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**GUIDE TO PREPARING SCIENTIFIC ILLUSTRATIONS IN  
ENTOMOLOGY ON AN EXAMPLE OF ICHNEUMONIDAE  
(HYMENOPTERA)**



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## **Guide to preparing scientific illustrations in Entomology on an example of Ichneumonidae (Hymenoptera)**

A.M. TERESHKIN

**A b s t r a c t :** Work is devoted to a technique of preparation of unified illustrations of zoological objects. In this work the methods of fulfillment of illustrations from completely manual up to performing the entire procedure in a graphics editor (Photoshop) are considered. The proposed technique enables fulfillment of scientific illustrations by specialists in concrete groups of organisms not necessarily possessing art skills. In the work main principles and approaches to fulfillment of scientific images of objects are stated. On an example of ichneumon flies of fam. Ichneumonidae, fulfillment of all actions necessary for creating illustrations, both of total object, and features of morphology of taxonomically significant parts of a body, is described in details and step by step. The sequence of actions from fulfillment of a contour of objects up to preparation of the final table of illustrations of a taxon in a color format is demonstrated. The possibilities of usage of intermediate layers of files with drawings as illustrations of characters for taxonomical analysis, and for revealing regularities of development of same or other characters and as illustrations in identification keys are considered. All necessary operations are illustrated with 864 drawings and the results with 47 color tables containing 285 finished color pictures of total images of imago and taxonomically significant body parts.

Principles, techniques and the sequence of operations developed for model group of insects can be used for preparation of the unified scientific illustrations of any objects of wildlife.

The guide is intended for scientists and graduate students specializing in taxonomy of any wildlife objects. It can be used in the practical training of students studying for biological specialties. The article may be useful to animal painters and designers who use computer graphics in their work.

**K e y w o r d s :** zoological object, insects, ichneumon fly, Hymenoptera, Ichneumonidae, scientific illustration, scientific picture, technique of scientific illustration, graphics editor, Photoshop.

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## Introduction

Importance of a scientific illustration of objects of wildlife does not need additional argumentation. At the present time, in a time of increasingly growing access to global information resources, the availability of unified scientific illustrations of taxa of different ranks is becoming more relevant.

The necessity of preparation of scientific illustrations in entomology is dictated by two circumstances. On the one hand, there are a lot of groups of insects the description of signs of which is a very difficult process and key couplets for such groups are presented by the texts of a considerable volume that makes identification of taxa of different ranks extremely difficult. Combination of alternatives is especially complex. For example, "... if petiole in the middle has approximately square cross-section, the same time on the border with postpetiole with knoll, or its lateral side is smooth and lower border is not edged (simultaneously ...), or ..." etc. (RASNITSYN 1981). A good example of such group is ichneumon flies subfamily Ichneumoninae (fam. Ichneumonidae). Their morphological diversity is generated not by a diversity of constant combinations of characters, but by a free, almost random combination of the same characters, that is related to character of group evolution, that leads to a plenty of closely related and difficult to distinguish species. Furthermore, the determination of superspecific taxa is more difficult than the determination of species (RASNITSYN 1978). According to G. HEINRICH (1967a), "...in a young subfamily, as the Ichneumoninae probably are, intermediate characters can be expected to be still in existence more frequently than in most other groups. Hence the genera can not be so sharply separated as our taxonomic mind would like...". One of the ways to make easier superspecific taxa identification is preparation of the tables of illustrations of typical or the most characteristic species of subfamily genera. One of the requirements of a successful solution of this problem, in our opinion, is a standard table preparation performed only by one author who specializes in investigation of the same particular group. All of the above served as the basis for preparation of this work.

On the other hand, at the description of new taxa, especially high ones, taxonomist must have typical or comparative material from different, often difficult to access collections. The solution of these problems is also seen in preparing maximally unified illustrations and descriptions of taxa and publishing them in the Internet for maximum ease of access to researchers. The availability of correctly prepared illustration of taxon by taxonomist, makes it possible to avoid the necessity of using typical material and representatives of relative taxa. In higher taxa of the subfamily, the above obtains special significance because of the mode of group evolution and morphological definiteness of higher taxa being based, as a result, on a combination or conjunction of comparatively small number of taxonomic characters.

Fulfillment of a scientific illustration in entomology is quite a laborious occupation, requiring availability of specific skills and capabilities, and also considerable time expenses. According to the German researcher of botanical illustration C. NISSEN (1951) "a combination of artist and researcher in one person is largely rare because the human life is short, and the power is too limited to achieve perfection in both fields".

The present work is aimed at facilitating solving this problem as much as possible by using modern methods of digital processing of images.

The level of development of modern digital image processing allows to prepare a scientific illustration of taxon practically without resorting to "a pencil and paper". Moreover, with a certain amount of practice, it becomes accessible to a taxonomist who has no

drawing skills. It is especially important, because the illustration which fulfilled by a professional artist not familiar with the significance of some or others taxonomic characters, usually has, despite of qualitative fulfillment, low scientific value.

Thus, the illustrations prepared by the specialist on concrete group of insects are the most valuable and in this case scientific proficiency of the author has the decisive role.

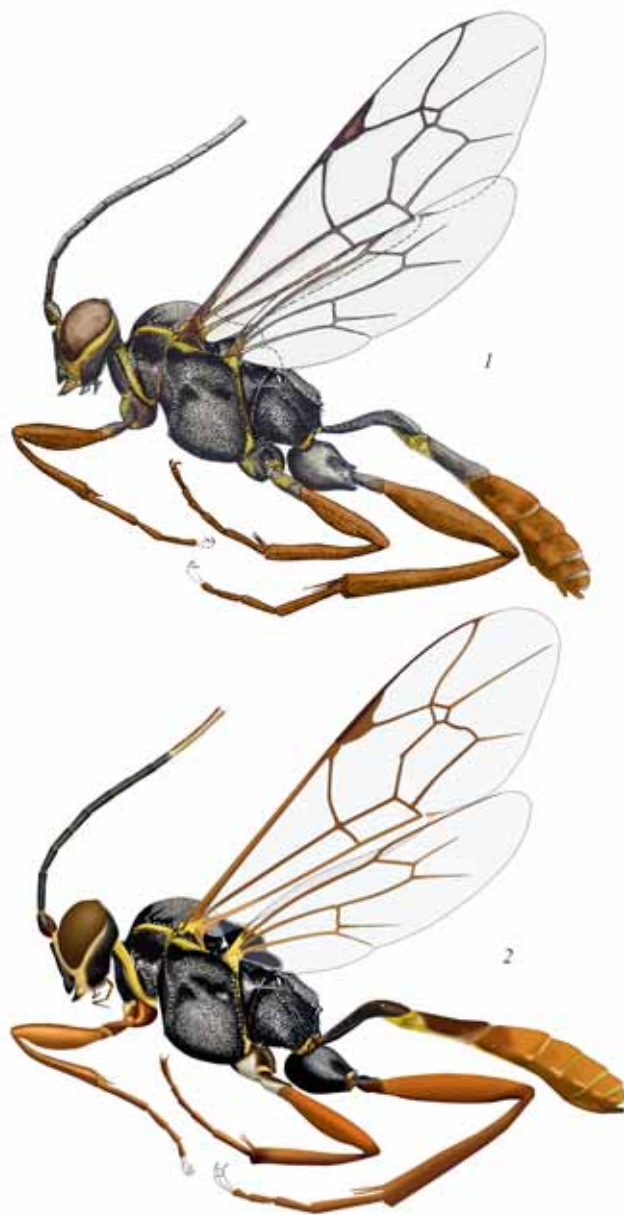
Taxonomic research works should be illustrated only with illustrations fulfilled by the author of work, not photographs. The basic difference between scientific picture and a photograph, according to our opinion, is the following – a photograph is only image of object that is fulfilled with this or that degree of skill, whereas the picture is, first of all, graphic presentation of scientific knowledge about object at the given stage and author own concepts. Based on the above, in the process of preparing a total image, primary goal is the accentuation of taxonomic signs of object, both their graphic fulfillment and relocation of minor characters on "background scene" under the condition of preservation of a general view and features of object as a whole. Other important condition is the graphic fulfillment of illustrations of objects in unified foreshortening, that is necessary for the comparative analysis.

The basic principle of a graphical representation of morphology of object is the maximum unification of images. **The given approach is vitally necessary for successful fulfillment of further researches, as well as for fulfillment of new descriptions of taxa of a different rank, and taxonomic generalizations.** These provisions have served as the preconditions for development of a methodology of preparation of illustrations and illustration plates.

Taxonomic illustration can be fulfilled in three ways – completely manually, using Indian ink and watercolor, or manually, with subsequent editing of figures in the graphic editor Photoshop (for entomologists having art skills), or completely in the Photoshop editor. In the **Plate I**, the pictures of imago of ichneumon fly, fulfilled both completely manually (1), and completely in the graphics editor (2) are shown. In all cases, irrespective of chosen method, following a number of rules is necessary. Fulfillment of figures, both total and parts of a body, having basic taxonomic characters, should be performed in a unified scheme. One of the known schemes of graphical representation of Ichneumonidae was designed and offered by Henry TOWNES (1969-1971).

By preparation of the table of illustrations mandatory observance of following conditions is necessary: 1 – arrangement of a figure of imago and parts of a body with basic taxonomical characters should have standard pattern in the table (for ichneumon flies, a standard position of legs, wings and flagellum must be followed), 2 – accuracy of detailed representation of taxonomical characters, 3 – accentuation of taxonomical characters and moving them out to "foreground", 4 – preservation of the general appearance of an object subject to accentuated basic taxonomical characters, 5 – fulfillment of figures in much greater scale, than sizes of objects in the final table, that allows to eliminate inaccuracies of images in the process of scale reduction.

The devices required for preparation of color images should be calibrated. The color image of an object on the monitor screen should match the color gamma on a hard copy. Therefore, calibration of devices is performed in correspondence of image on the screen by a type of ink of the ink-jet printer, and by a type of photographic paper. The printed out table of images is necessary for preparation it for printing in a publishing house, that is correspondence of image on screen of the file in the CMYK format and image of the finished product.



**Plate 1:** Comparison of *Hirtolabus alienoris* HEINRICH figures of imago, fulfilled by watercolor (1) and the same fully in a graphic editor (2) (according to TERESHKIN 2008).

A mandatory condition, regardless of author abilities, is usage of a grid in a microscope for fulfillment of the contour of object. It is necessary for maintaining precise proportions of object drawing. One of the main merits of any taxonomic work is a possibility of



using it in a comparative aspect to carry out subsequent investigations. The key to the solving this problem, in our opinion, is the maximal unification of both the taxa descriptions and their graphical presentation.

The foundation of unification of taxa description was laid by GERD HEINRICH (1962-1977), and unification of illustrative material, as already mentioned was laid by HENRY TOWNES (1969-1971). We made an attempt to go further in those directions and strengthen and unite each of them. We consider a fundamental principle of the preparation of taxonomically most successful works to be simultaneous fulfillment in a unified scheme of the description and the graphic representation of taxa. It will subsequently facilitate the advancement of the study of the group and will allow fulfilling the descriptions of new taxa of various ranks without necessary of obligatory visual investigation of all its representatives. Modern digital technologies allow fulfilling the descriptions and graphical representation of taxa without trying to save space (as opposed to paper). It is necessary to maintain a strict sequence in the description of taxonomical characters, with indication of their presence or absence, if it is characteristic for at least one representative of the taxon of given rank, not being afraid of repetition. While maintaining the order of presentation of the body parts it is desirable to divide the descriptions of separate segments with full stop. Such scheme is more preferable both for further comparative analysis as well as during preparation of new descriptions. Descriptions of taxa are implemented following the principle of identification keys. If a character is present in at least in one taxon of the same rank, an indication on its absence is added in the description of all of the others taxa. For example, only in genus *Notoplatylabus* (tribe Platylabini) "pronotal base with angular projection above front coxae". In this case, it is necessary to indicate morphology of the pronotal base describing other genera of the tribe, e.g. "pronotal base gradually rounded", thus preserving an order of characters description (TERESHKIN 2009, 2011).

Thus, one of problems of the given work is popularization of idea of unified description of objects and their graphical representation and possibility publishing them in the Internet for an easy access by researchers.

