that there is no difference in the legs between males and females.

Hind femur length : width ratio

This ratio is very frequently used. Unfortunately, there is sometimes quite some variation between different authors regarding the same species. The figures however correspond very well with the descriptions. In the descriptions the value 3, 3.5 and 4 are the most used, and therefore this variable is divided in three categories corresponding to these values.

1	2	3
short l:w < 3.2	medium 3.2-3.8	long > 3.8
 C. flavipalpis (P3)	 C. predator (P6)	 C. retusus (P4)

Hind tibia length : hind tarsus length ratio

This variable is used for almost half of the species. The main values given are '<1', '1' and '>1', and a few times 1.1 or 1.2. It makes sense to use these same categories, but what are the limits for '<1' and '>1'? Preferably the difference in length between tibia and tarsus should be seen without measuring, which means that there must be a significant difference to be '<1' or '>1'. A 10% difference seems reasonable.

1	2	3
short tibia : tarsus < 0.9	medium 0.9 - 1.1	long > 1.1

Hind tibia (longest) spur length : metatars length ratio

The length of the hind tibial spurs compared to the length of the metatars is also often used. Most often the inner spur is the longest, but sometimes the outer spur. For simplicity, the longest spur is used here for this ratio. The most frequent values for this variable is '0.5', followed by '< 0.5' , '0.4' and '0.3'. The only useful division in categories is:

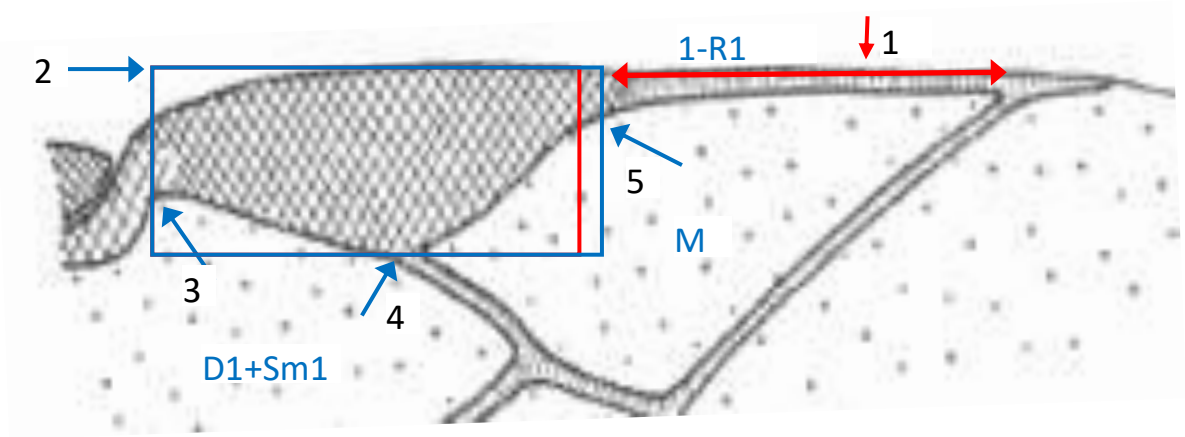
1	2
short clearly less than half of metatars spur : metatars < 0.45	long half or more of metatars >= 0.45
 C. submuticus (P1)	 C. obscuratus (P2)

Wings

Wing venation is often described in detail, which suggests that it is a an important factor in identifying *Chelonus* species. Veins can usually be measured accurately, with a few exceptions. It is often difficult to exactly define the bounds of the pterostigma, especially the point where the pterostigma turns into the vein 1-R1 (metacarp) is subjective (at least in figures).

Vein 1-R1 length : pterostigma length

The ratio between the length of 1-R1 and the pterostigma length is an often used variable. However it is often difficult to determine the point where the pterostigma begins and where it turns into vein 1-R1.



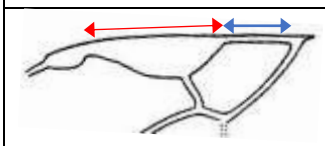
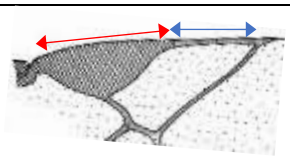
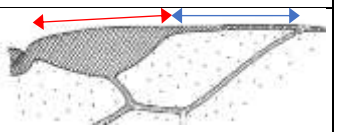
Chelonus annulipes [P1]

To measure the pterostigma and the start of the vein 1-R1 in a standardized way (from figures), I follow the these steps:

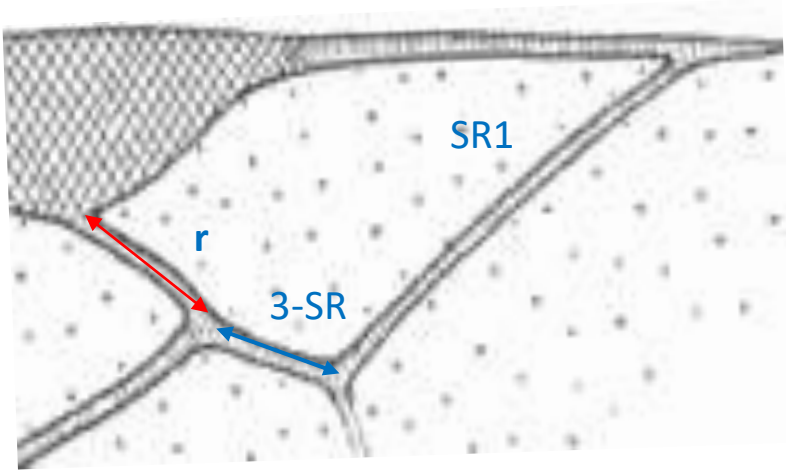
1. rotate the figure so that vein 1-R1 is horizontal
2. draw a box around the pterostigma, with the top aligned with the highest part of the pterostigma
3. align the left side of the box with the highest point of cell D1+Sm1
4. align the bottom of the box with the leftmost point of cell M
5. most difficult, align the right side of the box with the point where the pterostigma turns into vein 1-R1. This is fairly subjective, especially in figures or when the pterostigma and 1-R1 have the same color.

The length of vein 1-R1 varies from about 0.35 to 1.2 of the pterostigma length. Measurements from figures give a ratio that is about 0.1 lower than the values from the descriptions. In part that may be because for many species the ratio is given as ‘1’ (rough estimation) or ‘slightly less than 1’ (how much is ‘slightly’?). To match the figures with the descriptions, the pterostigma must be assumed shorter and the vein 1-R1 longer, so arrow 5 in the figure above should point more to the left (red line).

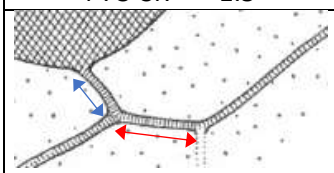
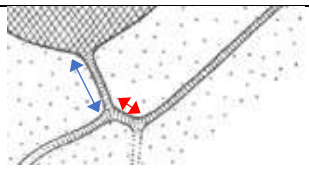
Half the species have a ratio of ‘1’ or slightly more or less, which is also the highest value. A fair number of species have a ratio of about 0.7, and several species have a short vein 1-R1 of about 0.5. The categories are:

1	2	3
short 1-R1 : stigma < 0.6	medium 0.6 - 0.8	long > 0.8
		
C. dolosus (T17)	C. elaeaphilus (P13)	C. microphtalmus (P1)

Vein r length : vein 3-SR length



Also often used is the ratio of vein r and vein 3-SR length. Individual values from descriptions and figures vary from 0.4 to 3, but for most species there are several measures and the variation within a species is large. Almost all species have one or more values around 1. There a few species where all values are clearly higher. In the descriptions for these species the ratio is given as ‘2’ or ‘3’, the values from the figures show values from 1.5 to 2.6. These species with a long vein r can be separated from the others using the categories r : 3-SR <= 1.5 and r : 3-SR > 1.5.

1	2
vein r short	vein r long
r : 3-SR <= 1.5	r : 3-SR > 1.5
	
C. microphtalmus (P1)	C. latrunculus (P1)

Vein SR1 length : vein 3-SR length

The length of vein SR1 compared to vein 3-SR is almost standard in species descriptions. However if you combine all datapoints from descriptions and figures, the variation within species is almost as large as between species, for species with several datapoints. There are a few species which stand out with a very large SR1 : 3-SR ratio (> 7), but these are the same species that have the highest r : 3-SR ratio, both due to a very short vein 3-SR. This variable may be informative for individual species, (which?), but is useless in a general key.

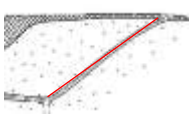
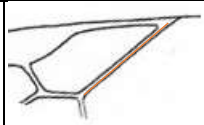
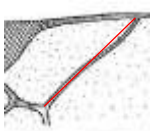
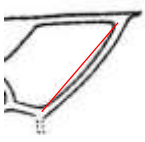
The variability in the ratio SR1 : 3-SR may originate in its dependence on both the shape of the marginal cell and the division of the proximal border of the marginal cell in vein r and 3-SR. With a small vein like 3-SR the measurement errors become large. To compare the shape of the marginal cell between species it would seem better to use the ratio of the long and the short side of the marginal cell, this would be expressed in the ratio SR1 : (r + 3-SR), where the relative size of r and 3-SR is no longer affecting the outcome. However this measure is also not distinctive.

Shape vein SR1 (straight / concave / convex)

While the length ratios of the veins are not very helpful in identifying species, perhaps the shape of veins is. The shape of vein SR1 is often described, from 'straight' to 'slightly curved', 'curved' or '(slightly) S-curved'. Unfortunately most of the time it not stated whether the vein is curved inwards (concave) or outwards (convex) relative to the marginal cell, but luckily there are figures of wings for most species which solves that problem. In the figures the deviation seems fairly constant within each species and variable between species, which makes it a promising character.

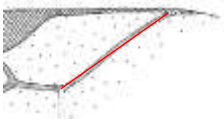
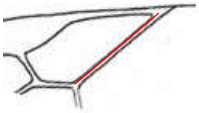
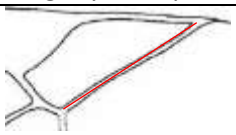
The shape of vein SR1 in the figures is calculated in the following manner: Draw a straight line from start to end of SR1. Measure the length of this line, and the length of the maximum deviation of SR1 from this straight line. Divide the deviation by the length of SR1 and multiply by 100 to get percentage. The values obtained in this way range from -9% (concave) to +9% (convex). It seems easiest to maintain the categories used in the descriptions, from concave, slightly concave, straight, slightly convex to convex.

Several species have an S-shaped vein SR1, concave basally and convex near the wing border. This trait does not fit in with the range from concave to convex, requiring a separate variable. Species with S-shaped SR1 are here included in the categories 'straight', 'slightly concave' or 'slightly convex', depending on whether the concave and convex aspect is dominant. In a separate variable you can then indicate the level of S-shape of the vein SR1.

