SCIOL GENETIC SCIENCE

SCIENCE OPEN LIBRARY

ISSN: 2631-407X

RESEARCH ARTICLE

The Mutations Disturbing the Bilateral Symmetry in *Drosophila*

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Citation: Chadov BF, Fedorova NB (2019) The Mutations Disturbing the Bilateral Symmetry in *Drosophila*. SCIOL Genet Sci 2019;2:139-152

Accepted: October 19, 2019

Published: October 21, 2019

Abstract

Secondary mutations, modifications, and morphoses emerge in the progeny of the *Drosophila melanogaster* individuals carrying conditional mutations. Morphoses (monstrosities) are the local abnormalities of different degrees in the appearance of an adult fly. The rate of the progenies with morphoses varies from several to several tens of percent. Secondary mutations and modifications appear symmetrically at both sides of the fly's body. Morphoses interfere with a bilateral symmetry of the body: They emerge on one of the sides (left or right). It is assumed that the differences in relations of the common mutations and morphoses to symmetry are explainable by the differences in the activity type of the Mendelian genes and ontogenes. Mendelian genes are responsible for common mutations, whereas ontogenes are involved in emergence of conditional mutations. Mendelian genes control the synthesis of macromolecules. A chemical synthesis is independent of space and, thus, bears no relation to symmetry. Ontogenes control the division of cells and their orientation in space after division. This requires a mechanism that is fundamentally different from chemical synthesis. Any damages in ontogenes result in emergence of morphological defects with a broken symmetry. An autonomous biochemical mechanism underlying the development of the living and comprehensively mastered by the current genetics can be most likely supplemented with still understudied *biophysical mechanism*. The nature of this mechanism is hypothesized.

Keywords

Conditional mutation, Ontogenes, Morphosis, Bilateral symmetry, Electromagnetic field, *Drosophila*

Introduction

Drosophila is an organism with a bilateral symmetry. According to the genetic doctrine, the phenotype is a derivative of the genotype. Thus, the genes involved in development of the symmetric structures must be responsible for this symmetry. For example, the genes involved in the development of the fly's wing must provide the formation of two wings, the left and the right ones, rather than a single wing. These structures are *the entities similar in their structure but not interchangeable.* The left wing cannot replace the right one and vice versa. Current genetics yet does not know how symmetric structures are formed and which particular genes are capable of providing this symmetry.

Bilateral symmetry is typical of a normal fly phenotype. Noteworthy that numerous mutations affecting and changing different organs of the fly do not broke this symmetry [1] besides some exceptions, namely, the mutation *tetraptera* [2], some alleles of the *eyeless* gene [1], and several other cases [3]. Astaurov [4,5] based on the symmetry disturbances caused by the *tetraptera* mutation suggested existence of a specific type of biological variation that was neither genetic nor environmental. This type of variation was later named *implementational* variation [6]. However, the mechanism underlying development of symmetric structures yet remained vague.

In 2000, the mutations later named *conditional* were obtained in *drosophila* [7,8]. As a rule, these conditional mutations are lethal. They manifest themselves under restrictive conditions and do not appear under permissive genetic conditions [8,9]. According to the method of their generation and their manifestation pattern, the con-

ditional mutations are a result of local DNA damages caused by ionizing radiation. Similar to the Mendelian mutations, conditional mutations are inherited, maintained in culture [9,10], can be located using deletions [11], and pass a complementation test [9]. On the other hand, conditional mutations are fundamentally different from Mendelian mutations by their conditional manifestation. The Mendelian mutations are independent units of heredity, whereas the conditional mutations are dependent ones.

A specific feature of the conditional mutations is morphoses, i.e., specific abnormalities of the ontogenesis in the progenies of mutants [12]. That is why the genes responsible for formation of conditional mutations were named *ontogenes* [13-15]. Morphoses appear on only one side of the body, the left or the right. Unilateral defects do not result from elimination of a bilateral manifestation. Our collection contains enough morphoses that insignificantly change the fly appearance, for example, the morphoses that change the leg segmentation. It is difficult to imagine that the presence of such defect from both sides of the body could cause elimination of the progenies.

The goal of this paper was to analyze the cases of broken bilateral symmetry in the progenies of *Drosophila melanogaster* conditional mutants. These abnormalities will enhance clarification of the specific features of ontogenes, responsible for emergence of conditional mutations. The role of ontogenes in individual development [16,17], phylogenesis [9,18-20] and the phenomena of inbreeding depression and heterosis [21,22] appears most important. The very fact of existence of the ontogenes as a specific category of genes suggests that they perform a certain still vague but important function of the genetic system, which cannot be fulfilled by any Mendelian genes.

Materials and Methods

The objects of this study were the *D. melanogaster* stocks carrying conditional mutations in chromosomes X, 2, and 3. The conditional mutations in the X chromosome were maintained as a heterozygote with the Muller-5 chromosome; in chromosome 2, with the SM1 balancer chromosome; and in chromosome 3, with the In(3LR)D inverted chromosome. In these cultures, the conditional mutations behaved as recessive lethals without any apparent phenotype. The progenies of mutant individuals with certain changes in normal phenotype emerged from time to time. They were classified as 1) Secondary mutations; 2) Modifications, and 3) Morphoses. The visible manifestations were recorded as digitized color images. The resulting collection comprises approximately 1000 images; about 100 of them grouped according to individual *drosophila* body parts are shown in the review [23]. The color images of secondary mutations, modifications, and morphoses were captured not only when they emerged in the stocks of conditional mutants, but also in the progenies of the crosses between conditional mutants and various strains. Here, we have conducted a phenotypic analysis of the mutations, modifications, and morphoses for the symmetry of their manifestation.