Simultaneous presence of the unified description and the unified table of illustrations allows: 1 – to quickly master a morphological terminology and thereby concrete group of organisms to novice researchers, 2 – to discover presence of new, undescribed taxon of the given rank and 3 – to combine in separate tables contour drawings from intermediate layers from images of different taxa of one rank and to arrange them in such a manner, that to reveal the tendency of development of characters in a specific taxonomical group. Thus the latter point indicates that the given technique serves the research purposes as well.

In conclusion it is necessary to note that principles and methodology of fulfillment of a scientific illustration developed on an example of concrete group of hymenopterous insects can be modified and used without special work for fulfillment of scientific illustrations of any objects of wildlife.

### Manual preparation of illustrations and their finalization with graphic editor

If an entomologist specializing in the study of some group of insects has artistic abilities and skills then "manual" method of scientific illustration with the subsequent improvement using the graphics editor can be chosen. Very often, this method under specified conditions could be easier and more economical in terms of time than full preparation of a picture in graphics editor.

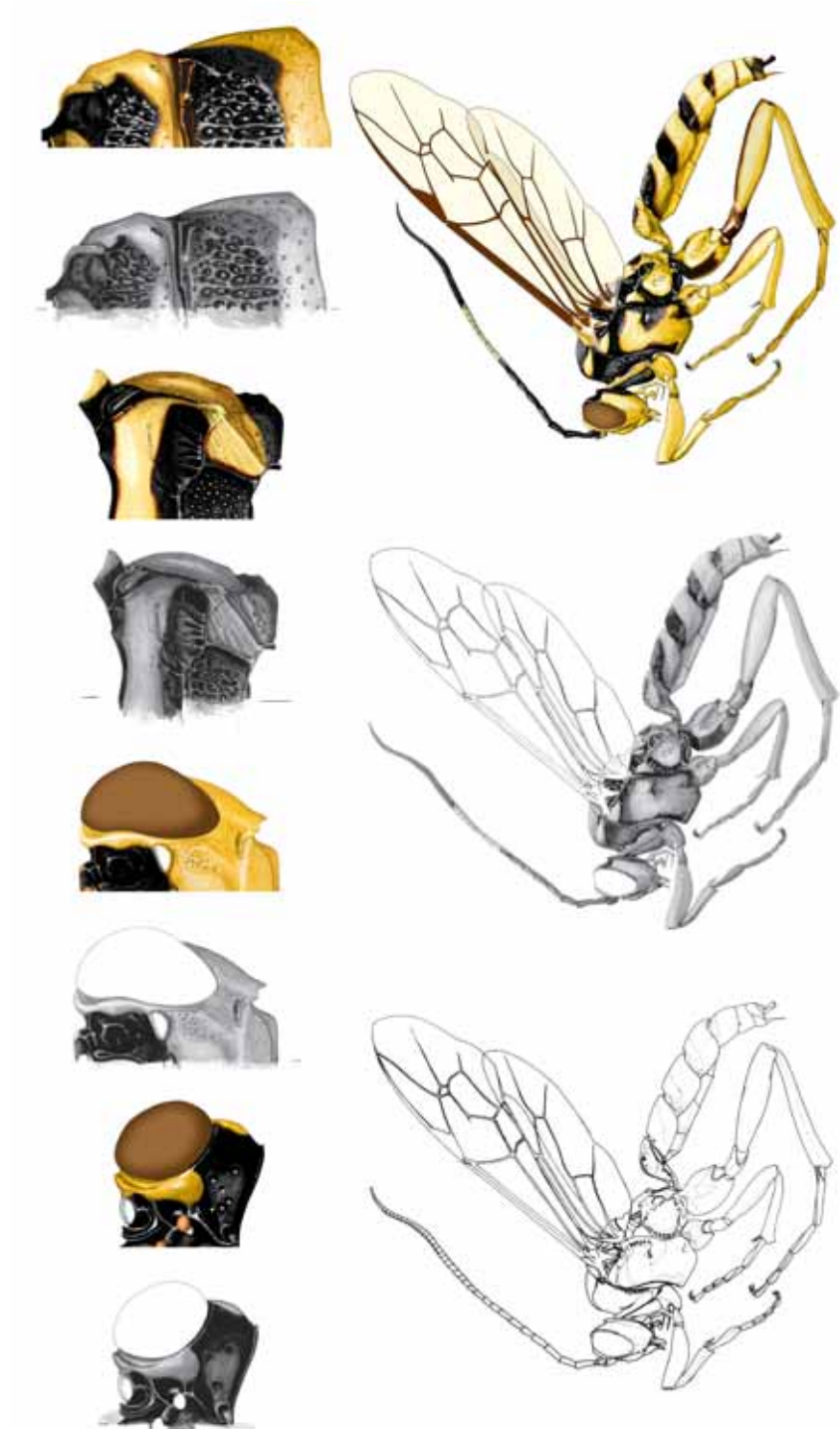
The first step is fulfillment of pencil drawing of contours of separate segments of imago and parts of the body (0.5 in a longitudinal section) with basic taxonomical characters of the studied group on cross-section paper using a grid in the ocular of a binocular microscope. All parts of the future final table of images are being fulfilled in a much larger scale, because with decreasing of images various minor errors and irregularities of the lines will be eliminated. The outline of figures of wings and flagellum are fulfilled with a help of diascope or device for reading microfilms, as described below in detail. Then pencil contours are transferred to a paper suitable for usage at fulfillment of subsequent operations by means of the blueprinting technique.

Assembling of the contour of imago is performed in compliance with the standard arrangement of the body, flagellum, wings and legs during the process of blueprinting to the paper, that suitable for usage of Indian ink and watercolor. The most suitable density of paper for fulfillment of these operations, from our point of view, is density of utilized photographic paper (back side) and photographic paper for printers (back side). The contour is outlined by Indian ink, using a rapidograph (0.18, 0.25 mm). If the constituent elements have been fulfilled on a small scale drawings can be scanned with a subsequent increase, fulfillment of a contour in the editor, and then printing on a laser printer on the mentioned kinds of a paper.

The next stage is operation of giving volumetric appearance to table elements. It is done with black watercolor by a thin paintbrush. Detailing and punctuation of composite elements are performed with a help of rapidograph. These operations can be done using colored watercolor. However it requires considerable drawing skills and aptitudes.

At the following stage images are scanned and finalized with the graphics editor. For editing and deleting some irregularities of lines of an external contour of objects, lines limiting veins of the wing and etc, tools "Polygon Lasso" or "Eraser Tool" with the pressed Shift key are used. In the latter case in palette Brushes the maximum value of parameter of Hardness and minimum values parameter of Spacing should be specified. Also for elaboration of a contour, it is possible to use hard brush (Hardness – 100%, Spacing – 1%) with diameter 3px, while holding Shift key. The alternative method is outlining of necessary parts by the vector tool Line, as described in detail below. Coloring the objects, pouring and coloring of an eye and ocelli, coloring a wing membrane are also done in the graphic editor in the sequence that is described in the corresponding sections below. The stages of preparing an illustration by the named above method are shown in the **Plate 2**, and an examples of a completely finished tables in the **Plates 9-29**.





**Plate 2:** Stages of table preparation manually with subsequent improvement in a graphic editor (on example of *Abzaria latipetiolaris* CAMERON) (according to TERESHKIN 2008).

### **Complete preparation of a scientific illustration in the graphic editor (Basic Principles)**

As mentioned above, the development of modern digital technologies allows preparing scientific illustration without recourse to "pencil and paper". Modern versions of Photoshop graphics editor open up the best possibilities for the preparation of scientific illustration of wildlife objects. Using of this editor makes it possible to solve the problem of preparing quality images of the objects, not only total ones, but of taxonomically important parts of a body and various structure characters that have a great importance in taxonomy separate groups of organisms as well.

It is the preparation of scientific illustration in Photoshop editor that makes it possible to specialists, specializing in research of specific groups of organisms to prepare qualitative unified illustrations without resorting to the services of professional artists. Illustrations of the objects and theirs characters, that are fulfilled by specialists on specific groups of organisms, as mentioned earlier, have undoubtedly incommensurably more scientific value.

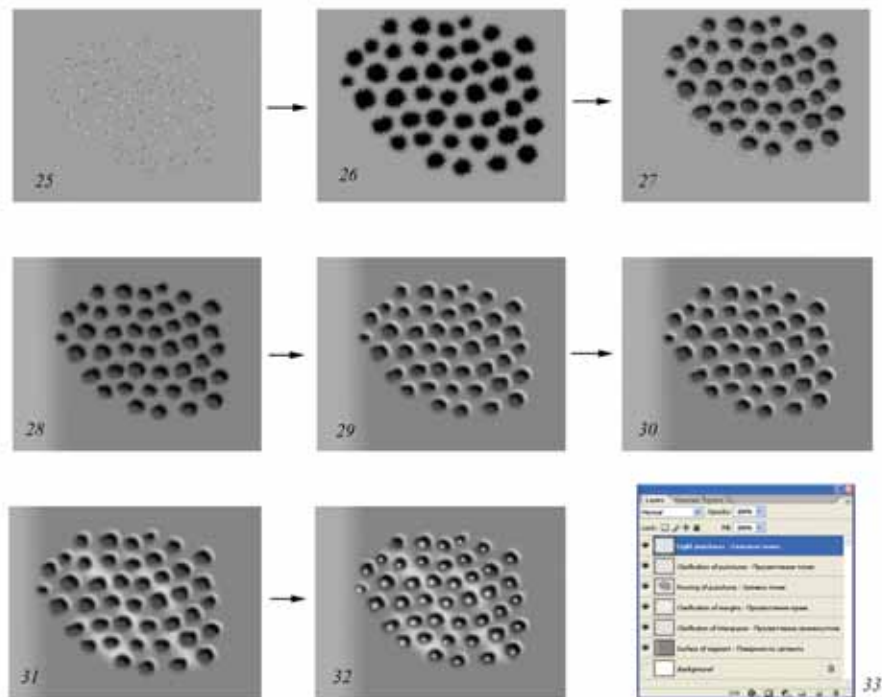
Maximum use of tools of selection and facilities of using of parameter Feather in determining of the limits of selected area for giving to object the volumetric appearance and for elaboration (sculpturation) its structures, and also maximum use of the layers are the key in performing scientific illustrations in the Photoshop editor. Photoshop editor gives an ability to carry out all the operations in separate layers, like Wrinkles, Big and Small punctures, Cells with subsequent theirs clarification and contrasting in accordance with base layer (Pouring and volume). It allows choosing the best variant of final picture. Fulfillment of different structures (cells, wrinkles, punctures et al.) by mentioned manner in different layers makes it possible additionally to correct their shape and size, using different options of function Transform (Scale, Rotate, Warp et al.).

The key to obtaining high quality images in the editor is an accurate elaboration of the smallest details of the sculpture at high magnification. Details of elaboration may not be visible in the final image, but will give the image accuracy and "natural appearance". Therefore, size of the separate object in the editor should be several times larger than its image on the final plate with images. This proposition can be considered as the basic.

During preparation of the total image, drawings of segments should be fulfilled separately, on separate canvases (in separate files). It is necessary for subsequent "arrangement" of imago with a demanded (standard) locating of body segments and its processes.

During preparation of the images, each operation should be fulfilled in a separate layer: "Navigator", "Main lines", "Pouring and volume", "Sculpturation", "Puncturation" etc. In Preferences (Menu: Edit-Preferences) maximum number of commands (Preferences-History States=100) should be set. This is important for their withdrawal in case of need. All the layers used in the preparation of a concrete object should be saved until the final image. This is necessary to correct the image in a case of need, and to illustrate the description of the individual structures, or in the preparation of identification keys and illustrations for taxonomic analysis of the group too. Using drawings from separate layers of taxa illustrations in concrete groups (high taxa) and theirs aggregation to the tables of drawings give additional facilities for taxonomic analysis and identification of trends in the development of various structures and characters.