1	2	3		4	5
concave dev : SR1 < -4%	slightly concave -4% - -2%	straight	S-shaped	slightly convex 2% - 4%	convex > 4%
		-2% - 2%			
					
C. oculator (A1)	C. microphtalmus (P1)	C. kopetdagicus (T14)	C. elaeaphilus (P13)	C. parcicornis (P15)	C. dolosus (T17)

S-shape vein SR1

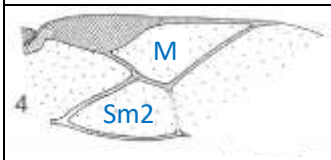
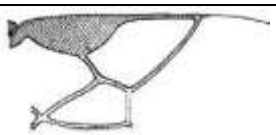
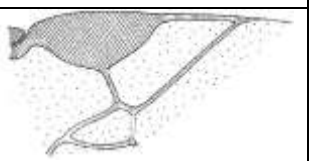
As stated above, the vein SR1 can sometimes be S-shaped (sinuous). This trait cannot be included in the range from concave to convex, necessitating this new variable. Veins that are not really S-shaped but apically or basally convex or concave can also be included here, in combination with 'concave' or convex' in the previous variable.

1	2	3	4	5
apically concave			apically convex	
S-shaped	slightly S-shaped	not S-shaped	slightly S-shaped	S-shaped
no species found	 C. microphtalmus (P1)	 C. kopetdagicus (T14)	 C. elaeaphilus (P13)	 C. lukasi (TL3)

Marginal cell size : 2nd submarginal cell size

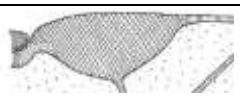
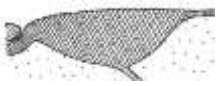
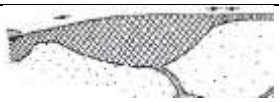
Next to measuring vein lengths, comparing wing cell sizes is also used to describe species. The area of the marginal cell (M) is often compared to the area of submarginal cell 2 (Sm2), and also to the area of the pterostigma.

There is some variability in this character. Tobias & Lozan (2007) show the variability in wing venation in three figures of *C. fumipennis*, where one figure has a much lower ratio of M : Sm2 than the other two. Unfortunately the data in descriptions are mostly given in rounded numbers such as 1.5, 2 and 2.5, resulting in differences when compared with measurements from figures. However, in general the data agree fairly well for each species. As the ratio M : Sm2 shows a wide range between species, varying from 1.0 to 3.7, this may be a useful character.

1	2	3
Sm2 large M : Sm2 < 1.7	Sm2 medium 1.7 - 2.4	Sm2 small > 2.4
 C. annulipes (P1)	 C. longiventris (P16)	 C. latrunculus (P1)

Pterostigma length : width ratio

Given the uncertainties with defining the start and end of the pterostigma and the variability seen in the wing veins, one could expect the pterostigma length : width ratio to have a large uncertainty. However, when the data from the descriptions and measurements from the wing figures are compared, there are clear patterns visible, allowing the values to be divided in three categories.

1	2	3
pterostigma short l : w < 2.4	medium 2.4 - 2.9	long > 2.9
 C. latrunculus (P1)	 C. flavipalpis (P1)	 C. antennalis (P2)

Radial vein from pterostigma

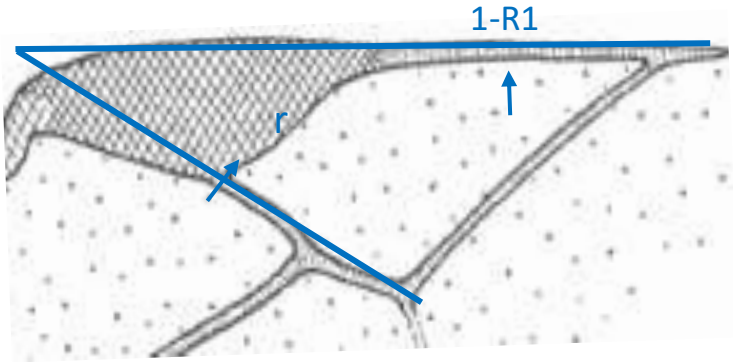
Where the radial vein connects to the pterostigma is regularly described, making it a possible candidate character. The options are 'originating from middle of pterostigma', 'slightly distal' (from middle) or 'distal' (from middle). Comparing these categories with the measurements from the available figures results in the following conclusions:

1. Almost all species have a vein r originating 'distal' or 'slightly distal' from the middle of the pterostigma, and the values from the figures are mostly in the range of 0.55 to 0.65. This makes it hard to differentiate between species.
2. There is very little correlation between the descriptions and the measured values. A species with the qualification 'distal' may have a figure showing a vein originating almost from the middle and vice versa.
3. There is also a large variability between figures of the same species.

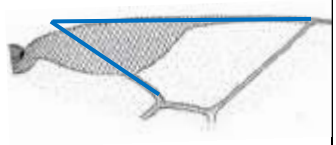
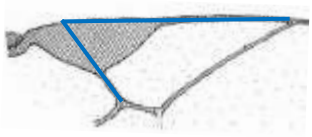
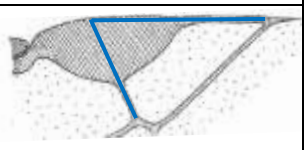
This leads to the conclusion that the position of the radial vein relative to the pterostigma is not a useful variable.

Angle between radial vein (r) : vein 1-R1

In addition to measuring the length of veins or the area of wing cells, you can also look at the angle a vein makes relative to another vein. The angle between vein r and the wing margin is a character which seems to differ between species. *C. verticalis* (Tobias 1995) is presumably named after this character. From the species description: '*Radial vein runs almost vertically to longitudinal axis of pterostigma'*. There are only a few remarks made on the angle of vein r, with terms like 'acute', 'oblique' and 'nearly perpendicular'. There are however many figures where this angle can be measured in a standardized way. For measuring this, the angle of r with 1-R1 is used, because the wing margin at the pterostigma is often curved, while the margin at 1-R1 is almost always straight. If r is curved, the first third of r is used to determine the angle.

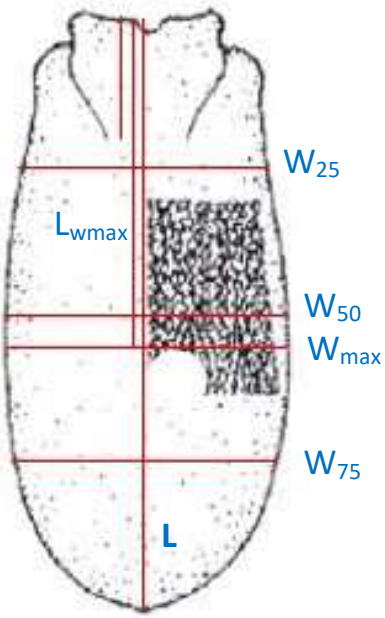


The measured angle varies from 28 to 85°, with an average of 45°. It is unclear how constant this character is, but species with multiple figures show only a limited variation. Any possible errors are reduced by dividing the values in only three categories.

1	2	3
sharp <= 40°	medium 40 - 55°	blunt > 55°
		
C. fenestratus (P6)	C. gravenhorstii (P6)	C. latrunculus (P1)

Metasoma dorsal view

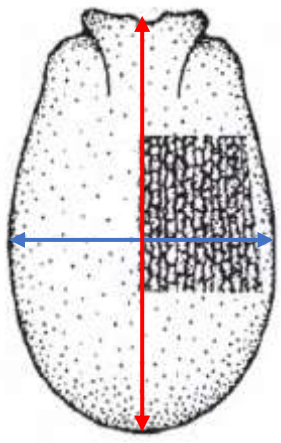
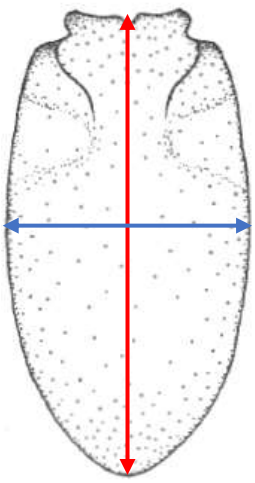
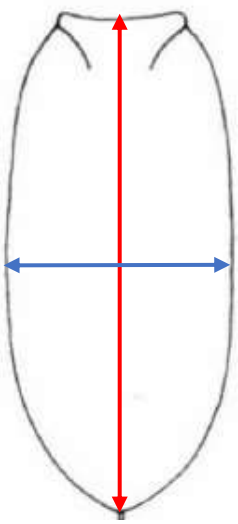
The shape of the metasoma (carapace, abdomen) is an important character in identifying Chelonus species. In many Hymenoptera males and females differ in the shape of the metasoma, probably partly because it contains the different genitalia. Therefore the morphological data may have to be recorded separately for the two sexes. Because The metasoma is described in both dorsal view and lateral view.



The shape of the metasoma in dorsal view can be separated in a number of variables; the length (L) : width (W_{max}) ratio tells whether it is elongated or contracted, and the ratio W75 : W25, combined with the position of maximum width (L_{wmax} / L) gives information on whether the metasoma is longitudinally symmetrical, or more tapering towards the base or towards the apex. In species descriptions this information is usually combined in descriptions which cannot easily be quantified. Luckily, there are many figures of the dorsal view of the metasoma which can be measured. Finally the shape of the apex is often described, from rounded to pointed, but this is probably related to the metasoma tapering towards the apex or not.

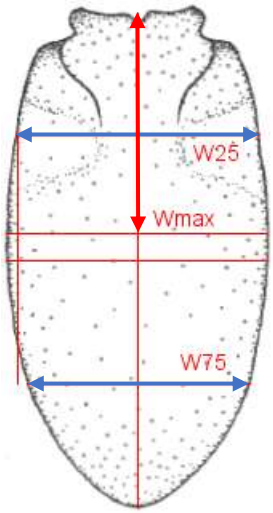
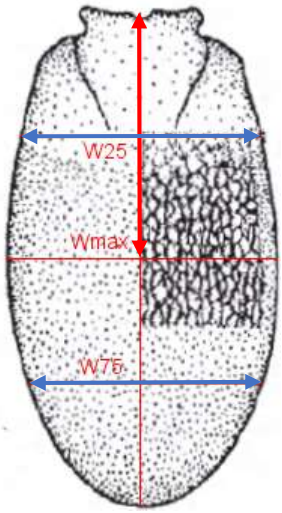
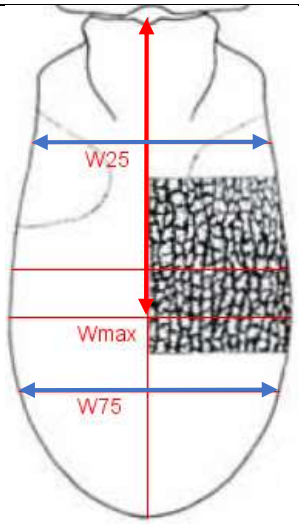
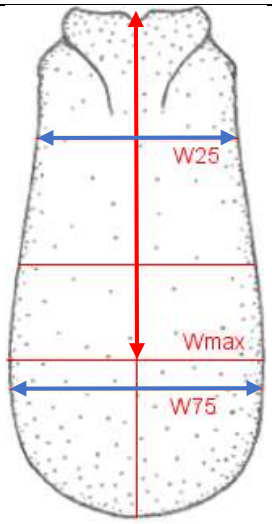
Length : width ratio of metasoma

Due to the fixed tergites the length of the metasoma of Chelonus is fixed (per specimen), which is not so in most other Hymenoptera. In dorsal view the ratio of length (L) and maximum width (W_{max}) of the metasoma can therefore be exactly measured. It is also one of the most used variables in descriptions. The length : width ratio varies from 1.4 to 2.7, with an average value of 1.9. There is a large variation between the species, but the differences within species are also significant. In some species there are significant differences between males and females, but for most species the differences are within the range of variability, or are simply not given for one sex. In this case it is assumed that the data are the same for both sexes. For this variable 3 categories seem suitable:

1	2	3
short l : Wmax < 1.75	medium 1.75 - 2.05	long > 2.05
 C. breviventris (P2)	 C. annulatus (P1)	 C. longiventris (P3)

Narrowing towards base or towards apex

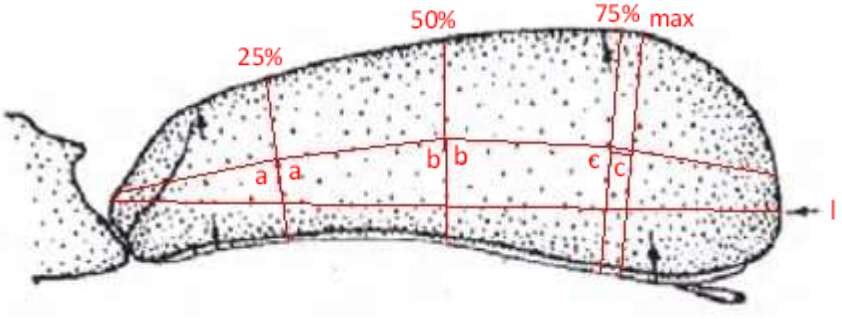
Some species have a metasoma that is tapering towards the apex, and are widest at the basal half, others are narrowing towards the base with the largest width in the apical half, and some are symmetrically oval and are widest in the middle. The ratio between the width at 75% and the width at 25% of the metasoma length is taken to quantify this character. The position of maximum width at the metasoma relative to the metasoma length is strongly correlated with this ratio and can be used as an additional measure.