When fulfillment of operation of sculpturation of an object, usage of instruments of



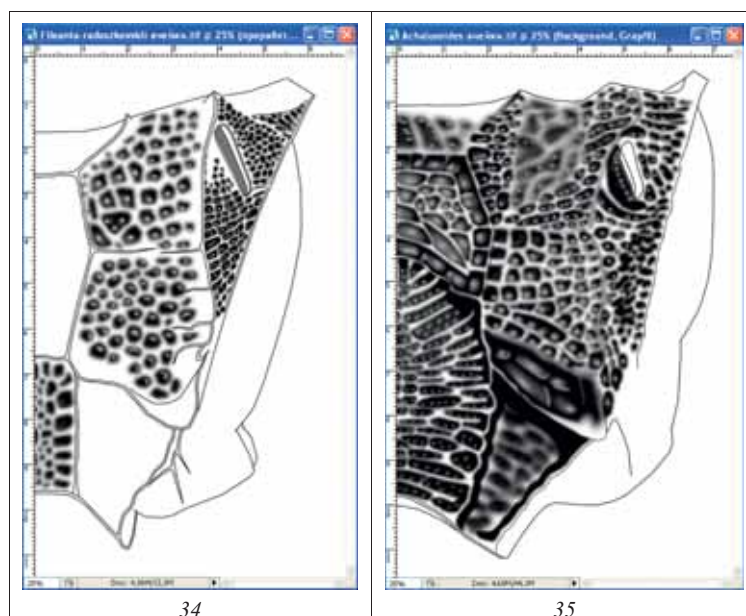
**Fig. 25-33:** Order of operations at fulfillment of image of homogeneous structure (large puncturation) (explanations in the text).

After fulfillment of all listed operations, all other layers, except listed above are disconnected. Then merging of layers by command Merge Visible (Ctrl+Alt+E) is carried out.

### Cellular sculpture of a surface

The cellular sculpture is characteristic more often to propodeum of ichneumon flies (**Plate 9, 10, 12, 15, 18, 19, 21, 22, 27, 30, 33, 35, 37, 49**). Fulfillment of a cellular sculpture is similar to fulfillment of large puncturation. The given type of a sculpture is fulfilled by instruments of selection with use of several layers. As well as for large puncturation, a total fulfillment of all cells by instruments of selection, for their simultaneous pouring is necessary. The cellular sculpture can be peculiar to several fields of propodeum. In this case usage of several groups of layers or separate layers according to number of fields with a cellular sculpture will be expedient. As well as for big punctures of puncturation at fulfillment of this type of a sculpture, usage of four layers located from top to down in a following order: 1—"Light punctures"; 2—"Pouring of cells"; 3—"Clarification of margins"; 4—"Clarification of interspaces" is expediently. Cells have the diversified shape. Frequently cells are with the expressed corners. Therefore, the basic difference of procedure of their fulfillment from fulfillment of big punctures is

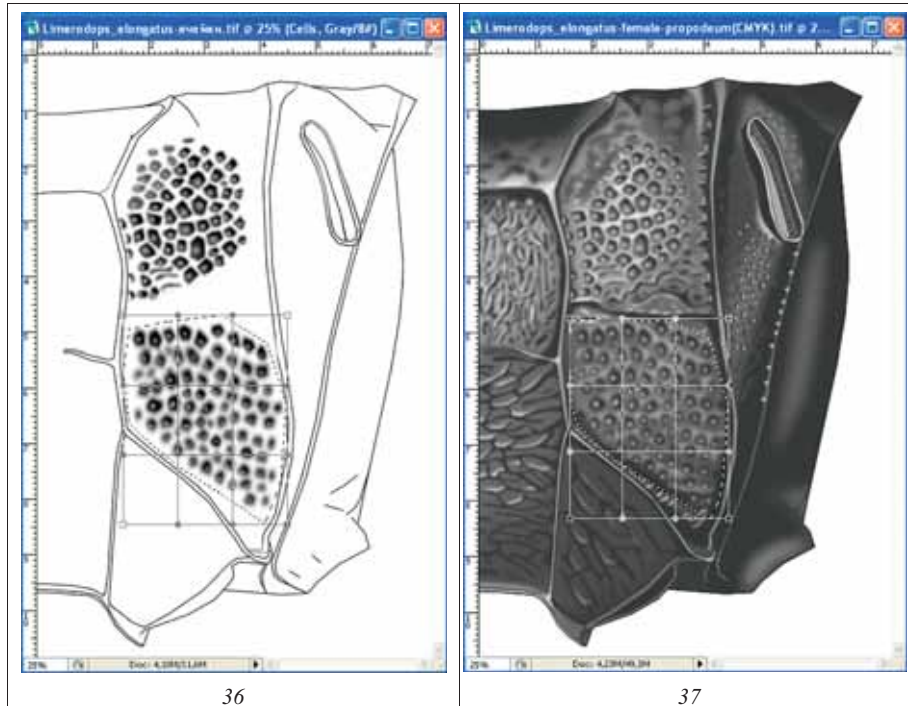
usage first of all an instrument Polygonal Lasso Tool. At fulfillment of cellular strulpture by this tool in a layer "Pouring of cells", the size of parameter Feather has a great value. Before fulfillment of the bulk of cells, its size is determined by periodically fulfillment of selection and pouring of trial cells. After fulfillment of all the cells, or the cells of a concrete field, theirs simultaneous pouring by the black color is fulfilled. Further without deselection, the selected areas are shifted in accordance with light direction on a field of propodeum. Then, clarification of parts of cells is fulfilled using command Menu: Image–Adjustments–Brightness/Contrast in the same layer (Pouring of cells). However, more often area for giving to cells of volumetric appearance is fulfilled separately for each cell. Area is selected by instrument Lasso Tool at pressed key Shift and by use of the pen of Pen Tablet. Then, already after fulfillment of all areas of selection, simultaneously all cells of group are clarified, giving to them of volumetric appearance. The further procedures, in other layers are similar to procedures described above for big punctures (fig. 34, 35).



**Fig. 34-35:** General appearance of the layers with cells of propodeum: (34) *Fileanta radoszhkowskii* (BERTHOUMIEU), (35) *Achaisioides epistomalis* TERESHKIN.

Fulfillment of such difficult structures as cells in a separate layer gives additional possibilities on their correction. It is not only the regulation of brightness and contrast of cells, allowing to achieve conformity to the basic layer (Pouring and volume), but also possibility of their modification. In a case, if some kind of group of cells not quite corresponds to real object already after their fulfillment, it is possible to modify their shape and the dimensions, using various variants of option Transform (Scale, Rotate, Warp, etc.). So, if cells of all fields of propodeum were fulfilled in only one layer, a group of the cells which need modification is preliminary selected by instrument

Polygonal Lasso Tool. In drawings 36 and 37 example of modification of already ready cells of 2nd lateral field of propodeum is shown. After selection of group of cells, the menu command: Edit–Transform–Warp (Scale, Rotate) is fulfilled, for achieving necessary conformity of the cellular sculpture, which is observed at object.



**Fig. 36-37:** Correction of shape and arrangement of cells fulfilled in a separate layer: (36) correction of cells of propodeum *Limerodops elongatus* (BRISCHKE) in layer "Pouring of cells", (37) the same, at all switched on layers.

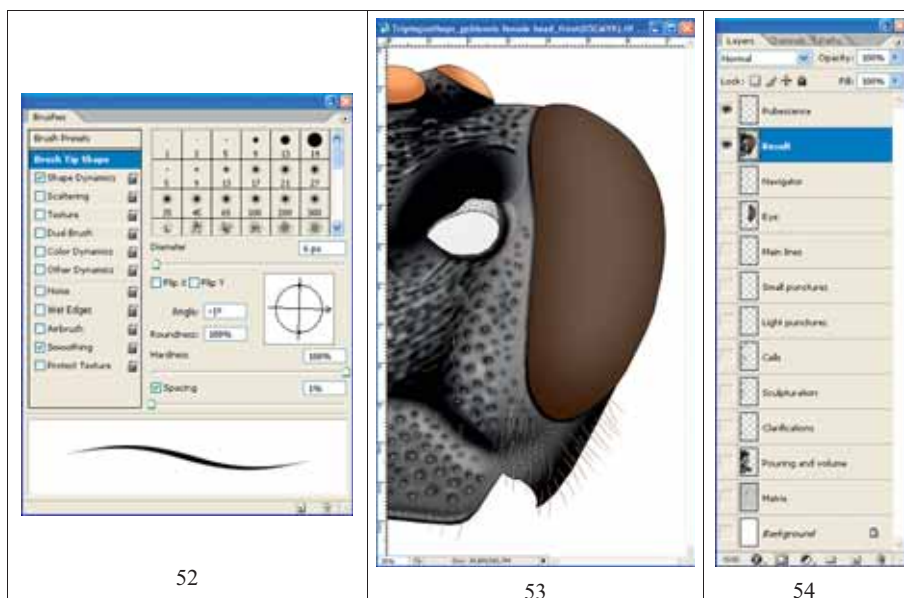
### Wrinkled sculpture

Wrinkled or wrinkly-punctured sculpture is peculiar to many parts of a body. Process of detailed representation of wrinkles is similar to process of fulfillment of large punctures of puncturation. Unlike big punctures, wrinkles are usually fulfilled by instrument Polygonal Lasso Tool, previously having selected up experimentally a value of Feather parameter. Wrinkles are usually fulfilled in two layers - "Wrinkles" and "Clarification of interspaces". In a case when wrinkled sculpture has slanting or sinuous character, areas of clarification of intervals are selected separately, as well as the wrinkles actually. When fulfillment clarification of interspaces, it is possible to use and the basic layer with the volumetric image of object (Pouring and volume). In this case the basic layer should be duplicated (Pouring and volume copy). It is necessary for secure, in case of correction of errors in case of need.

Longitudinal or parallel wrinkles are more often peculiar to



Object coloring is always fulfilled in the final layer "Result" which is formed as a result of merging of all layers in which all previous operations was performed. The exception is a head and a layer with pubescence, in case of its presence.



**Fig. 52-54:** Fulfillment of pubescence of head capsule of *Triptognathops gobiensis* TERESHKIN from front: (52) selection of parameters of Brush, (53) finished image, (54) hierarchy of layers before merging of layers "Result" and "Pubescence".

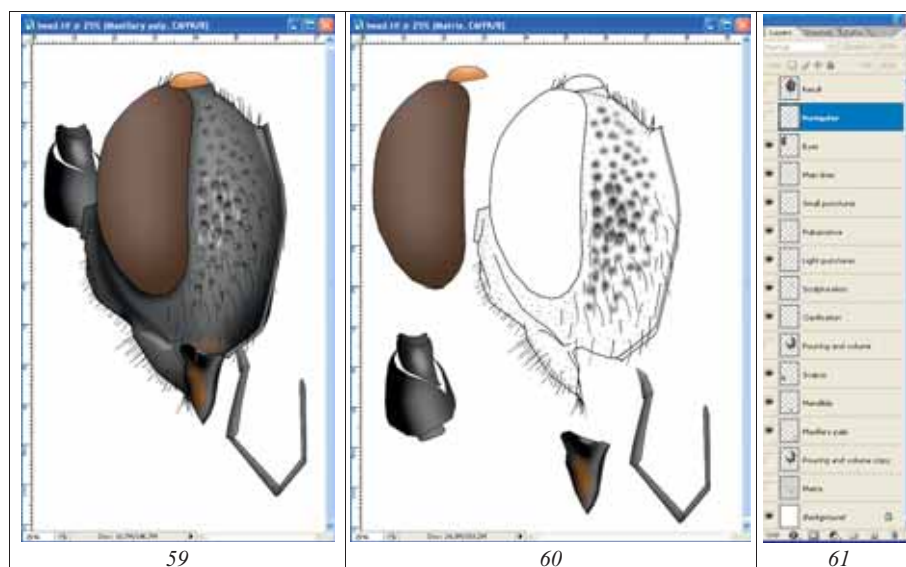
If the object was fulfilled in Grayscale Mode, a file is translated to CMYK Mode (Menu: Image–Mode–CMYK Color). In a pop-up menu a command "Don't Flatten" is chosen, preserving all layers. At the first stage, the basic coloration of object entirely (part of a body, a segment or segments) is fulfilled. For example, the abdomen or 1-2nd its segments are of a reddish-brown coloration. At the first stage in palette Swatches the color of a stainable part, closest to the main is selected. Further, operation on coloring of the selected part is fulfilled: Menu: Image–Adjustments–Hue/Saturation (Ctrl+U). In a pop-up window Hue/Saturation by means of cursors (sliders) a color and a saturation of an object are selected. At operation fulfillment it is necessary to remember, that in window Colorize the flag should be set (see e.g. fig. 361, 536 from chapter "The detailed description of sequence of operations at fulfillment of the table of illustrations on an example of single species").

For coloring of separate fragments, spots, strips, etc., theirs are selected preliminarily, usually with tool Polygonal Lasso Tool, having selected preliminarily parameter of Feather. Usually values of the parameter of Feather are small, more often 5-7px. After selection of necessary parts, theirs coloration is fulfilled as it is described above. It is necessary to note, that already in image that was performed in a Greyscale, the parts for coloring have been clarified to necessary level.

Special case of coloring is an imparting of hue to the certain parts of object (more often bluish or violet). For fulfillment of this, separate parts of a body, or separate segments



Besides obligatory layers enumerated above, layers which necessary for sculpturation of a head capsule are added. In figures 59-61, layers necessary for fulfillment enough complex image of a head of ichneumon fly with a file consisting of 16 layers, arranged in obligatory hierarchy are presented.



**Fig. 59-61:** Image of a head of ichneumon fly *Triptognathops gobiensis* TERESHKIN: (59) final result of fulfillment of operations (layer "Result"), (60) elements of a head fulfilling separately, (61) hierarchy of layers.

P o u r i n g of a head contour is fulfilled by instrument Paint Bucket Tool (G) separately for a head capsule, scapus, maxillary palp and mandible. Further for each element which located in a separate layer, the operation on giving to them of volumetric appearance is performed with usage of the instrument of selection Polygonal Lasso Tool, using various values of parameter of Feather.

F o r e l a b o r a t i o n of a sculpture of surface of head capsule of ichneumon fly, various quantities of layers depending on complexity of sculpture of the object are used. The strict locating of layers over volumetric images of elements, i.e. their hierarchy is obligatory. More often at elaboration of a sculpture of a head following layers are used, located from top to down in a following order: small punctures, pubescence, light punctures, large punctures, wrinkles, clarification of interspaces, microsculpture, etc.

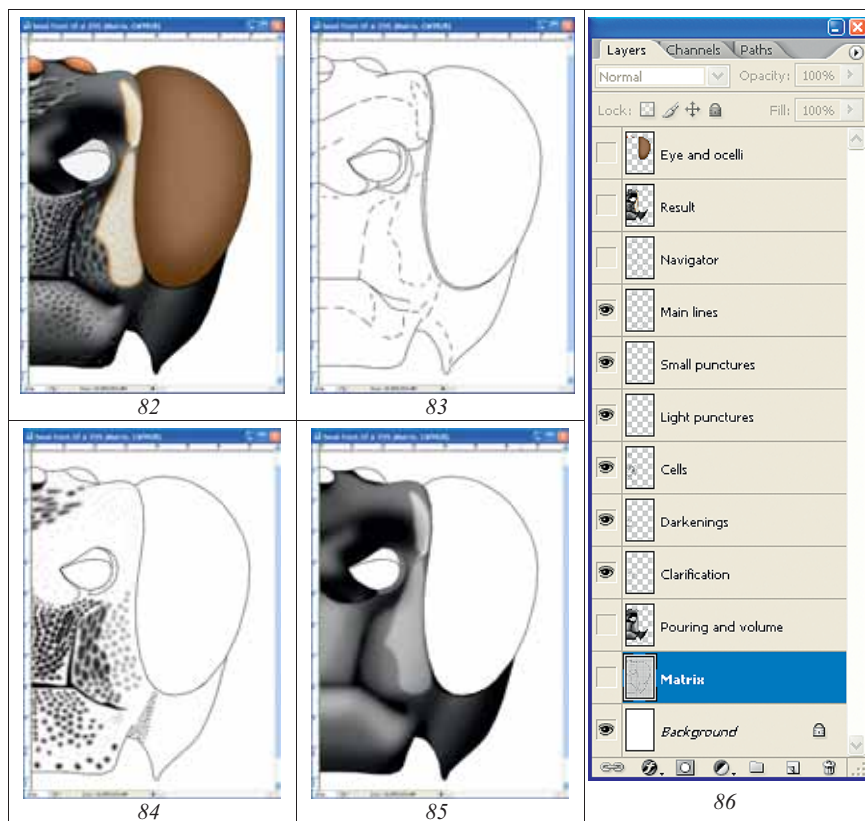
After elaboration of sculptural peculiarities, an operation of merging of layers with underlying layer "Pouring and volume" is fulfilled, separately for a head capsule and for its processes (Menu: Layer–Merge Visible, Shift+Ctrl+E).

After elaboration of sculpture of a surface and merging of layers, coloring of an object is started. If the previous operations were fulfilled in a file in a Grayscale, the file is necessary to translate in a color mode by command Menu: Image–Mode–CMYK Color. Operations on coloration of head capsule proper, scapus, mandible and palp are fulfilled separately. In case if a head or its processes have a light pattern, these areas are clarified,



**Plate 5:** Variants of the image of different parts of imago body of ichneumon fly: (1-24) head, (25-30) thorax, (31-34) abdomen (designations see Legends to color plates).

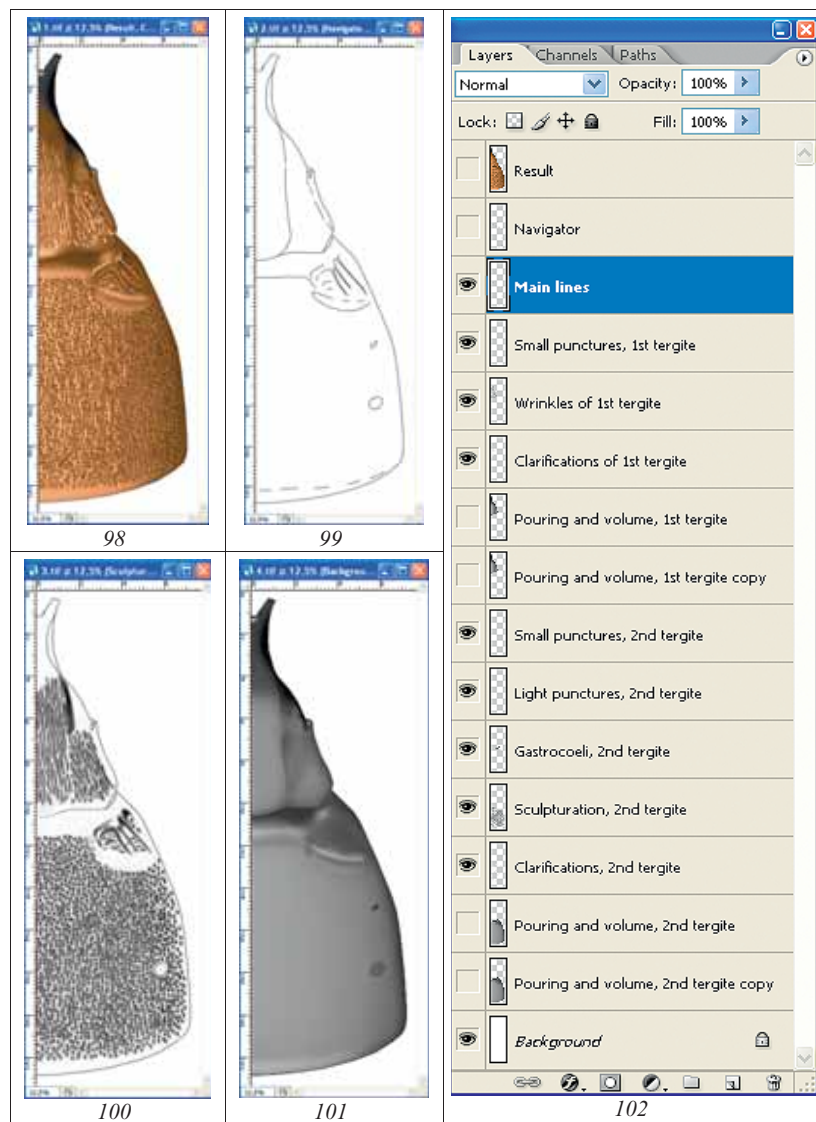
Shaping for a head of volumetric appearance is begun from pouring by Grey color (Gray 10%) of a contour by means of instrument Paint Bucket Tool in layer "Pouring and volume". Operation on giving to a head of volumetric appearance is fulfilled in the same layer. For shaping of volumetric appearance, instruments of selection, first of all instrument Polygonal Lasso Tool is used. Choice of parameter Feather, determining degree of blur (rigidity) of border of selection area has a great value. At the first stages value of parameter Feather can reach 150px. Selection is begun from the highest (area of ocelli, a dorsal view) or the most projecting (middle field of face, the front view) areas of object to periphery. External borders of area of selection should leave more than twice behind external border of an object.



**Fig. 82-86:** Basic layers when fulfillment of head image (front view) of ichneumon fly *Achaiusoides epistomalis* TERESHKIN: (82) merged layers "Result" and "Eye and ocelli", (83) layer "Navigator", (84) layer "Main lines" with layers of elaboration, (85) main layer "Pouring and volume", (86) hierarchy of layers.

Area of selection is darkened using the menu command: Image-Adjustments-Brightness/Contrast, using at the first stages small values of decreasing of brightness (10-30%). Selected areas gradually are shifted to object periphery (see section "Shaping of volumetric appearance to an object").

Before fulfillment of coloring of segments, a file is converted to mode CMYK by command Menu: Image–Mode–CMYK Color (Don't flatten). Coloring of object is performed as it has been described above in section "Coloring of an object" and in the chapter "The detailed description of sequence of operations at fulfillment of the table of illustrations on an example of single species".



**Fig. 98-102:** Variant of set of layers at fulfillment of image of segments 1-2 of abdomen (*Hybophorellus injucundus* WESMAEL): (98) layer "Result", (99) layer "Navigator", (100) general appearance all switched on layers of elaboration of surface (see fig. 102), (101) general appearance of layer with volumetric image (layer "Pouring and volume"), (102) hierarchy of layers.

Unnecessary lines in layers "Main lines" and "Pouring and volume" are being deleted. To last layer, after pouring by the grey color, a volumetric appearance is imparted (fig. 106). In the additional layers, observing strict hierarchy, elaboration of sculpture is fulfilled. In case of presence of pubescence, it is executed in a separate layer. Layers "Result" and "Pubescence" are merged only after coloring of object (fig. 103-107).

Additional volumetric color illustrations of parts of a body for the characteristic of high taxa are presented more often by mandibles, rarely by peculiarities of scutellum morphology, still to a lesser degree by other fragments of an object (**Plate 7**). The parts of a body of Ichneumoninae, presented on a color Plate are used for additional illustration of taxa characters of generic and tribal level and not presented in the standard table of illustrations of taxon (a head in two foreshortening, propodeum, tergites 1-2 of abdomen and total image of imago).

#### **Fulfillment of illustrations of separate characters and schematic images for taxonomic analysis and identification keys**

A considerable array of illustrations it is the drawings which used in the taxonomical analysis of certain groups and as the illustrations for identification keys. Preparation of illustrations for these purposes is carried out by several paths: 1 – usage of the single-type fragments from ready tables for the comparative analysis, 2 – making of separate pictures of morphological formations of certain type in the volumetric image, 3 – fulfillment of schematic volumetric images of morphological formations of single-type, 4 – making tables of contour drawings with usage of the intermediate layers of components of tables of illustrations of taxa.

1. After finalization of the complete preparation of tables of illustrations of one or another taxon, higher then generic level, use of tables of fragments of one type, or segments of a body is seemed advisable for definition of tendencies of development of group or separation of groups of taxa (for example genera).

At fulfillment of all elements of the total table, the numerous layers had been used, that allows to copy separate elements as directly from layers, and also from ready images. In the latter case a necessary fragment is selected before copying by instrument Polygonal Lasso Tool with parameter Feather=0. Illustrations of tables of characters are fulfilled in mode Grayscale (Menu: Image–Mode–Grayscale). As an example of such illustrations, morphology of 1st tergite of abdomen in genera of subtribe Amblytelina (fig. 108-123) can serve. After copying of all fragments to the ready table, fragments can be distributed according to the tendency of change of taxonomic character which under study. As the examples of such illustrations the table of variability of areolet in genera of tribe Platylabini (fig. 124-154) can serve.

2. The certain morphological characters which are not entering into standard tables of illustrations can have important taxonomical value, not only for model group, but also for the various circle of insects taxa. First of all it is peculiarities of genitals or adjoining structures. For example, for a number of groups of Ichneumoninae the morphology of males hypopygium has important taxonomical value. Preparation of volumetric detailed images of morphological formations is fulfilled under the described above scheme in a black-and-white variant.