1	2	3	4
narrowing to apex W75 : W25 < 0.95	widest in middle 0.95 - 1.05	widest below middle 1.05 - 1.15	tapering to base > 1.15
			
C. annulatus (P1)	C. antennalis (P2)	C. cesa (P7)	C. annulipes (P1)

Metasoma lateral view

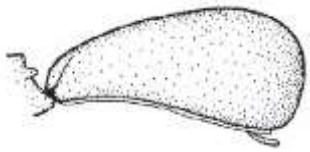
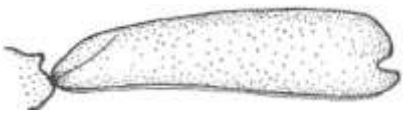
The metasoma of Chelonus species is often convex or curved, and often gradually increasing in height. In lateral view the dorsal side is always longer than the ventral side. Still the difference in height between the base and the apex is an often used variable, and is clearly different between different species. The statements made in descriptions such as 'In lateral view about twice as high posteriorly as anteriorly', are hard to interpret. For 'posteriorly' one can take the position of maximum height, but how do you determine this height if the metasoma is curved? And where is 'anteriorly' on a gliding slope? It is not clear how these measurements are made, so there may be a considerable error due to different methods. In the figure below (Papp 1997) it is not clear how the lines to measure the height at base and apex are chosen (see black arrows). To standardize these measurements I take the height at 25% and 75% of the metasoma length (as well as at 50% and at the position of maximum height).

How to measure the height of a Chelonus metasoma at fixed positions when such a metasoma can be curved or strongly increasing in height? The suggested approach is as follows: First draw a line in 4 segments from base to apex dividing the metasoma. mark the 3 points connecting the segments. Then draw lines from the lower side of the metasoma to the top through these points, making sure that this line makes the same angle with both bordering line segments. Measure these lines. Next find and measure the maximum height perpendicular to the 4-segmented line, and measure its position on this line. This method is used to measure all Chelonus lateral metasoma figures found in the literature. The shape of the metasoma in lateral view can then be expressed as 25% : 50% : 75%.



Length : height ratio of metasoma

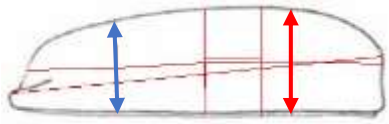
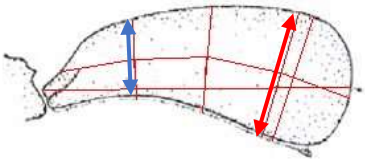
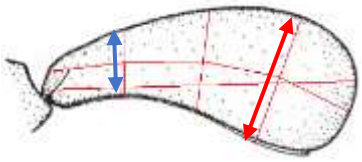
The ratio of metasoma length and the maximum height as measured above gives a range of values from 2.0 to 4.6 (in descriptions from 1.7 to 5.0, excluding an erroneous 1.4), most species have a length : height ratio of around 3. In some species there is a clear difference between males and females, but in most species this difference is not noticeable. The variation within species is considerable, so only three categories are possible. These categories are <=2.6, 2.6-3.4 and >3.4.

1	2	3
short l : h <= 2.6	medium 2.6 - 3.4	long > 3.4
 C. breviventris (P2)	 C. mucronatus (P2)	 C. lugubris (P1)

posterior : anterior height ratio of metasoma

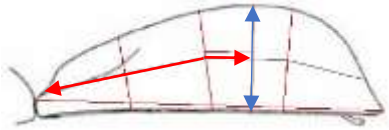
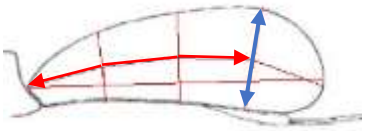
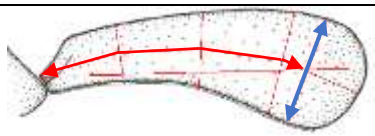
In all species the height of the metasoma increases from anterior (25%) to posterior (75%), but still there is a marked difference between species in the shape of the metasoma, which in some species is almost parallel, in others much higher in the apical part (see figures above).

In descriptions phrases like ‘about 3 times as high posteriorly as anteriorly’ is meaningless if it is not clear where ‘anteriorly’ is located. These values sometimes correspond with the measured values from figures, but are sometimes deviate considerably. There are a few species where the sexes are very different, for other species the ratio is very similar, and for most species there are too few datapoints to draw any conclusions. On average the ratio is 1.62 for females and 1.73 for males, but for males there are far fewer datapoints. When data for one sex is lacking, male and female are presumed to be in the same category.

1	2	3
small < 1.4	medium 1.4 - 1.8	large h75 : h25 > 1.8
 C. atripes (P4)	 C. corvulus (P2)	 C. bidentulus (P2)

Position of maximum height

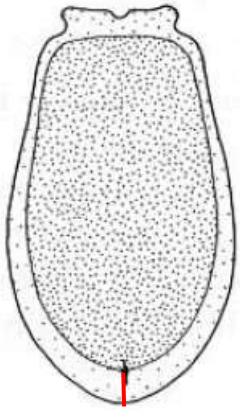
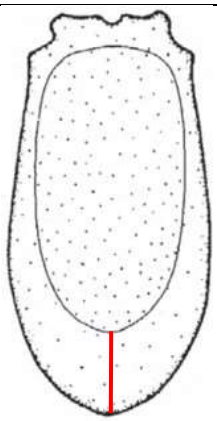
The position where the height is maximal, expressed as % of metasomal length, could be expected be strongly related to the previous variable. This is only partly the case because the height at 25% of metasomal length is an important factor in that ratio, but has little impact on the position of maximum height. The position of maximum height varies from 60 to 85% of metasomal length for females, and 70 to 85% for males. More than 75% of males have a maximum height beyond three quarters of metasomal length, for females that is less than 50%.

1	2	3
anterior < 70%	medium 70 - 80%	posterior > 80%
 C. erosus (P3)	 C. caradrrinae (P12)	 C. canescens (P1)

Metasoma ventral view

Metasoma posteriorly curved forwards

Some species of Chelonus have the end of the carapace more or less strongly curved forward ventrally. This character is often described as ‘incurved’ or ‘slightly incurved’, and as a measure the length of the ventral cavity of the metasoma is sometimes compared to the metasomal length. From the few figures of the ventral side of the metasoma this ratio can also be calculated. This can then be converted to %incurved. Comparing the descriptions with the measurements from the figures (of same species) gives the following categories:

1	2	3
(almost) not 0 - 5%	just/slightly incurved 5 - 12.5%	(distinctly) incurved > 12.5%
 C. sulcatus (P4)	 C. elaeaphilus (P13)	 C. bidentulus (P2)

♀ ovipositor shape

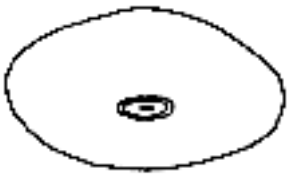
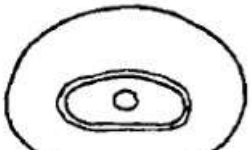
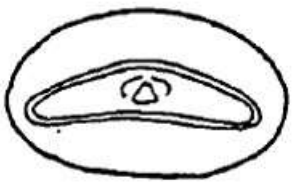
The ovipositor of *Chelonus* females can be extended, but is often hidden. Size of the ovipositor is difficult to estimate if you don't know how far it is extended. If the ovipositor is visible it is possible to see if it is thin or thick, and straight or curved. The information however is scarce, and the description for most species is 'straight'. A few species have a curved or even falcate ovipositor, which can be very distinctive. An ovipositor is sometimes associated with a ventral groove on the posterior side of the metasoma. In only 8 species a groove, from weak to deep and wide, is mentioned.

♂ apical aperture (posterior view)

Many males of *Chelonus* (the males of the *Microchelonus* group) have an apical aperture on the posterior end of the metasoma, which varies in shape and size. According to Tobias (2104), without this feature it would be almost impossible to identify males of *Microchelonus*, as they as much more alike than the females of the different species. Both shape and size are important; the size can range from a small dot on the posterior end to a large slit like opening extending forward for half of the metasomal length. The size is expressed as aperture width : metasoma width, aperture height : metasoma height and aperture length : metasoma length. The shape varies from round to oval or bean shaped to slit like.

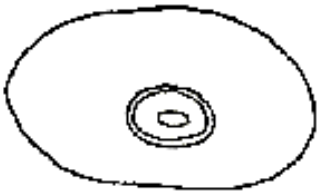
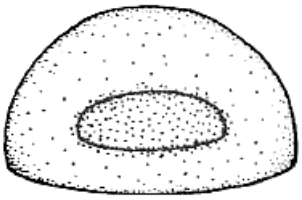
Aperture width : metasoma width

The ratio aperture width : metasoma width varies from 0.1 to 1.0 (0.15 to 0.95 in figures). A large group of species has values around 0.3, a second group from 0.5 to 0.6 and several species have a very wide aperture which results in values of 0.7 and higher. Species without an apical aperture are in a special category. The categories are:

1	2	3	4
no aperture	small <= 0.4	medium 0.4 - 0.65	large > 0.65
	 C. minifossa (LT2)	 C. scabrosus (TL)	 C. risorius (TL)

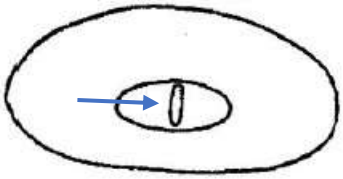
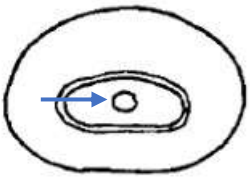
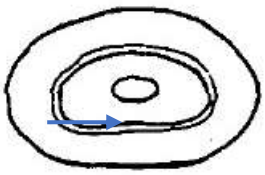
Aperture shape (width : height ratio)

The shape of the male apical aperture is described as ‘round’, ‘nearly round’, ‘oval’, ‘long oval’ or ‘slit’. These descriptions are of course directly correlated with the aperture width : height ratio. In addition the aperture can sometimes be bean shaped or triangular, which may have the same width : height ratio as ‘oval’. The width : height ratio overlaps with the previous variable aperture width : metasoma width, but is for some species different, and for many species only one of these two characters is mentioned. By including this variable more species are compared.