The file with image of fragment of a body includes necessary number of layers for elaboration depending on complexity of a sculpture (fig. 155-160). Drawings are fulfilled in



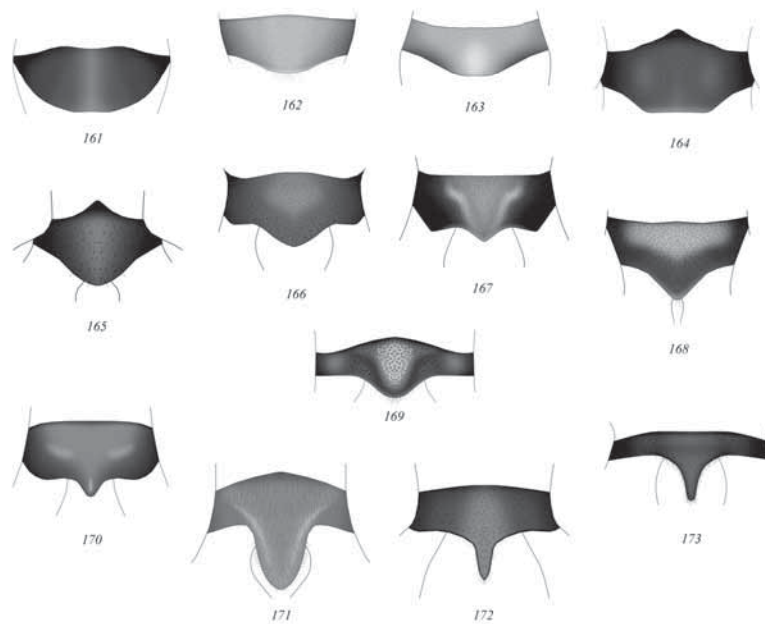


**Plate 7:** Additional fragments of a body used for illustration of characters of high taxa of Ichneumoninae: (1-38) mandibles, (39-40) tyloides on flagellum of males, (41-48) scutellum from above and from side, (49) front part of a thorax from above, (50) apex of abdomen of female, (51) apex of abdomen and oedeagus of male, (52-53) claws of female tarsi (designations see Legends to color plates).



4. As already has been repeated in all sections, the significant condition of preparation of the image of a fragment of a body of an insect is fulfillment of operations in separate layers. Moreover, after finishing of fulfillment of the image and merging of necessary layers (layer "Result"), all layers are restored and saved in the file. As it was already told, saving of all layers is necessary not only for the subsequent correction, in case of need, but also for usage of separate intermediate images for preparation of illustrations of different groups which necessary for the taxonomical analysis. More often for preparation of tables of illustrations, layers with contour drawings – "Navigator" and "Main lines" are used. For obviousness, lines of a contour can be contrasted, and the background of drawing can be poured by grey certain saturation by using of instrument Paint Bucket Tool.

Tables with the contour drawings used for an illustration of characters when the taxonomical analyses of group (Amblytelina) are presented in figures 203-218, 219-234.



**Fig. 161-173:** Hypopygium of males of Amblytelina genera (according to TERESHKIN 2011): (161) *Ctenichneumon funereus* (GEOFFROY), (162) *Amblyteles armatorius* (FÖRSTER), (163) *Fileanta radoszkowskii* (BERTHOUMIEU), (164) *Triptognathops gobiensis* TERESHKIN, (165) *Achais oratorius* (FABRICIUS), (166) *Hepiopelmus melanogaster* (GMELIN), (167) *Limerodops elongatus* (BRISCHKE), (168) *Diphyus amatorius* (MÜLLER), (169) *Tricholabus strigatorius* (GRAVENHORST), (170) *Limerodes arctiventris* (BOIE), (171) *Eutanyacra crispatoria* (LINNAEUS), (172) *Spilichneumon occisor* (FABRICIUS), (173) *Triptognathus uniguttatus* (GRAVENHORST).

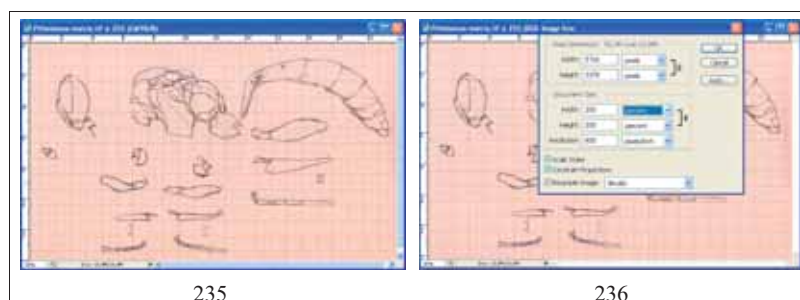
## The detailed description of sequence of operations at fulfillment of the table of illustrations on an example of single species

### Stages of preparation of total image of imago

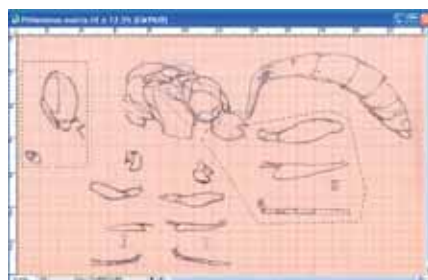
#### Sequence of operations

##### Preparation of matrix

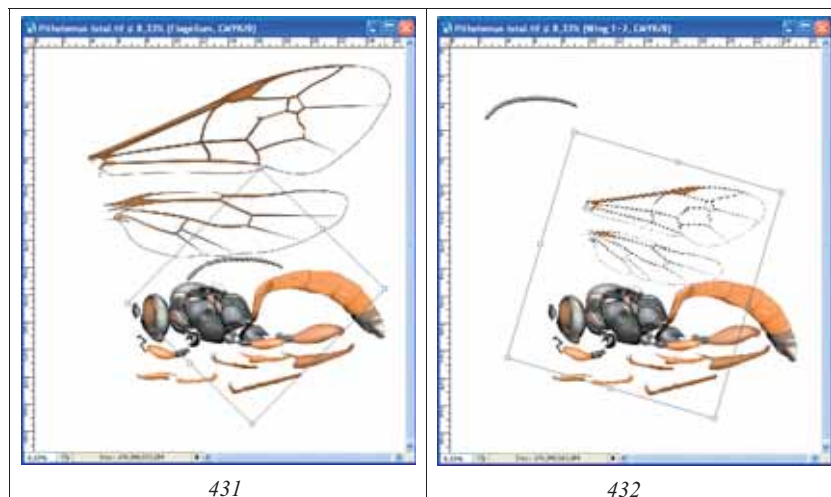
Pencil contour of all parts of a body, with exception of flagellum and wings, is fulfilled in the unified scale by the method described above. Scanned tables of drawings are increased to a standard size. For example, the usual increase of pencil drawings, which fulfilled on graph paper, is 150-200%. On the document window title by right mouse button is clicked. Then, in pop-up menu, Image Size is selected. In the window that appears, the units "%" is set up instead of "cm" and a value of 150-200 is inserted, depending on the size of the original image. As a rule, the percentage of increasing is calculated from the length of the head in the final image of imago (4-5 cm). For example, the initial length of the head on pencil matrix is 2 cm. In this case the image size is increased up to 200% (fig. 235-236). Resolution required for further work is 600 pixels/inch.



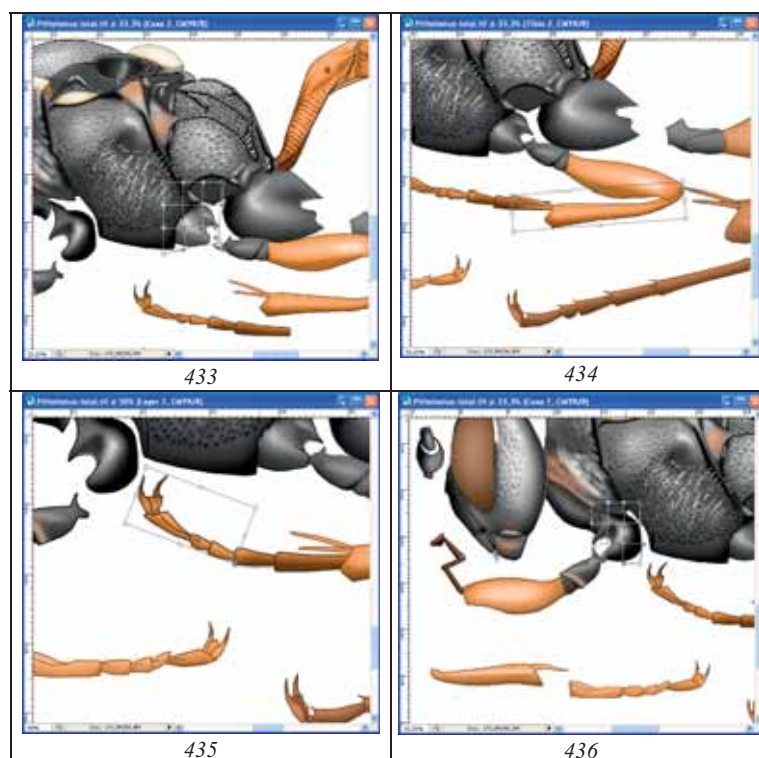
**Fig. 235-236:** Increasing the size of a pencil drawing of the contour to the desired of the working size: (235) matrix of initial size; (236) parameters of pop-up window at increasing of matrix.



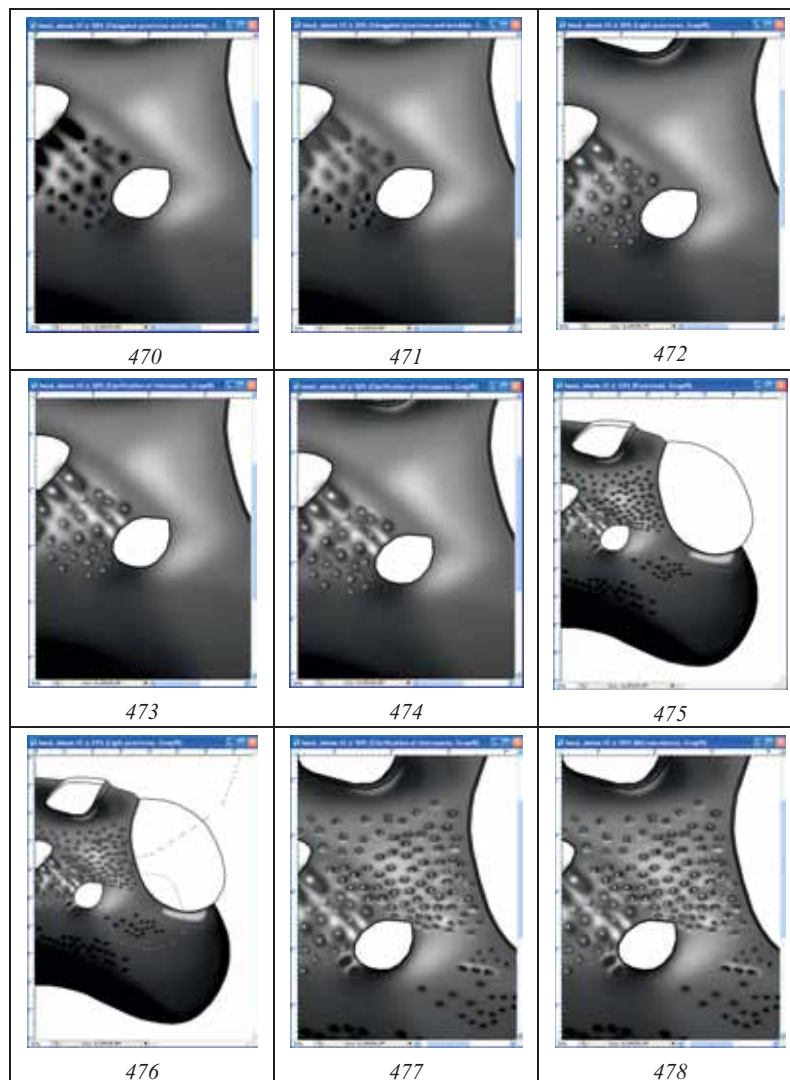
**Fig. 237:** Copying of parts of a body of ichneumon fly for creation of separate files.



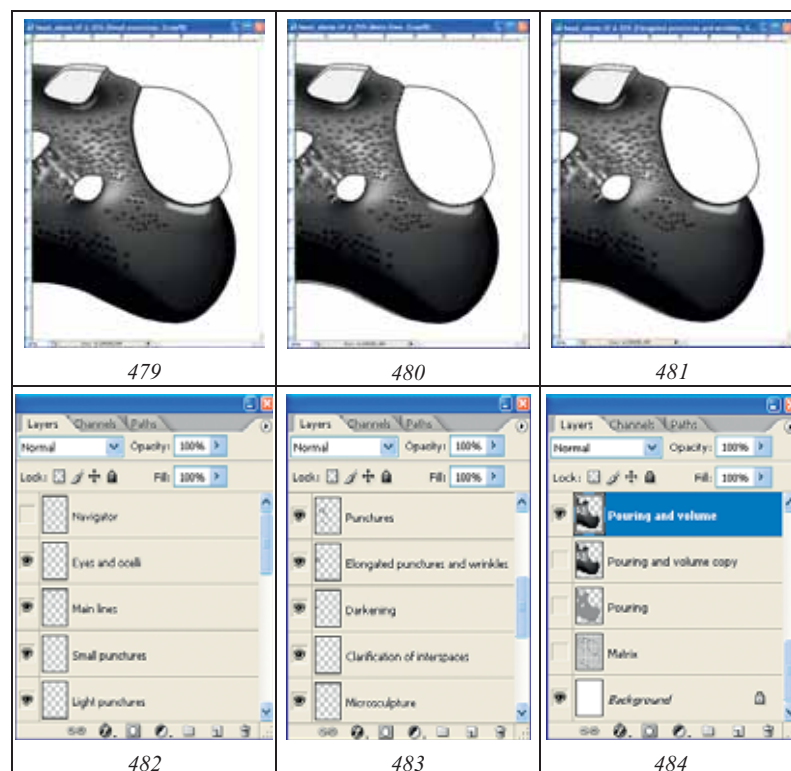
**Fig. 431-432:** Scaling of flagellum and wings: (431) scaling of flagellum, (432) scaling of wings.



**Fig. 433-436:** Arranging of legs of object: (433) modification of middle coxa by function Warp, (434) giving to tibia of necessary position by function Rotate, (435) change of position of segments of middle tarsus, (436) modification of front coxa by function Warp.



**Fig. 470-478:** Elaboration of head capsule of ichneumon fly (from above): **(470)** darkening of impressions in area of ocellar triangle, **(471)** shifting of areas of selection and clarification, **(472)** light points of 10% Gray, **(473)** clarification of intervals, **(474)** additional darkening, **(475)** puncturation, **(476)** light points 10% Gray (Diameter = 10-17px), **(477)** clarification of margins of punctures by instrument Brush Tool in layer "Clarification of interspaces", **(478)** elaboration of area with a microsculpture (layer "Microsculpture").



**Figs 479-484:** (479) small points in layer "Small punctures", (480) elimination of "imperfections" in area of front ocellus, impression around eye and area of occipital carina, (481) final result of operations on elaboration, (482-484) layers in final file.

The gleams at the edges of punctures are fulfilled by instrument Brush Tool in layer "Clarification of interspaces", that is situated below. In the same layer the gleams of the most shining areas are performed with usage of instruments of selection and subsequent pouring of selected areas by grey color (10%) (fig. 477).

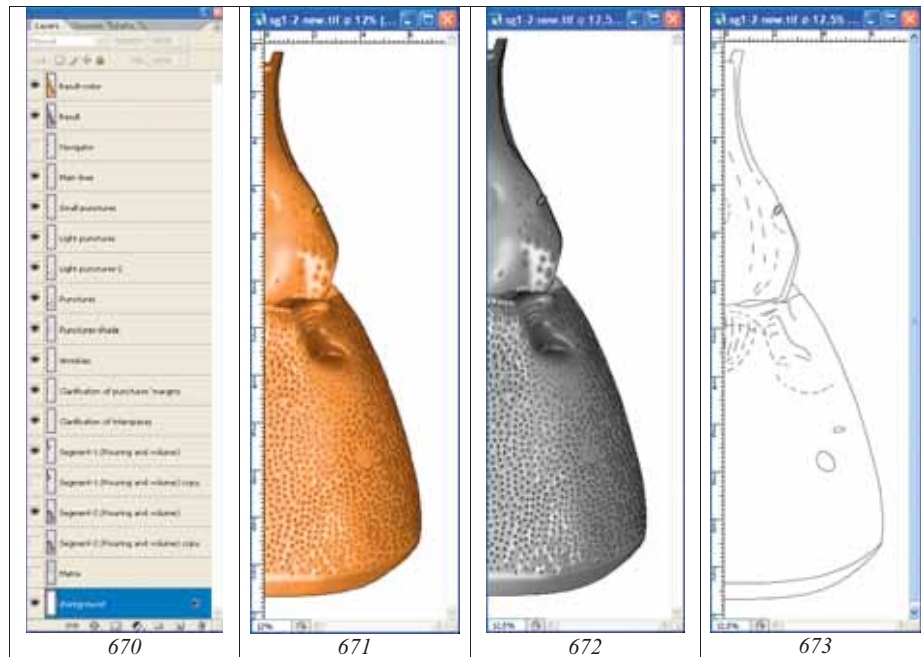
Area between an eye and ocellus with indistinct microsculpture is punctured by means of shallow dark and light points with diameter of brush 7px in layer "Microsculpture" (fig. 478).

At the last stages, a conditional darkening of antennal fossa is fulfilled. Internal part of hind margin of antennal fossa and the fossa proper are poured by grey color (10%). The fossa proper is selected by instrument Magic Wand Tool. Then, brightness is reduced on 10% by means of function Brightness/Contrast. In layer "Small punctures", an internal part of hind margin of antennal fossa is punctured schematically by means of shallow points. Some parts of a head capsule are punctured similarly, for giving to object more "natural appearance". Diameter of points at the given size of a picture is normally 5-7px. Hardness of a brush has been lowered. Parameter Spacing should have great values for preventing of coalescence of points at usage of a pen of Pen Tablet (fig. 479).

At the elaboration finishing stage in layer "Main lines", by means of instrument Magic

Visible (Shift+Ctrl+E)) is fulfilled. The image in the merged layer is selected by command Ctrl+A, and then, it is copied to the buffer (Ctrl+C). After that, the previous actions are cancelled (Menu: Edit-Step Backward (Alt+Ctrl+Z)), returning into place all layers merged previously. Layer "Main lines" is marked as the working and a command of insert (Menu: Edit-Paste (Ctrl+A)) is fulfilled. New layer is entitled "Result" (fig. 668,672). By means of instrument Move Tool (V), a layer "Result" is combined precisely with underlaying layers. Layer "Result" is duplicated, having named it as "Result-color" (fig. 671), using it for giving of coloration.

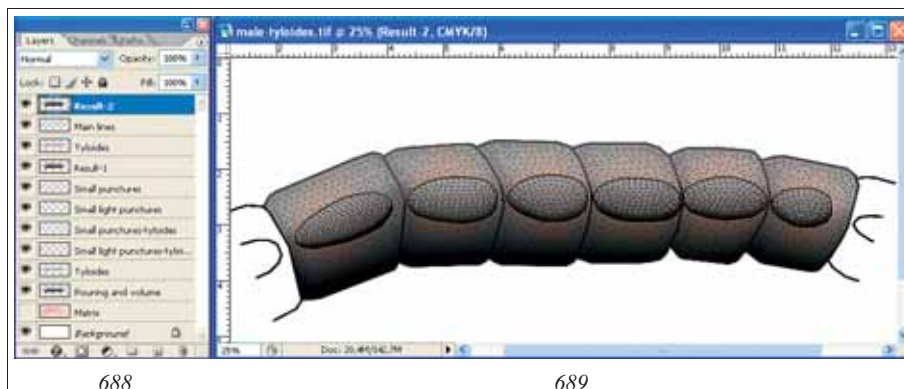
C o l o r i n g of tergites of abdomen is begun from transformation of the image from mode Grayscale to mode CMYK - Menu: Image-Mode-CMYK Color (Don't flatten). 1-2nd segments of abdomen of ichneumon fly are red-brown with slightly darkened base of tergite 1. Therefore, for giving of coloration, there is no necessity for selection of those or other areas.



**Fig. 670-681:** Layers in a file "segment 1-2" (674-677 at switched on layer "Main lines"): (670) hierarchy of layers, (671) colored image in layer "Result-color", (672) black-and-white image in layer "Result", (673) layer for orientation "Navigator", (674) layer with fine points "Small punctures", (675) layer "Light punctures-2", (676) layer of punctures which were fulfilled by instrument Brush Tool ("Punctures"), (677) layer of volumetric punctures ("Punctures-shade").

**Fig. 678-681:** Layers in a file "segment 1-2" (at switched on layer "Main lines"): (678) layer "Wrinkles", (679) layer "Clarifications of punctures' margins", (680) layer "Segment-1 (Pouring and volume)", (681) layer "Segment-2 (Pouring and volume)".





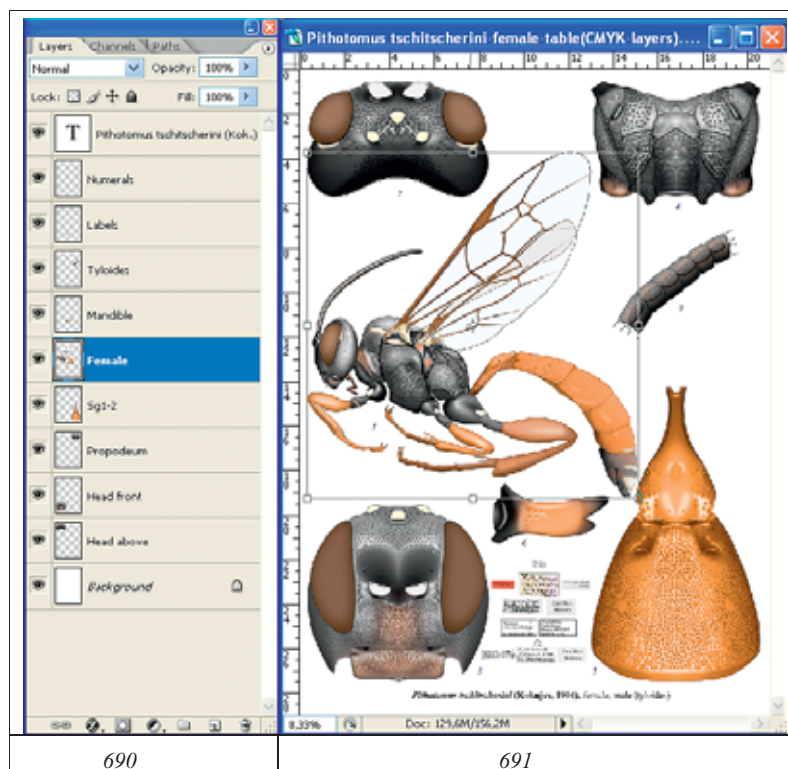
**Fig. 688-689:** Fulfillment of a fragment of flagellum of male with maximum number of layers: (688) hierarchy of layers, (689) tyloides on segments 13-18.

#### Preparation of the final table of taxon illustrations

At the given stage in directory "Result" there are 10 files from which it is necessary to prepare the total table: "Pithotomus tschitscherini-female-head\_above(CMYK)", "Pithotomus tschitscherini-female-head\_front(CMYK)", "Pithotomus tschitscherini-female-propodeum(CMYK)", "Pithotomus tschitscherini-female-sg1-2(CMYK)", "Pithotomus tschitscherini-female-total(CMYK)", "Pithotomus tschitscherini-female-mandible(CMYK)", "Pithotomus tschitscherini-male-tyloides(CMYK)" and three files with scanned labels of specimens which were used at preparation of pictures: "Pithotomus tschitscherini-female-lable(Holotype)", "Pithotomus tschitscherini-female-lable(orig)" and "Pithotomus tschitscherini-male-lable". All of enumerated files are in the format "TIFF".

For table preparation, a new file in format CMYK of the size A4 21x29 cm and the resolution 600 dpi, is created. In an active window, a ruler and a grid which necessary for positioning of separate segments (Menu: View-Rulers; Show-Grid) are switched on. File is named as "Pithotomus tschitscherini-female-table(CMYK-layers)" and it is saved in directory "Result".