1	2	3	4
n.a.	(nearly) round w: h <= 1.75	oval 1.75 - 3.5	elongate - slit > 3.5
	 C. bosonohyi (TL4)	 C. pedator (P1)	 C. sulcatus (P3)

Median process width : height ratio

Often there is a median process, or a tubercle, visible in the apical aperture, sometimes protruding from the aperture. The difference in shape is remarkable, with a group of species having a clearly vertical process, while others have a more or less horizontally elongated tubercle. Tobias (1995a) gives a key to subgenera where ‘[aperture] with vertical middle carina occupying almost entire height’ leads to the subgenus *Stylochelonus*. In many figures the tubercle is not drawn, while it is present according to other figures or to the description. It is a very small structure, and it is not certain how exactly it is drawn in the figures. Still, as the aperture is such an important feature for identifying the males of *Chelonus*, and Tobias (1995a) uses it as a key distinctive element, it is included as a variable with three categories.

1	2	3	4
n.a.	vertical carina w: h < 1	horizontal, nearly round 1 - 2	horizontal oval > 2
	 C. mucronatus (T14)	 C. scabrosus (TL)	 C. macrellips (TL)

Sculpture

In addition to morphology and colour, surface sculpture is important in identifying *Chelonus* species. Definitions of sculpture seem to vary between authors. There is a wide overlap between 'striate' and 'rugose', and between 'punctate', 'areolate/foveolate' and 'reticulate'. The terms 'rugulose', 'granulate' and 'coriaceous' also seem to be mixed. This makes it difficult to compare the descriptions of sculpture, especially from different authors. Below a list of terms used in *Chelonus* literature is given with definitions, frequency of use, and figures when available.

For the direction of the sculpture 'transverse', 'longitudinal', 'concentric', 'sinuous' and 'irregular' are used. 'Longitudinal' describes all sculpture in the direction from front to apex and on legs from proximal to distal, 'transverse' runs perpendicular to this direction. The use of 'longitudinal' for rugae or striae on temples by some authors is probably wrong; while the rugae run lengthwise over the temples, they are transverse in relation to the body axis.

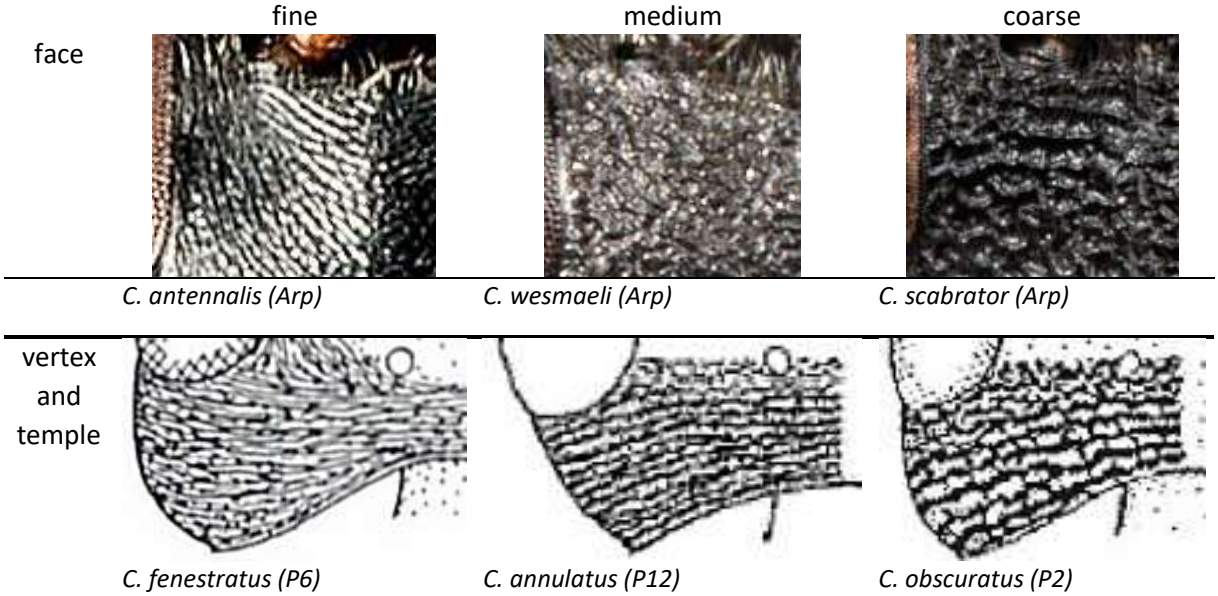
The location on the body part where the sculpture is looked at is very important; the sculpture of the middle or the side of the face can be different, the same applies to the clypeus, and the sculpture of the metasoma is often very different for the anterior, lateral and posterior parts.

Head

The sculpture of the head is often described in detail. The clypeus, face, vertex behind ocelli and the temple are most often reported, and sometimes also of the frons and the antennal scrobe (frontal fossae, antennal fossae). The clypeus is most distinct, being punctated instead of rugose, and much smoother and shinier. The face and frons sometimes have reticular elements, while the vertex and temple are almost always transversely striate to rugose.

There are large differences between species in the coarseness of the sculpture, which varies from very fine to coarse. After comparing the available data for all species it can be concluded that, as might be expected, the sculpture coarseness is very much the same for face, vertex and temple. The coarseness can therefore be expressed as a variable for the coarseness of the whole head (excluding the clypeus). The coarseness is divided in three classes, below depicted for face and vertex/temple.

head sculpture coarseness

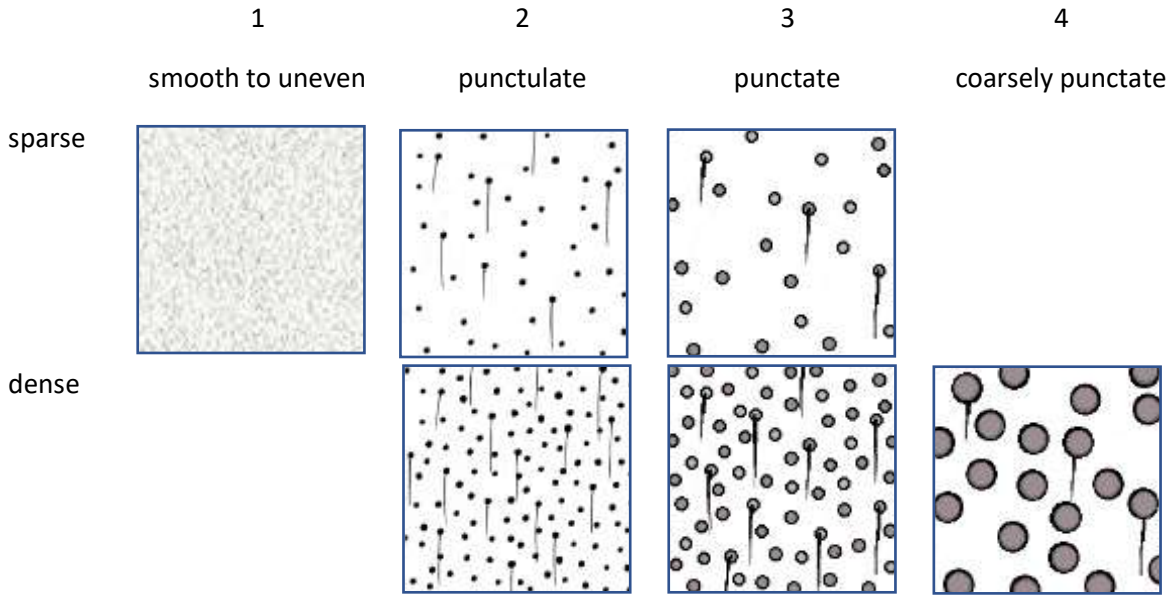


Clypeus

The clypeus almost always has a very different sculpture from the remainder of the head. The border between clypeus and face is therefore often distinct. The sculpture at the base (upper part) of the clypeus may not be the same as the sculpture near the lower border. To compare species, it is best to look at the sculpture on the same location on the clypeus. A spot medially on the clypeus, somewhat towards the base is usually a smooth area with uniform sculpture. The most frequent sculpture here is 'punctate', with a gradient from 'smooth', 'punctulate', 'punctate' to 'coarsely punctate' and a gradient from 'smooth', 'sparse', 'medium' to 'dense'. In a few species this is combined with striate or rugose elements. The clypeus and the scutellum are the only parts that have a punctate sculpture in the definition of Harris (1979): 'fine, impressed points or punctures appearing as pin-pricks'. The term 'punctate' as used in other parts often refers to larger pits or depressions that would be better named 'alveolate', 'areolate' or 'reticulate'.

Next to surface sculpture there are also the characters 'shiny', 'slightly shiny' or 'matt', and the amount of pubescence on the clypeus. Almost all species have a shiny clypeus, the few exceptions are species with rugulose or densely punctated sculpture. Pubescence is sometimes described, especially when it is dense. As there are considerable differences it seems like a character to include, although more data is required to be really useful.

clypeus sculpture in median part



Face

The sculpture of the face varies from striate to rugose to reticulate and punctate, and from fine to coarse. If the sculpture is striate or rugose, the direction of the striae or rugae can be completely transverse, transverse in the middle and longitudinal near the eye or concentric or fan-shaped, diagonally running from the upper corners of the face to the middle. If there is no overall direction (rugose, reticulate or punctate) the direction is irregular. If combined this leads to a large collection of possibilities, making it difficult to fill and choose the right options. It is easier to keep the variables 'sculpture type', 'coarseness' and 'direction' separate. The coarseness is already included in the overall coarseness of the head. Two variables remain:

facial sculpture type

1
striate

C. antennalis (Arp)

2
punctate-rugose

C. wesmaeli (Arp)

3
reticulate

C. oculator (Arp)

4
punctate
?

direction of facial sculpture

1
irregular

C. wesmaeli (Arp)

2
transverse

C. scabrator (Arp)

3
transverse-longitudinal

C. elaeaphilus(?) (Arp)

4
diagonal /concentric

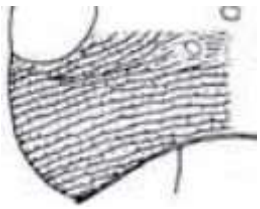
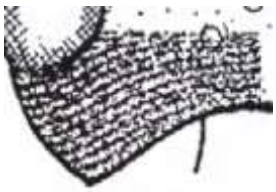
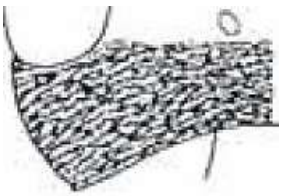
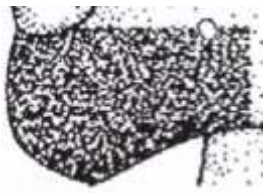
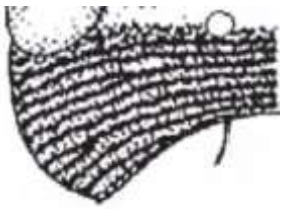
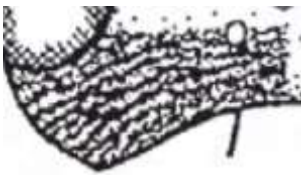
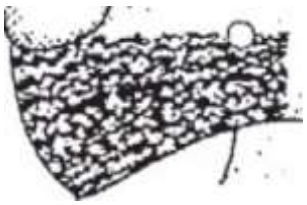
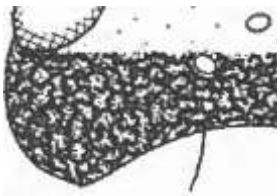
C. antennalis (Arp)

Vertex behind ocelli and temple

Although the temple is often described separately from the vertex, they almost always share the same sculpture, as seen in the figures below. Therefore, the vertex and temple are combined in this analysis.

The sculpture of the vertex behind the ocelli and the temple is very often described. Almost all species have a transversely rugose/striate vertex, with a few exceptions which are irregularly rugose or rugulose. The few descriptions of a reticulate-rugose sculpture are all from Zhang (2008) suggesting a different definition of the term 'reticulate', perhaps where others use 'anastomosis' to indicate cross-wrinkles between the striae or rugae, or it may be a translation error from the Chinese text. The main difference is in the coarseness of the sculpture, which is already taken care of in the general coarseness of the head.

Remains the difference between striate and rugose. This appears to be distinct in many cases, although there is also overlap in many descriptions, and the terms are not always used in the same manner. Luckily, Papp very often drew the sculpture in his figures of the head in dorsal view, and as they are made by the same author who apparently thought this important, these figures may be a good source. In the figures below a range of sculptures is shown, depicting 4 categories from striate on the left to rugose on the right. Examples of both fine (top row) and coarser sculpture (bottom row) are given.

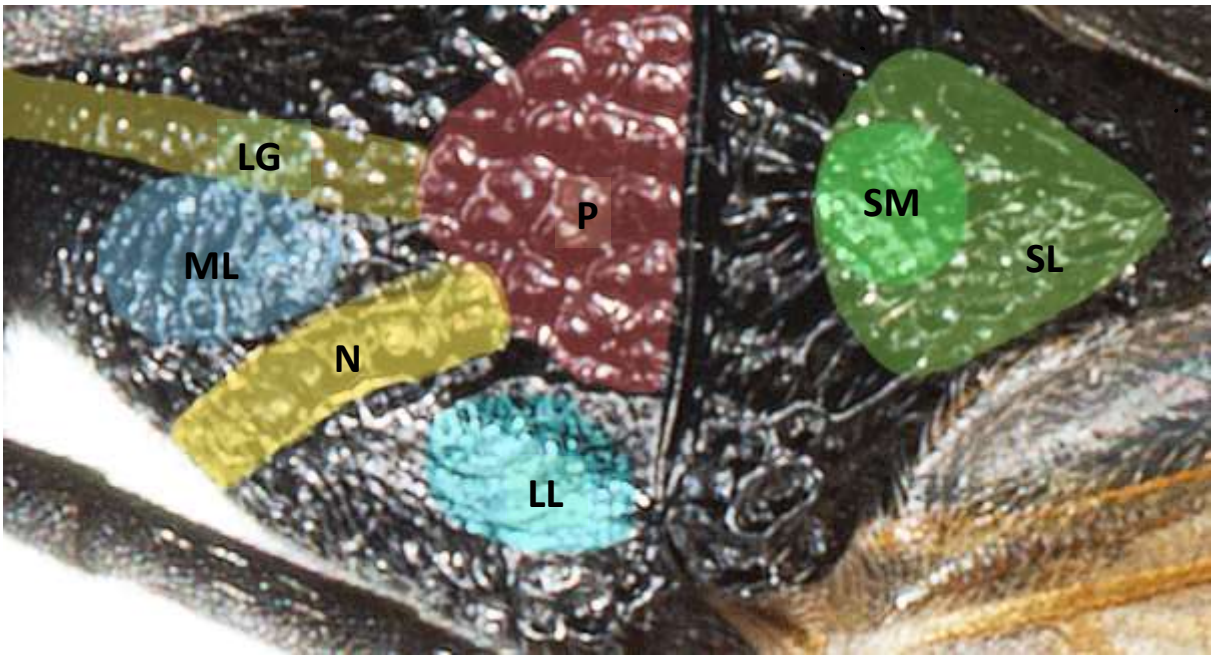
1	2	3	4
striate (striolate)	striate-rugulose	transverse rugulose	rugulose
			
C. pellucens (P3)	*C. pannonicus (P7)*	*C. elongatus (P7)*	*C. mucronatus (P2)*
striate	striate-rugose	transverse rugose	rugose-reticulate
			
C. humilis (P2)	*C. breviventris (P2)*	*C. cylindrus (P2)*	*C. pilicornis (P1)*

Other potential variables

Other characters of the facial sculpture have been described, some of which seem promising, such as the presence of a border between clypeus and face, and the sculpture of the antennal fossae (antennal scrobe). Unfortunately there are yet too few records of these characters to include these variables in the key.

Mesosoma

Data on the sculpture of the mesosoma is predominantly available for the mesoscutum and the scutellum. The mesopleuron and propodeum are sometimes mentioned, the pronotum seldomly. The main focus is therefore on the sculpture of the mesoscutum and the scutellum. The sculpture of the mesoscutum is not uniform, especially the posterior part before the scutellum is often much coarser sculptured than the remainder. The scutellum often has a different, much smoother sculpture in the middle than in the lateral and posterior parts.



LG: longitudinal groove; N: notaulus; ML: middle lobe of mesosonum (smooth patch); LL: lateral lobe of mesonotum (patch); P: posterior part of mesonotum; SM=middle of scutellum, SL= lateral and posterior part of scutellum

Mesonotum sculpture

It is difficult to describe the sculpture of the mesoscutum in one term as the sculpture is far from uniform. However, there is a pattern in the variation of the sculpture. The mesoscutum is divided by two grooves, the notauli (N), in a middle lobe (ML) and two lateral lobes (LL). The middle lobe sometimes has a median longitudinal groove (LG) dividing it. The often coarse notauli and longitudinal groove come together in the posterior part of the mesonotum, resulting in a much coarser sculptured area just before the scutellum (P).

The mesoscutum of several species was examined in order to find differences between species and to see how this matches with the written descriptions of these species. In some species there is a gradual transition between the often rough sculpture of the notauli, the longitudinal groove and the coarse lateral edge of the mesoscutum and the center of the mesoscutal lobes, leaving small smoother patches in the middle of the lobes (ML and LL). In other species the notauli are absent, and in some they are present but clearly distinct from the sculpture of the lobes. The same applies to the coarsely sculptured patch in front of the scutellum which may either be strictly separated from the lateral lobes, or the sculpture may be gradually overflowing. The notauli are frequently mentioned in the descriptions. The options mostly given are: ‘indistinct’, ‘slightly distinct’ and ‘distinct’.

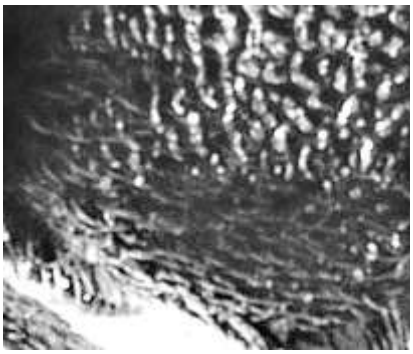
The challenge is to find some easy recognizable traits from this information, that can also be extracted from the species descriptions. After looking at many specimen, it seems that a

combination of characters can be selected to divide the species into these categories, although translating the different descriptions into these categories may be difficult:

1	2	3
notauli distinct	notauli slightly distinct through coarser sculpture	notauli indistinct
sharply contrasting sculptured areas	gradient in sculptures	mesonotum uniformly sculptured
fine & coarse	gradient fine → coarse	entirely more or less coarse

C. wesmaeli

C. scabrator



C. pedator

There seem to be several other potential characters of the sculpture of the mesoscutum which differ between species, such as the presence and shape of a median longitudinal band (ridge or groove), and the sculpture of the smooth patch on the mesoscutal lobes, but as these characters only rarely have been specified in the descriptions there is not enough information to use this in a key.

Scutellum, sculpture middle part

The sculpture of the scutellum is much simpler than that of the mesoscutum. The center is often smooth and the border rarely, while the border is much more frequently rugose or reticulate. Both areas are often punctate or rugulose. The surface is often shiny when smooth or punctate, subshiny or matt when rugose or rugulose. The center of the scutellum is consequently more often shiny than the border.

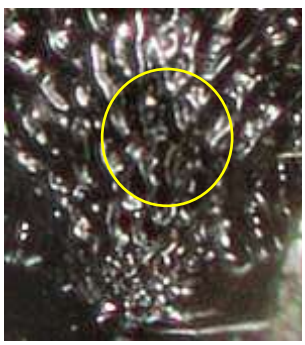
For the middle of the scutellum different options for sculpture are:

1	2	3	4
smooth	punctate	rugulose	rugose / striate

C. oculator

C. flavipalpis

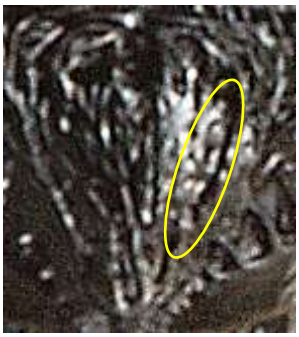
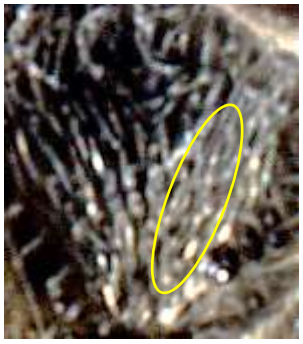
C. pedator



C. sp.

Scutellum, sculpture at margin

The sculpture of the margin of the scutellum can be classified as follows:

1	2	3	4
punctate	rugulose	rugose / striate	reticulate / crenate
			
C. flavipalpis	*C. pedator*	*C. wesmaeli*	*C. oculator*

Prescutellar sulcus and scutellum shape

The prescutellar sulcus can be narrow in the middle and wide at the margins, or it can be evenly wide over its length. This results in a scutellum that varies from diamond shaped or triangular. There is unfortunately hardly any information on this character available.

Legs

The sculpture on the dorsal side of the hind coxae is sometimes used in species descriptions, mostly by Telenga (1941). This sculpture varies from (almost) smooth and shining to slightly rugose to rugose. However, of only 17 species data are available, of which only two have a smooth coxa, while the rest is rugose. This character is useful for additional information of species, but not for use in the key.

Metasoma

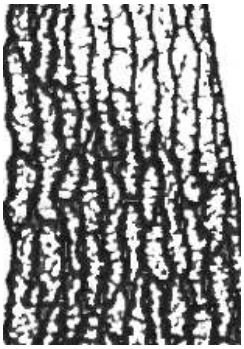
For the average Chelonus species the metasoma is rugose/striated at the base and towards the apex the sculpture becomes less coarse and the longitudinal elements disappear. The species can vary in the following characters:

sculpture at base / middle of metasoma

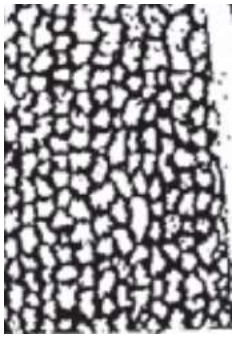
The sculpture at the base of the metasoma can range from sulcate/striate - striate-rugose - longitudinally rugose - rugose / reticulate, where the longitudinal element varies from very strong to absent. Thanks to the many figures in publications by Papp the different categories can be illustrated using several examples. However, the borders between the categories are vague, and even Papp sometimes uses 'longitudinally rugose' in combination with figures that in these categories would fall in category 2, 3 and 4. The figures from Papp show the sculpture from about 35 - 60% from the base of the metasoma. By far the most species are described as having 'longitudinally rugose' sculpture at the base of the metasoma, much fewer 'striate-rugose' or 'rugose / reticulate'. Only a few species have distinct (sulciform) striae.