Size of separate segments is selected proceeding from peculiarities of concrete taxonomic group. In our example (Ichneumonidae) the width of a head capsule of the ichneumon fly of 7,5 cm was as reference point for other components of a table. From files, listed above (from directory "Result") the images of segments are selected and copied (Ctrl+A-Ctrl+C). At first, image of head from above is copied and then, it is inserted into a file with the table by command Ctrl+V. After an insert of object, it is moved by the mouse cursor to the upper left angle of canvas and a command of Menu: Edit-Transform-Scale is chosen. Then, having pressed and not releasing key Shift, the image is scaled to the necessary size. Further, similarly, all other parts of a body are inserted and scaled by consistently. After an insert of images of segments, an image of imago total is inserted. By the menu command: Edit-Transform-Scale (Rotate), the image of imago is positioned in the central part of the canvas (fig. 691). The images of mandible and fragment of flagellum of the male with tyloides are inserted the last.



**Fig. 690-691:** Final plate with complete set of layers: (690) hierarchy of layers, (691) positioning of imago image in the table.

After inserting all the images in separate layers, scanned labels of the specimens which was used to fulfillment of a table are inserted. Further, the separate components of table are enumerated by selected font. Numbering is saved in a separate layer.

The scientific name of a taxon is fulfilled in a separate upper layer, having selected the conforming fonts and their size according to demands to the publication.

At the final stage all layers with drawings are merged and saved to a final file for the publication with layers: "Images", "Labels", "Numerals", "Species name" and "Background". File prepared for the publication is saved under new name "Pithotomus tschitscherini-table (CMYK-without layers)" in format "TIFF".

### **The unified description of a taxon and its conformity to graphic representation of characters**

As it was already spoken in introduction, the purpose of the work is to advancement in the maximum degree of the unified system of the description of the taxa and graphic representation of theirs characters. At the closing stage of work we present as much as possible unified, from our point of view, a description of a taxon of a specific rank. For

this species, in the previous sections, a stage-by-stage preparation of illustrations, both the most significant taxonomically parts of a body, and an imago were described. Practically all characters of a taxon in the description have graphic presentation in the table (**Plate 8**). In the scientific description of the object and in the table they are marked by numbers. Only descriptions of the front margin of pronotum and transverse furrow of pronotum interrupted by keel have no graphic representation. However, these signs are obvious enough and do not require additional illustrations.

***Pithotomus tschitscherini* (KOKUJEV) (Plate 8)**

*Anisobas tschitscherini* KOKUJEV 1904 - Rus. entom. obozr., **4**,2: 199, ♀.

*Pithotomus rufiventris armenicus*: HEINRICH 1978. - East. Pal. Ichn.: 78, ♀.

*Pithotomus rufiventris*: HEINRICH 1980 - Spixiana, **3**,3: 225.

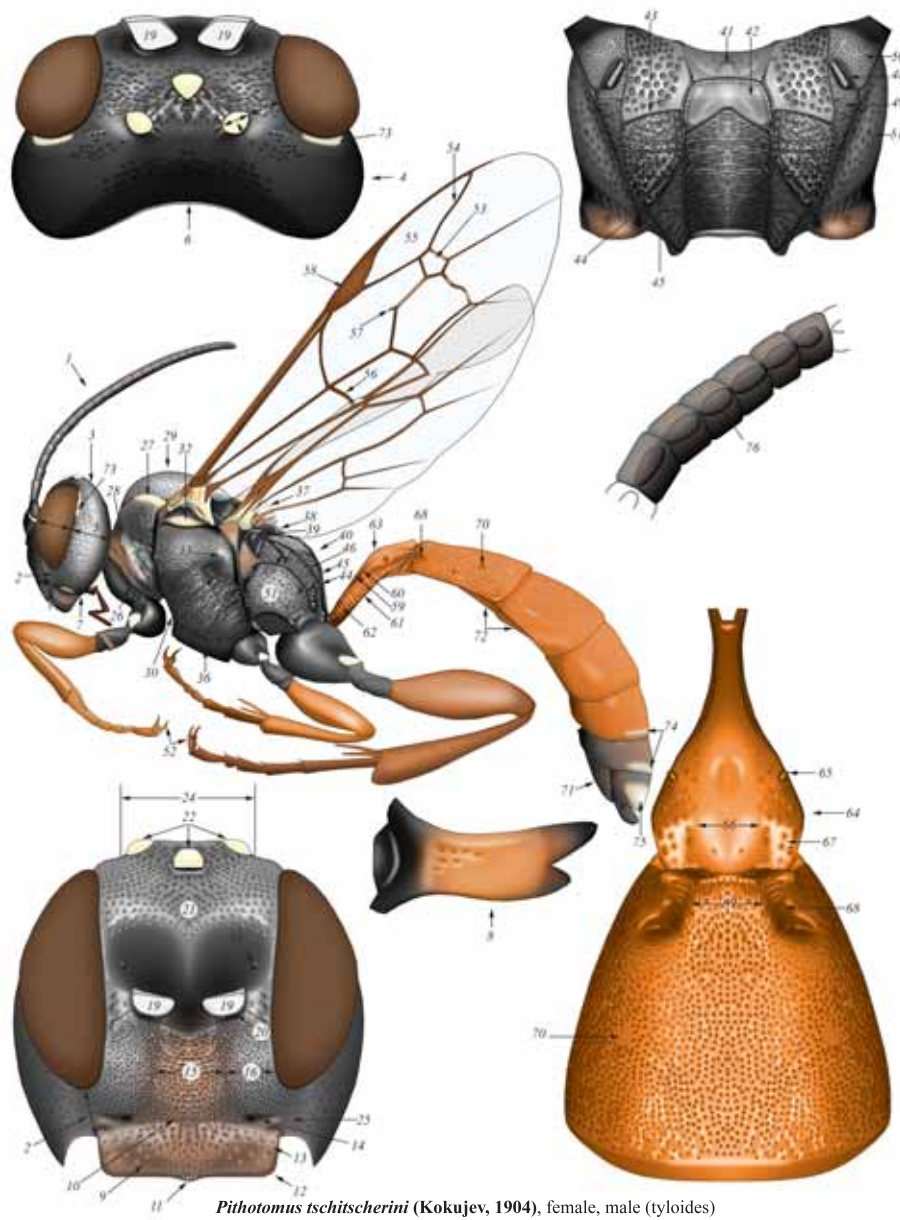
*Pithotomus tschitscherini*: RASNITSYN 1984 - Entomol. obozr., **63**,4: 794-796.

**F e m a l e**

**F l a g e l l u m** : Short, filiform, with 27 segments, without white annulus, slightly rufous, slightly widened and not flattened at the apical third (**1**); basal segments short, first segment 2 times longer than width at apex, segment 9 square from lateral. Flagellum 1,7 times shorter than the front wing and 2,3 times shorter than body length.

**H e a d** : Head contour from front slightly roundly narrowed downwards, rounded, with equal length and breadth; temples from front visible up to upper third of an eye (**2**); eyes not great; head from above stout, transverse, 1,6 times wider than length. Vertex from lateral roundly slanting down to occipital carina; (**3**); temples behind eyes from above roundly swollen (**4**), width of a head at level of temples more than at level of eyes; from lateral temples long, 1,4 times longer than longitudinal diameter of eye at middle (**5**), parallel to hind margin of an eye; occipital carina sharp all round, moderately high, from above roundly concaved, far not reach level of hind ocelli, and eyes (**6**) meeting with hypostomal carina on base of mandible (**7**); hypostomal carina not visible from lateral; malar space 1,5 times shorter than the mandible base width; mandibles wide and massive, sharply curved from above behind base almost at right angle, not narrowed to apex, parallelsided at most part and slightly swollen at apex, with two strong teeth separated by wide gape and situated in the same plane, upper tooth considerably longer than lower one (**8**); clypeus flat, transverse (**9**), 3,6 times wider than length, practically not separated from face (only by slight broad impression) (**10**), of peculiar shape, with impressed, thinned apex with broad medial projection (**11**) and enough distinct, but rounded lateral corners (**12**) and slightly elevated lateral margins under clypeal foveae (**13**); clypeal foveae (**14**) indistinct, only in a form of broad impressions between clypeus and lateral fields of face extended up to malar space; labrum slightly protrude from under clypeus, short, roundly-triangular, narrower than front margin of clypeus; surface of face slightly differentiated, clypeus separated from lateral fields of face enough distinctly (unlike other genera of tribe); middle field of face very slightly but distinctly expressed (**15**), 1,6 times wider than lateral fields in middle (**16**); antennal cavities (**17**) not big, deeply impressed, far not reach level of front ocellus and only just reach borders of eyes, laterally above antennal fossae with distinct lateral tubercles (**18**) and without of interantennal tubercle; margins of antennal fossae (**19**) slightly elevated above face surface (**20**); frons some under front ocellus with broad impression (**21**); ocelli moderately convex, small (**22**), diameter of lateral ocellus (**23**) 1,8 times less than distance from ocellus to eye; ocellar triangle not

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**Plate 8:** Complete table of pictures of species *Pithotomus tschitscherini* (KOKUJEV 1904) with numbering of characters (see description in the text).

**A b d o m e n :** Amblypygous, long, from above quite narrow with oblong apex; second tergite only just transversal, 1,1 times shorter than breadth at apex; tergites 2 and 3 quite strongly separated; tergites 6-7 projected on considerable length; sides of tergite 6 bending far onto the ventral side almost closing above hypopygium (as of some *Limerodops* HEINRICH); sheath of ovipositor from above only just protrude. Petiolus not flattened at base, dorsomedian carinae (59) visible only from base up to middle of tergite, dorsolateral carina (60) weak, ventrolateral carina (61) sharp; lateral surface of petiolus with distinct transversal ribs (62); petiolus from lateral with distinct but gradual transforming to postpetiolus (63), from above gradually broadened to postpetiolus (64); spiracles (65) small, distance between them 1,4 times more than distance from spiracles to apex of tergite; middle field (66) only slightly elevated and not carinated; its surface smooth, or sometimes with only just visible smoothed longitudinal striation, shining, with distinct impression at level of spiracles; lateral fields punctured (67). Gastrocoeli (68) not big, slightly but distinctly impressed, many narrower than interval between them (69); thyridia absent; lunulae (70) of moderate size in a form of more or less distinct impressions behind middle; interval between gastrocoeli (69) with slight longitudinal wrinkling at base; surface of second tergite very densely punctured by smoothed irregular punctures, medially punctures more big and elongated, shining, without microsculpture; puncturation of tergites more delicate to apex of abdomen; abdomen polished. Hypopygium (71) not compressed from sides with oblong apex, overlap slit of ovipositor, but not reach apex of ovipositor sheath. Sternites 2-4 strongly unsclerotized, with fold (72).

**C o l o r a t i o n :** Head and thorax black; white: narrow stripes at top of external orbits (73), pronotal ridge broadly (27), subalarum (32) and scutellum entirely (37). Abdomen red with darkened apex, white: apical stripes on tergites 5-6 (74) and spot on tergite 7 (75). Legs with exception of coxae and trochanters brownish-red; front tibiae with yellowish stripe outside.

**S i z e :** Body length - 8,5, flagellum - 3,7; front wing - 6,4 mm.

#### **M a l e**

Flagellum of males with 31 segments and broadly-oval tyloides (76) on segments 7-21, tyloides on segments 10-17 very big, almost on all length of segments. Carinae of propodeum more sharp and high. Unlike of females broad white bands not only on tergites 5-6, but on tergite 4, and tergite 7 white entirely.

### **Conclusion**

As a result of 25-years experience of preparation of scientific illustrations it is established that the scientific illustration that is fulfilled under a unified scheme is a necessary component of describing taxon, especially of high rank. Presence of the unified description of a taxon along with unified illustrations, allows describing new taxa without resorting to type material and avoiding research of the total volume of objects of its rank. A necessary condition of a successful result of investigation of any group of taxonomically defined objects is working out of the uniform, unified scheme of representation of their characters.



The major condition of valid scientific illustration of an object and its features is fulfillment by specialist in taxonomy of a particular group of organisms, rather than a professional artist who is not familiar with taxonomic features.

The level of development of modern methods of digital image processing allows preparing a scientific illustration of taxon practically without resorting to a pencil and paper. And, with availability of certain skills, it becomes accessible to taxonomist who has no artistic aptitudes. Precise elaboration of small structures at high magnification and maximal using of layer possibilities are necessary conditions at fulfillment of illustrations. On the final image of object, with its real size, these details can be not visible, but representation about any class of structures becomes maximally real. The developed and proposed technique of fulfillment of the unified images of a taxon and its characters along with its unified description allows reaching the maximum effect in taxon representation.

The sequence of operations described above is suitable without modification for preparation of scientific illustrations of any taxa of hymenopterous insects (Hymenoptera).

While working out the necessary scheme, the proposed technique can be used to fulfill illustrations of any wildlife objects.