1	2	3	4
(sulcate) / striate	striate-rugose	longitudinally rugose / rugose-reticulate	rugose / reticulate
straight lines without cross links	straight or wavy, clearly longitudinal	longitudinal elements less clear, but visible	irregular

C. sulcatus (P3)



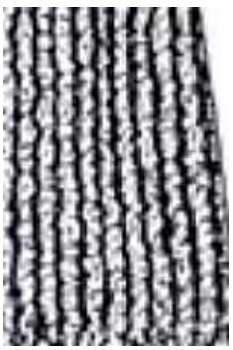
C. annulipes (P1)



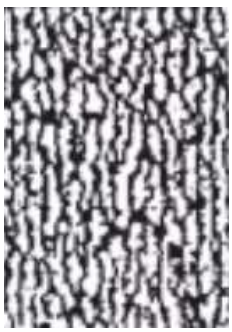
C. cesa (P7)

C. submuticus (P1)

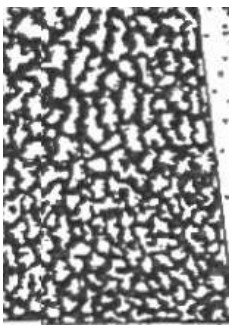
C. scabrosus (P3)



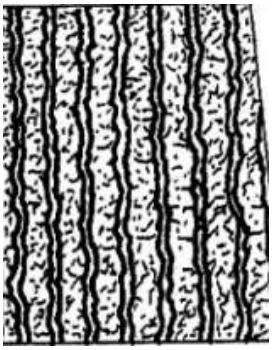
C. risorius (P3)



C. bidentulus (P2)

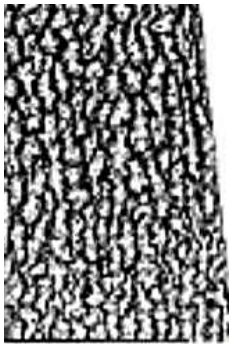


C. canescens (P1)

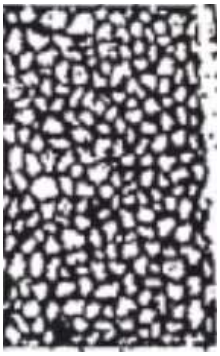


C. subsulcatus (P8)

C. fenestratus (P13)



C. lugubris (P1)



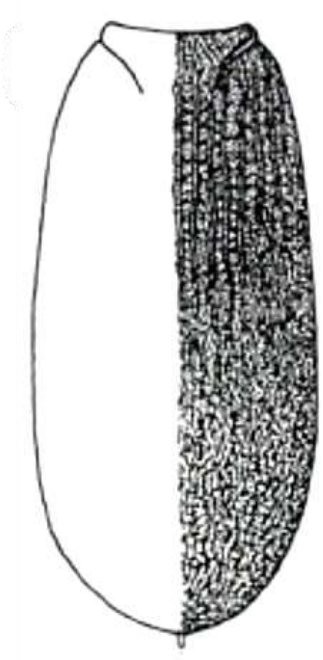
C. mucronatus (P2)

boundary between coarse and fine sculpture

The sculpture of the metasoma is often much finer on the posterior part. Often there is a more or less clear line where the sculpture changes. The position where the coarser longitudinal or reticular elements in the sculpture are replaced by smoother sculpture is variable, it can be limited to the base or may extend to the apex.

1

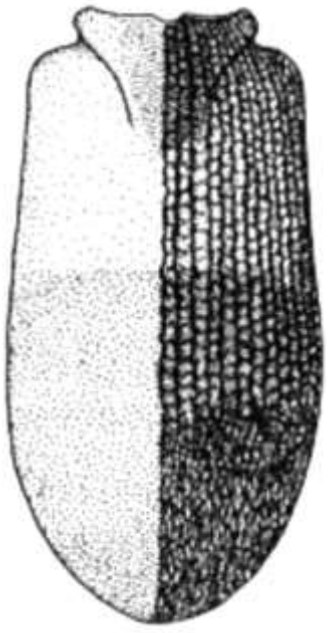
base (to 50%)



C. atripes IP4)

2

mid (50 - 70%)



C. fenestratus (P13)

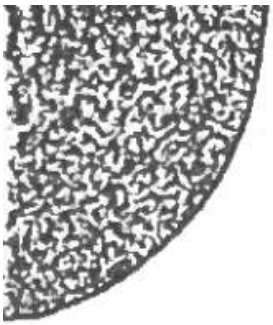
3

apex (>70%)

C. scabrosus (P3)

sculpture at apex of metasoma

The sculpture at the apical third is usually finer than the sculpture at the base, and can vary from smooth and shiny to rugulose to striate. For many species the sculpture at the apex is not mentioned. Looking at the available pictures however, leads to the conclusion that rugulose is the standard sculpture of the metasomal apex. When not mentioned, the sculpture is assumed to be rugulose. It is not surprising that most species are included in this category.

1		2	3
rugose-striate	(reticulate) / rugose	rugulose / coriaceous	smooth / uneven
			
C. scabrosus (P3)	*C. atripes* (P4)	*C. annulipes* (P1)	*C. annulatus* (P12)

Other characters

The striae may be connected by cross-carinae (anastomosis) or have microsculpture (rugulose or coriaceous), but for those characters too much information is lacking, and it would become too complex for the key. The length of the two basal carinae is sometimes mentioned, but are difficult to convert to meaningful values.

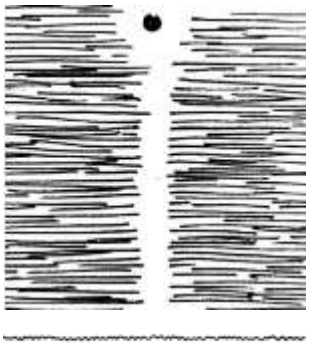
Surface sculpture terms used in *Chelonus* descriptions

All definitions of terms according to Harris (1979), except when marked 'M' (Martynova 2017).

aciculate

appearing as if irregularly scratched with a needle

used: *



aciculate (Martynova 2017)

---

alveolate

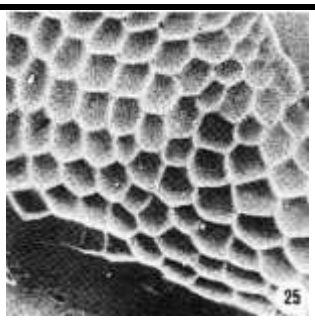
honeycombed; with regular, deep, angular cavities (alveolie) separated by thin partitions. Furnished with cells or alveoli

used: **

synonyms used: honeycombed

compound terms:
alveolate-rugose

~ areolate, reticulate



alveolate (Harris 1979)

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areolate

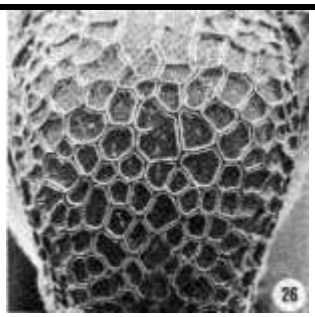
divided into a number of small, irregular spaces

used: ***

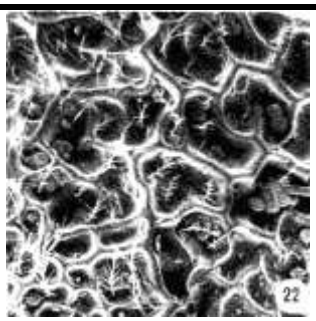
synonyms used:

compound terms:
areolate-punctate: *
areolate-rugose: ***
areolate-rugulose: *

~ alveolate, reticulate



areolate (Harris 1979)



areolate-rugose (Harris 1979)

areolate-rugose (Papp 2014a)

coriaceous

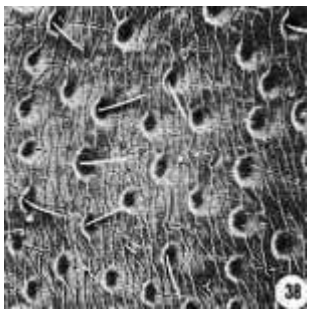
leather-like in sculpture; with minute cracks like the human skin

used: ***

synonyms used: **leathery**
coriarious: correct term for coriaceous according to Harris (1979), but hardly used for Hymenoptera.
shagreened

compound terms:
coriaceous-rugose (leathery-rugose): *

sub: subcoriaceous: *



coriaceous-punctate (Harris 1979)

coriaceous (Martyn)ova 2017

crenulate (crenate)

having the margin finely/evenly notched with (small,) rounded teeth

used: ***

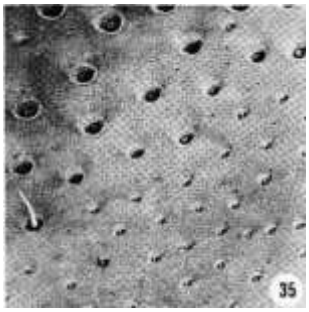
foveolate

with small deep pits; finely pitted

used: *

synonyms used:

compound terms:



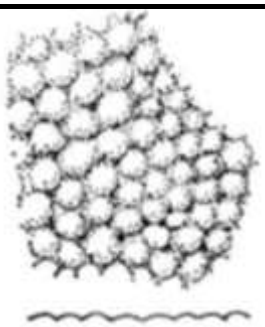
foveolate above, punctate below (Harris 1979)

granulate

covered with or made up of very small grains or granules. Also, minutely and densely verrucose or minutely farinose

used: ***

compound terms:
granulate-punctate: *
granulate-rugose: **



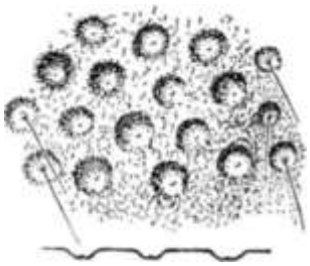
granulate (Eady 1968)

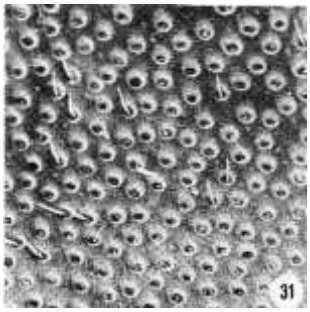
punctate

set with fine, impressed points or punctures appearing as pin-pricks

used: ****

compound terms:
punctate-reticulate: *
punctate-rugose*:* *
punctate-subpunctate*:* *



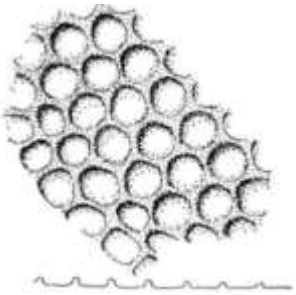


sub: subpunctate: **

punctate, with setae (Eady 1968)

punctate (Harris 1979)

~ foveolate, punctulate



punctate-reticulate (Eady 1968)

punctulate

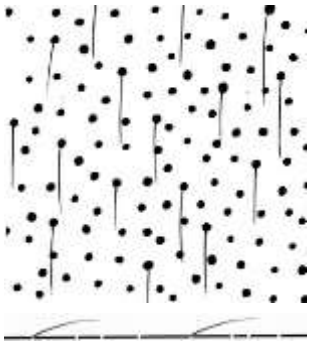
finely punctate; with numerous minute and close set punctures

used: ***

synonyms used: engraved points

compound terms:
punctulate-rugose: *
punctulate-rugulose: *

~ punctate



punctulate (Martynova 2017)

reticulate

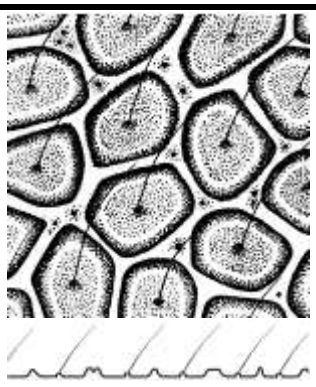
superficially net-like or made up of a network of lines; meshed; netted

used: ****

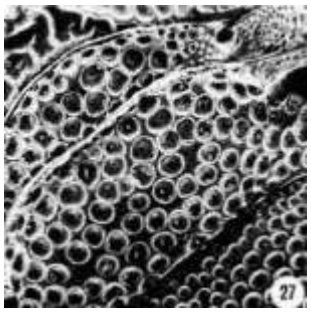
compound terms:
reticulate-rugose: ***
reticulate-rugulose: ***
subreticulate-punctate: *

sub: subreticulate: **

~ alveolate, areolate



reticulate (Martynova 2017)



foveate-reticulate (Harris 1979)

rimose

with minute, narrow and nearly parallel excavations (rimae) running into each other; chinky; resembling the cracked bark of a tree

used: *

compound terms:
rimose-rugose: *

rimulose

minutely rimose; with minute cracks or fissure-like openings with sharp edges

used: *

rugose

wrinkled (H), surface with irregular large, either shallow or deep rugae (M)

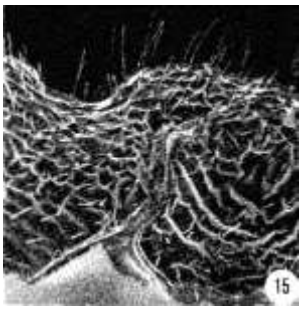
used: ****

synonyms used: wrinkles, folds

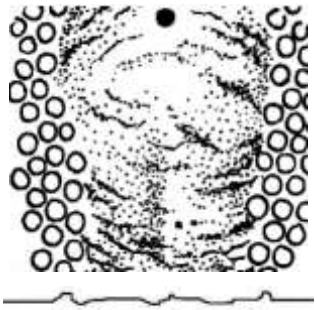
compound terms:
rugose-punctate: ***
rugose-punctulate: *
rugose-rugulose: **
rugose-striate: ***

adjectives: concentric (***), longitudinal (****), transverse (****) sharp (**), irregular (***), sinuate, wavy, tortuous, undulate, winding, serpentine (****), anastomosed (***)

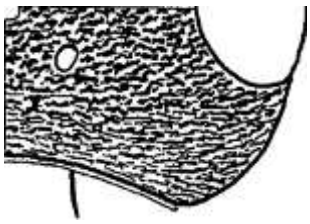
~ *scabrous*



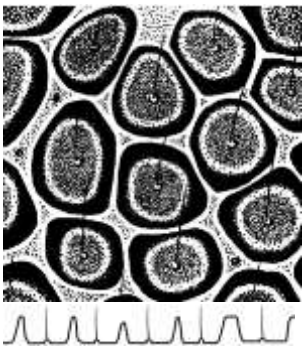
rugose (Harris 1979)



rugose (Martynova 2017)



rugose-rugulose (Papp 2014a)



rugose-punctate (Martynova 2017)

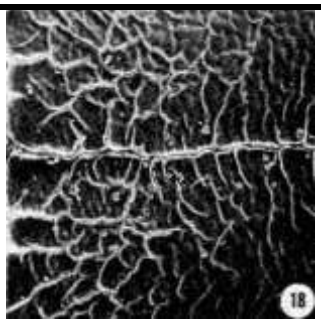
rugulose

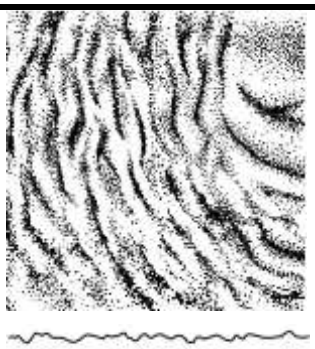
minutely rugose; minutely wrinkled (H). Irregularly sculptured surface with numerous fine confluent rugae (M)

used: ****

synonyms used: uneven = subrugulose?

compound terms:
rugulose-punctate **



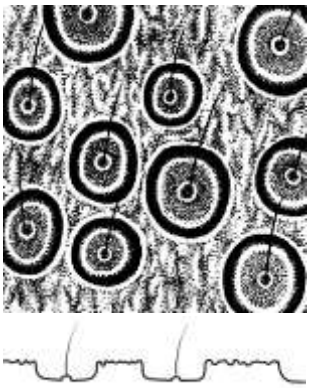


rugulose-striate: *
rugulose-striolate: *

sub: subrugulose: *

rugulose (Harris 1979)

rugulose (Martynova 2017)



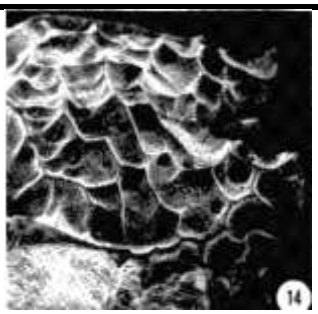
rugulose-punctate (Martynova 2017)

scabrous

rough; irregularly and roughly rugose; possessing short, sharp projections or wrinkles

used: *

synonyms used: scabrose



scabrous (Harris 1979)

scrobiculate

uniformly covered with short, oblong or trenchlike hollows

used: *

smooth

devoid of any sculpturing (sens. lat.)

used: ***

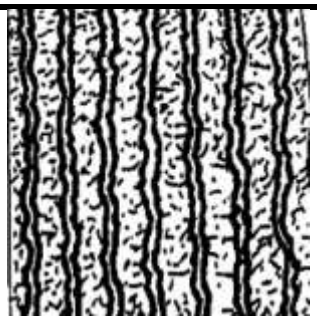
synonyms used:
glabrous: preferred term according to Harris (1979) but much less used and better to reserve for area without setae

striate

marked with parallel, fine, longitudinal impressed lines or furrows

used: ****

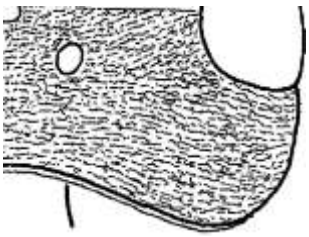
compound terms:
striate-reticulate-rugose: *



striate-rugose: **
striate-rugulose: *
striate-subrugulose: *

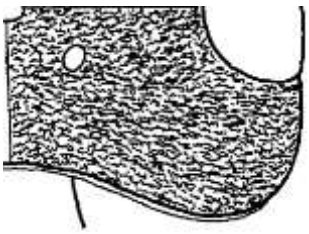
sub: substriate*:* *

~ strigate



finely substriate (Papp 2014a)

striate, interstriations uneven-rugulose (Papp 2014a)



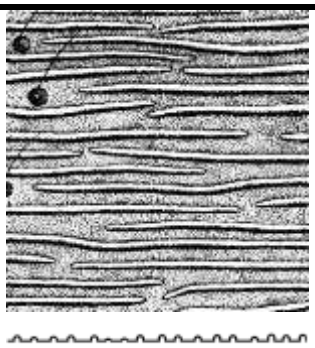
striate-subrugulose (Papp 2014a)

strigate

having narrow, transverse lines or streaks, either raised or impressed; composed of fine, short lines

used: *

synonyms used: strigose



~ striate

strigate (Martynova 2017)

striolate

minutely or finely striate; with numerous parallel and very fine longitudinal impressed lines or furrows

used: **

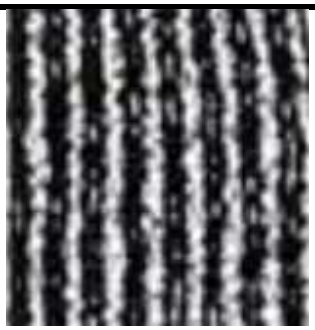
synonyms used: finely streaked: *

sulcate

deeply furrowed or grooved

used: *

synonyms used: sulciform striate



sulciform striate (Papp 2004)

*: 1-3 occurrences **: 4-10 occurrences, ***: 11-50 occurrences, ****: >50 occurrences

The prefix ‘sub’ modifies the meaning of the term, meaning ‘under’, ‘slightly less than’, or ‘not quite so’ (Harris, 1979).

Sculpture literature

R. D. Eady. 1968. Some illustrations of microsculpture in the Hymenoptera. Proceedings of the Royal Entomological Society of London. Series A, General Entomology. Volume 43, issue 4-6, 66-72.

R. A. Harris. 1979. A glossary of surface sculpturing. California Department of Food and Agriculture, Bureau of Entomology, 28, 1-31.

K.V. Martynova. 2017. Microsculpture of cuckoo wasps (Hymenoptera, Chrysididae): general overview with first attempt of classification. Ukrainian Entomological Journal 12: 7-19.

Colour

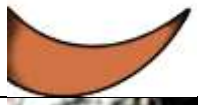
The default colour of *Chelonus* species is black. Many species are entirely black except a few light patches on the legs, other species have also white, yellow or orange/reddish patches on the metasoma in the shape of lateral spots, a medial spot, a basal band or a complete light coloured base. A few species have the mesosoma partly reddish. Some species have partly coloured antennae, and the colour of palpi and mandibles is variable.

The extend of colouration may be quite variable and is probably partly due to environmental conditions (especially temperature during pupal development). However, the colour pattern seems to be much more stable. Males are often darker than females, this is especially visible on the metasoma, where yellow patches in females are distinct but smaller or absent in males. The legs of males may be darker but as the colour patterns are usually the same, the sexes are here not separated, unless specific information is available.

Head

mandibles

Below are the four colour patterns that were found in descriptions and photographs of *Chelonus* mandibles. Mandibles of almost all species have a blackish base, so descriptions like 'mandibles red in middle' are included in the category 'dark tip'. Also the ultimate tip is also often black, even in the category 'light tip' or 'entirely light'. A 'black tip' means a substantial black tip of at least 25% of the mandible. The term 'dark' includes black and dark brown, 'light' is brown, red, orange, or rarely yellow. Very often the colour of mandibles and/or palpi is not mentioned. This could mean that they have the default colour, which is black, or that this character state is overlooked. As several species in which this data is lacking do have coloured mandibles (see *C. pictipes* and *C. antennalis* below), no information on palpi or mandibles is interpreted as missing data.

1	2	3	4
entirely dark	dark tip	light tip	entirely light
			
			
	C. pictipes		*C. antennalis*

palpi

The palpi can vary in colour from black to pale yellow. The chosen categories are as follows:

1	2	3	4
black, dark brown	brown, red	light brown, brownish yellow	yellow, ivory, white
			

			
C. scabrator		*C. wesmaeli*	*C. flavipalpis*

Antenna: scapus

The scapus is, just like the rest of the antenna, very often black or dark brown. In some species the scapus can be red, brown or rusty, and in a few cases reddish or brownish yellow. In the categories below the scapus can be completely or partially coloured.