### Acknowledgements

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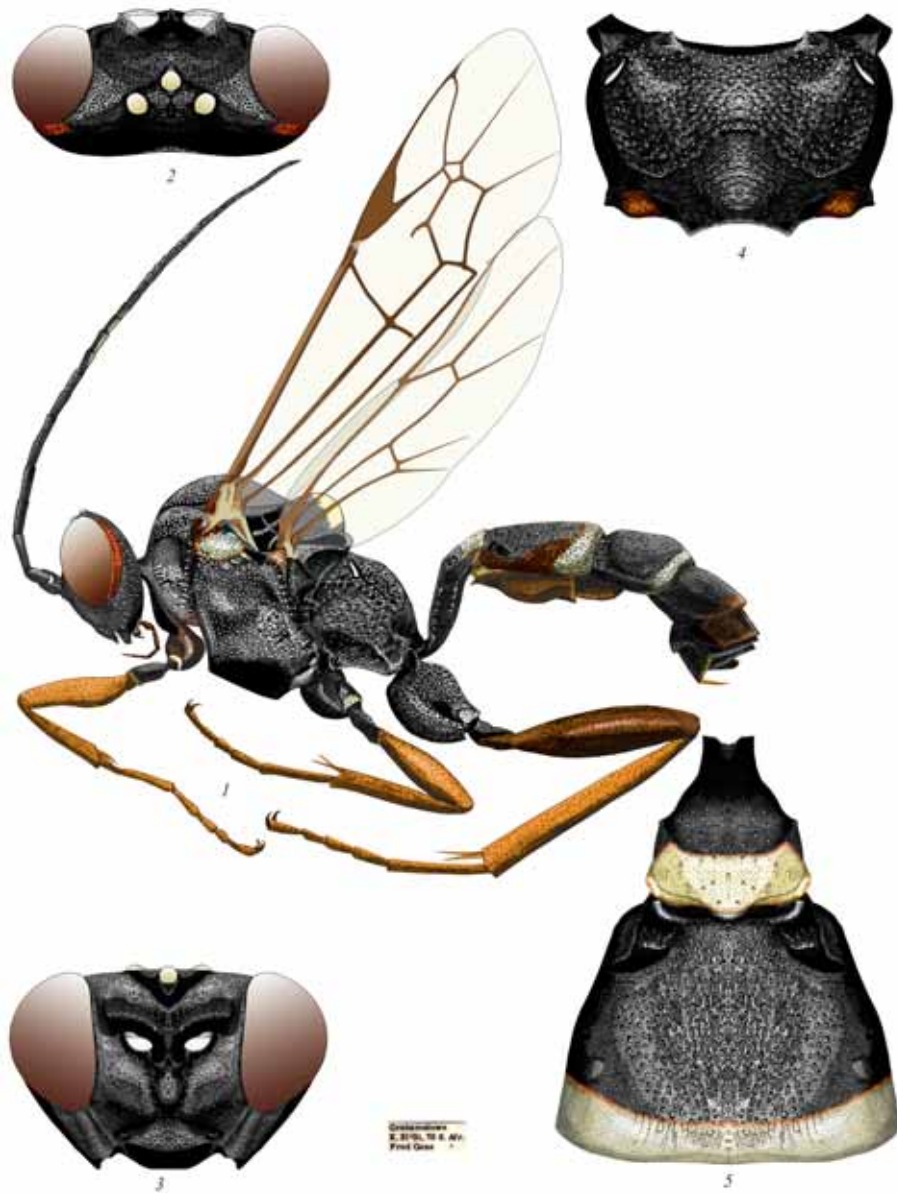


*variegatus* (SZÉPLIGETI), (46) *Callajoppa cirrogaster* (SCHRANK), (47) *Ttogus lapidator* (FABRICIUS). (49) **Front part of a thorax from above** *Clypeodromus thyridialis* TERESHKIN. (50) **Apex of abdomen of female** *Hymenura nigra* (HEINRICH). (51) **Apex of abdomen and oedeagus of male** *Tricholabus strigatorius* GRAVENHORST (52-53) **Claws of female tarsi:** (52) *Clypeodromus thyridialis* TERESHKIN, (53) *Pyramidophorus flavoguttatus* TISCHBEIN.

**Plate 9-56:** (1) imago, (2) head from above, (3) head from front, (4) propodeum, (5) tergites 1-2 of abdomen, (6) tyloides on flagellum of male, (7) mandible, (8) mesonotum from above, (9) area superomedia of male, (10) scutellum from above, (11) scutellum from lateral, (12) collar of pronotum from lateral, (13) collar of pronotum from above, (14) apex of male abdomen (15) apex of abdomen from above, (16) claws of tarsi, (17) maxillary palp.

**Examples of tables of illustrations of Ichneumoninae fulfilled manually and completed in the graphic editor (according to TERESHKIN 2009)**

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**Plate 21:** *Spanophatnus bicinctorius* (THUNBERG), ♀ (Platylabini).

1244



**Plate 23:** *Clypeodromus thyridialis* TERESHKIN, ♀, ♂ (6) (Clypeodromini).

1247



**Plate 26:** *Compsophorus (Epijoppa) verecundus angolae* (HEINRICH), ♀ (Compsophorini).

Examples of tables of illustrations of Ichneumoninae completely fulfilled in the graphic editor

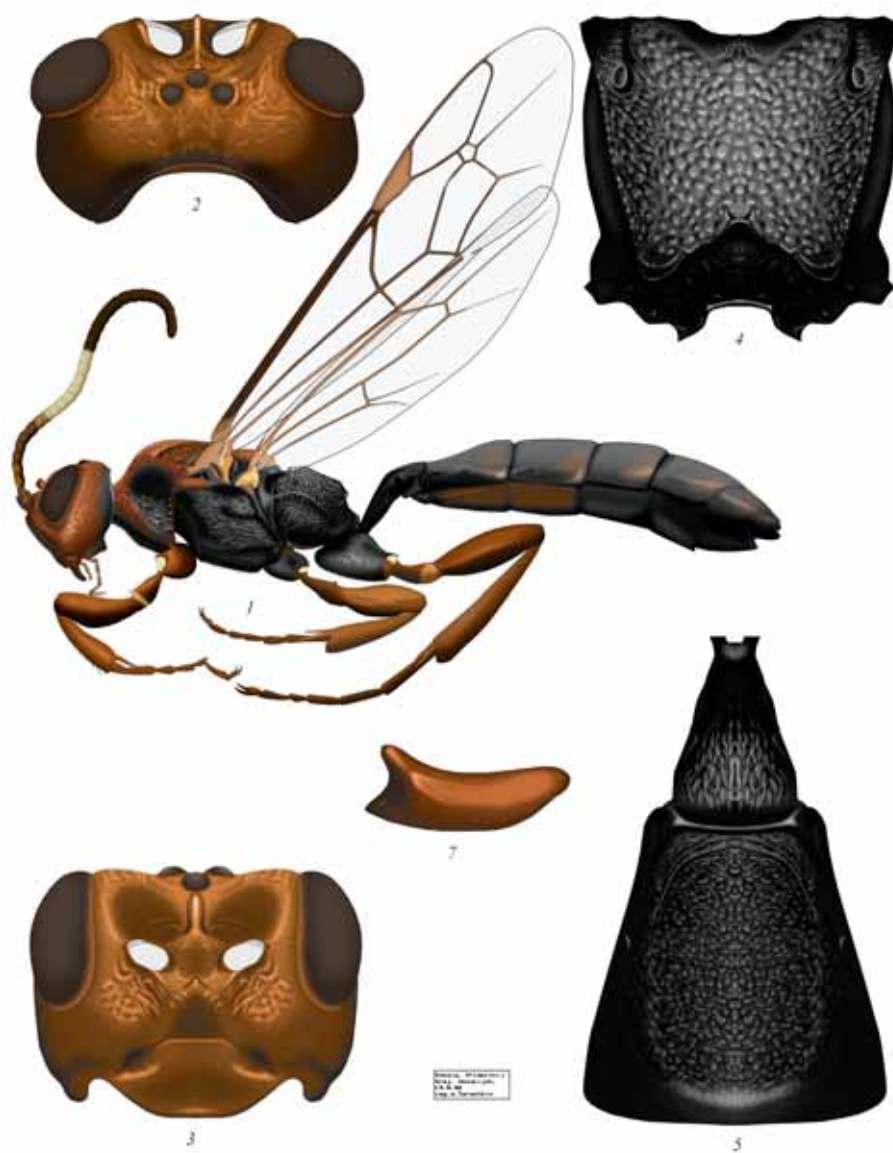


Plate 30: *Pseudalomya praevara* TELENGA, ♀ (Alomyini) (according to TERESHKIN 2009).



1253



**Plate 32:** *Pagarenes erythropus* CAMERON, ♀ (Platylabini) (according to TERESHKIN 2009).

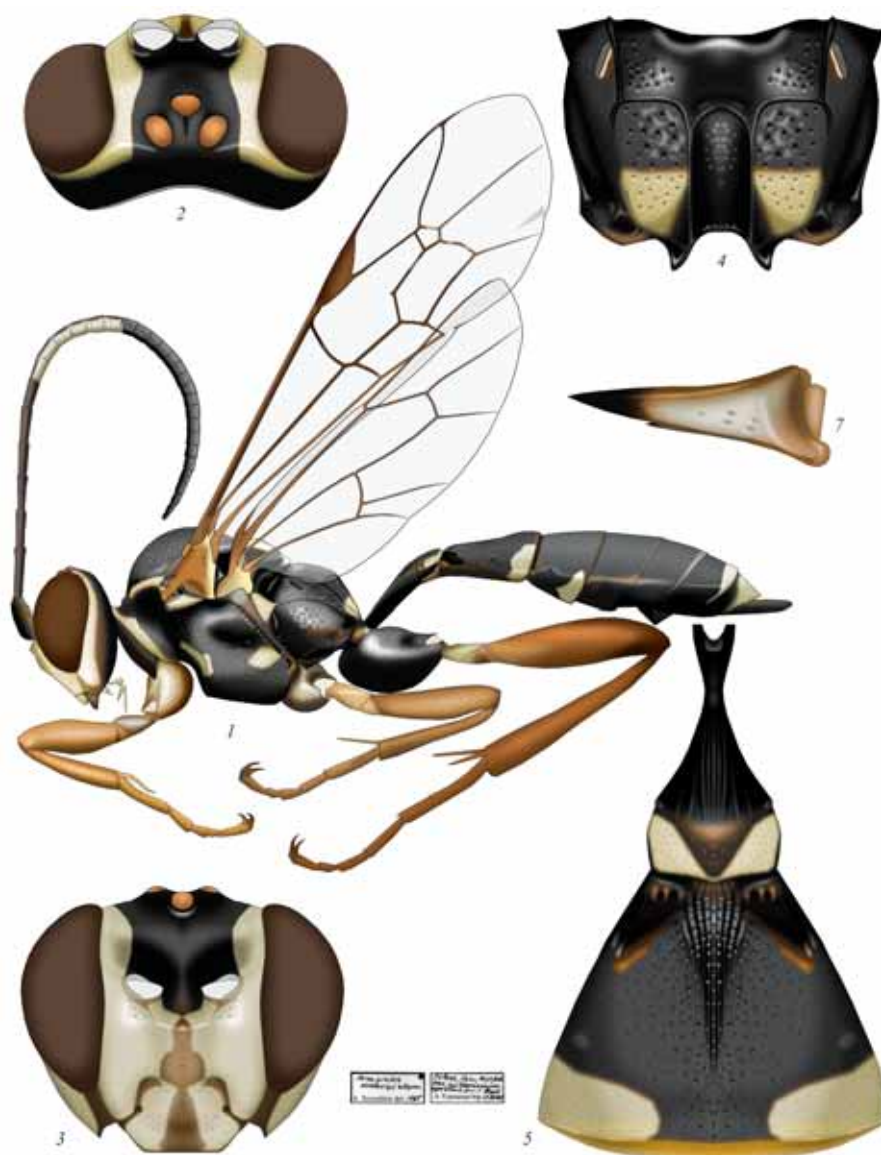


1255



**Plate 34:** *Euylabus torvus* WESMAEL, ♀ (Eurylabini) (according to TERESHKIN 2009).

1273



**Plate 52:** *Heresiarches eudoxius* (WESMAEL), ♀ (Heresiarchini) (according to TERESHKIN 2009).