1	2	3
black, dark brown	brown, red	reddish or brownish yellow
		
C. scabrator	*C. flavipalpis*	*C. antennalis*

Antenna: segment 3 and 4

The flagellum of the antenna is also sometimes partially or completely coloured, most often the basal segments but sometimes the basal half of the flagellum. Here we look at the colour of antennal segments 3 and 4 (flagellar segments 1 and 2), and use the same colour categories as for the scapus.

For many species no information is given on the colour of the antenna. As coloured antennae are rare for *Chelonus* we can assume that such a trait would be mentioned in a description, and that no description of colour means 'black'.

1	2	3
black, dark brown	brown, red	reddish or brownish yellow
		
C. scabrator		*C. antennalis*

Mesosoma

The only species in this area that do not have an entirely black mesosoma are *C. olgae*, which has a yellow-brown mesosoma, and *C. cyprianus* in which the mesosoma is reddish brown.

Legs

Colours

In photographs of several *Chelonus* species the hue of the colour of the legs (if not black) varies very little. In the HSL colour model (for hue, saturation, lightness) the hue is in the range from 26 to 36, from somewhat orange to brownish yellow. The main variation in colour is due to differences in saturation (gray - colour) and lightness. As the differences in hue are small, it is better to focus on the colour patterns on the legs, using only the categories black/dark, medium dark, medium light and light/white.

The colour of the legs is extensively described. Not only because the legs are often the only parts that have any colour, but the colouration of the legs is sometimes quite distinctive. Most frequently the colour and colour pattern of the hind tibia is mentioned, followed by the fore tibia, the tarsi, mid tibia, the femora and the coxae. The colour of the male legs may be darker in some species and lighter in others. If not specified males and females are assumed to have the same colour.

Fore coxae

The colour of the fore coxae is usually black or dark brown, but is in some species much brighter coloured. Often these species also possess largely brightly coloured fore tibia, but other species with light coloured legs have black coxae, so the colour of the fore coxae is not exclusively linked with the colour of the fore femur. If the colour of the coxae is not described, it is assumed to be dark. The majority of the species have dark fore coxae. The colour options are:

1	2	3
dark	medium dark	medium light
		

Fore femur colour and colour pattern

The fore femur is quite variable in colour between species, both in the lightness of the colour and in the extend of the colour. Indicate the lightest colour present on the fore femur. If there is no light colour, choose dark. The most frequent combination is a medium light tip.

1	2	3	4
dark	medium dark	medium light	light
			
black, dark (brown)	brown, red, orange brown	yellowish brown, brownish yellow	yellow

The fore femur can be uniformly black, uniformly coloured, or have a small or extended light apex. The femur is uniformly coloured if the colour is clearly lighter than the colour of the mesosoma.

1	2	3	4
entirely dark	tip light (<50% light)	base dark (>50% light)	entirely coloured
			

Fore tibia and tarsus colour and colour pattern

Although the fore tibia is the part of the legs most often described, it does not add much information to separate the species. A large majority of species have entirely medium dark to medium light coloured fore tibiae. A few species have completely dark or light tibiae, or have only the base or tip coloured. The differences in tibia colour also correspond well with the differences in femur colour. The same applies to the fore tarsus, which shows more or less the same differences in colour.

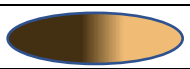
Mid leg colour

The middle legs seem to be intermediate between the fore and hind legs with respect to colouration. It is therefore better to focus on the colour of the fore and hind legs.

Hind femur colour and colour pattern

The difference in the colour of the hind femur is often used in keys and descriptions. It appears to be an important trait for identifying *Chelonus* species. In many species the hind femur is uniformly black to brown, others have a more or less light tip or base, or are entirely coloured. These characters are separated in the following variables:

lightest colour on hind femur			
1	2	3	4
dark	medium dark	medium light	light
			
black, dark (brown)	brown, red, orange brown	yellowish brown, brownish yellow	yellow

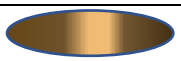
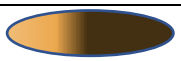
colour pattern of hind femur			
1	2	3	4
entirely dark	tip light	base light	entirely coloured
			

Hind tibia colour and colour pattern

Of all the joints of the legs, the hind tibia is most frequently mentioned, and this is also the most complex part, with very often a light coloured ring and a dark base and apex of variable size and colour.

To make this trait selectable we have to use two variables: the lightest colour and the pattern of this light patch.

lightest colour on hind tibia			
1	2	3	4
dark	medium dark	medium light	light
			
black, dark (brown)	brown, red, orange brown	yellowish brown, brownish yellow	yellow, white

colour pattern of hind tibia					
1	2	3	4	5	6
entirely dark	narrow light ring	narrow light base	wide light ring	wide light base	entirely coloured
<10% light	10-50% light		50-90% light		>90% light
					

Hind tarsus and hind basitarsus

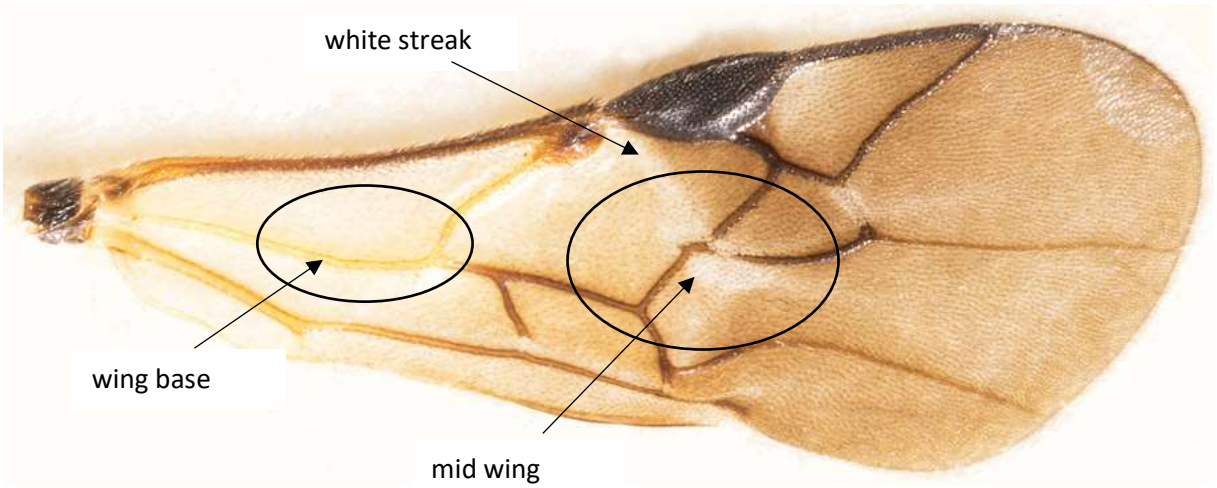
The hind basitarsus is sometimes distinctly brighter coloured than the remainder of the hind tarsus, and often also brighter than the remainder of the legs with an almost white or ivory colour. However, it can also be just as dark or light as the remainder of the hind tarsus. If no separate colour is given for the basitarsus, is assumed to be the same as the (remainder of the) hind tarsus. The tarsus colour is used in the following two variables:

lightest colour on hind tarsus segment 1 (basitarsus)			
1	2	3	4
dark	medium dark	medium light	light
			

lightest colour on hind tarsus segments 2-3			
1	2	3	4
dark	medium dark	medium light	light
			

Wings

Wing of Chelonus are often darkened or slightly darkened, but sometimes transparent. The base of the wing can be lighter or darker. Some species also have a whitish streak or a dark band below the base of the pterostigma. The colour of the pterostigma itself can vary from black to brown, occasionally brownish yellow, but in many species a range from black to brown is given. Basal veins can be significantly lighter than veins in the middle or apex of the wing, sometimes almost white, while in other species all the veins are black. The colour of the basal veins is correlated with the colour of the basal part of the wing; yellow or white veins corresponds with a pale, light or transparent wing base. Similarly, the colour of the mid- and apical veins agrees with the background colour of the wing.



To catch the relevant traits of the wing colour and the difference in colour between base and apex, we use the next two variables:

*colour of **middle** of wing and veins*				
	1	2	3	4
veins (mid wing)	dark *black, dark brown*	medium dark *brown*	medium light, *brownish, light brown*	light *yellowish, yellow*
mid wing	clearly darkened	darkened	slightly darkened	pale, transparent

*colour of wing **base** and basal wing veins*				
	1	2	3	4
basal veins	dark	medium dark	medium light	light, yellowish
wing base	clearly darkened	darkened	slightly darkened	pale, transparent

Tegulae

The colour of the tegulae is frequently described. It varies from black to yellowish brown but the variability is large; in many species the whole range of colours is given, making this a useless trait in these cases.

Metasoma

The most striking colours of *Chelonus* are visible on the metasoma. Although most species are entirely black, there are many that have white/yellow spots or bands on the base of the metasoma. The extent of the colour is very variable; in the same species the light patches can vary from very small spots (or absent) to large round patches or complete bands, and males are usually darker than females. Still, the pattern of these light patches can be very distinctive and some species can be directly identified based on these colours. Tobias (2001a) provides a key to *Microchelonus* species with yellow spots and pale body parts.

Of the 114 species in this area 36 can have colour on the metasoma. In almost all of these species the colour is restricted to the basal third (= 1st tergite) of the metasoma. The few exceptions are *C. pappi* where the metasoma is entirely brownish yellow, *C. bonelli* with large red spots on the apex, and *C. wesmaelii* which has an orange colour on the basal and middle parts of the metasoma. *C. basalis* may have a red to white colour up to half of the metasoma, laterally to two-thirds. Most of the species with colour on the metasoma have 1 or two light spots, or the base is completely coloured. Only four species may have a coloured band, where at least the middle of the anterior edge of the base is black.

The first step is to separate species with and without a coloured metasoma:

colour of metasoma		
1	2	3
entirely dark	colour only on basal third	colour reaching apical two-thirds
		
C. pedator	*C. scabrator*	*C. wesmaelii*

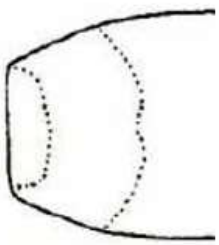
For the species with colour on the metasoma the next step is to indicate the lightest colour.

lightest colour on metasoma			
1	2	3	4
black, dark	medium dark	medium light	light, ivory, yellowish
			
			

The next three variables are used to separate the different shapes:

colour pattern of metasomal base (*basal third of metasoma*).			
1	2	3	4
entirely dark	1, 2 or 4 spots	band	entirely coloured
			
C. pedator	*C. scabrator*	*C. pictipes*	*C. antennalis*

number and position of light spots on metasomal base					
1	2	3	4	5	6
n.a.	1 medial spot	2 spots	2 spots	2 spots	4 spots
		lateral, small	lateral, large	anterior corner	
no spots					
	C. flavipalpis	*C. scabrator* ♂	*C. scabrator* ♀	*C. pictipes*	

shape of light band on metasomal base			
1	2	3	4
n.a.	regular edge	widest in middle, corners black (extended medial spot)	irregular edge, corners light
no band			
	C. albomacula (T7)	*C. flavipalpis*	*C. pictipes*