Experimental

The procedure of isolation of conditional mutations in *drosophila* [7,10,24] did not imply that these mutations could have any visible manifestations but they still emerged. According to the symmetry of manifestation and inheritance pattern, they were ascribed to two known genetic phenomena-mutations and modifications [25,26] and another one, the third, to a less known phenomenon, morphoses (monstrosities) [12,27,28]. A symmetric manifestation was assessed immediately on the emergence of a corresponding variant and its inheritance pattern was clarified in a series of successive crosses. Find below the data on morphoses, as well as on secondary mutations and manifestations. Our attention is focused on morphoses but the data on mutations and modifications obtained in the same experiments are also described since they are important for understanding the nature of morphoses.

Figure 1: The morphoses of the "plus tissue" type (surplus morphological structures): a) Groups of eye ommatidia (red spots) on the occiput; b) An additional eye on the right side; c) An additional thorax with an altered wing on the right side and a normal wing on the right side in a form of a structureless bubble; d) An additional wing on the right side (directed forward) and an altered thorax on the right side; e) A tergite fragment with bristles on the abdomen; f) Doubling of the external male genitalia; g) Four wing-like appendages with bristles instead of a normal wing on the right side; h) Tarsus on the abdomen; and i) An additional altered seventh leg.

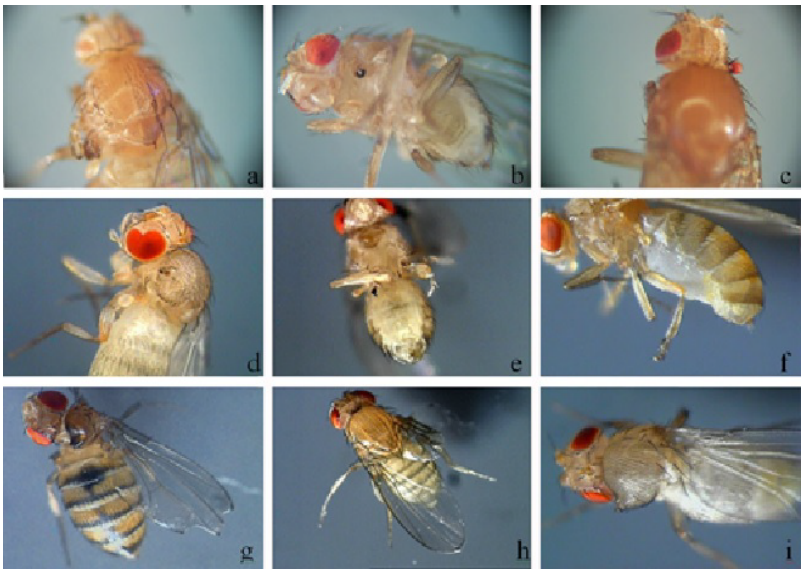

Figure 2: The morphoses of the "minus tissue" type (lacking morphological structures): a) Loss of a wing (stump) and bristles on the left thorax; b) Loss of a prothoracic leg on the left side; c) Loss of the head capsule and a major part of the right eye; d) Loss of the left wing and circular bristle pattern on the left thorax; e) One pair of legs instead of three pairs in the normal fly and different shapes of the right and left legs in the remaining pair; f) Reduced tarsus of the left metathoracic leg; g) Loss of a half thorax on the left side, including the wing, and a right wing with a *Notch*-type indentation; h) Circularly cut right wing; and i) Loss of the left wing and a cone-like stretched left thorax.

Phenotypic defects in the progenies of conditional mutants

Morphoses: The morphoses emerging in the progenies of mutants are local abnormalities of the adult fly phenotype manifested to different degrees (Figure 1 and Figure 2). A high rate of morphoses resulted in that the collection of their images rapidly reached a significant size, about a thousand of images [23,29]. The diversity of morphoses and the depth of the abnormalities are really amazing; however, they do not lead to a lethal outcome. Most morphoses do not interfere with the fly hatching from a pupa, common existence, mating, and even giving the offspring. Those working with flies observe emergence of morphoses but these are very rare cases. However, morphoses frequently emerge in the progenies of mutants and their fre-

Table 1: Emergence of morphoses in the progeny of a *mutation/y² ec cv ct v f* female.

Mutant strain no.	Total number of progenies	Rate of the progenies carrying morphoses (%)
2	485	11.3
3	244	10.7
5	362	26
6	596	2.4
7	317	17.9
8	405	14
9	428	14.7
10	271	6.6
11	390	16.7
27	108	6.5
29	471	3.2
30	243	11.1
31	417	8.6
32	415	12.8
33	97	15.5
34	737	10.9
35	478	11.9
36	327	25.7
38	126	3.2
41	408	16.4
Control	3687	0

Table 2: Emergence of morphoses in diallelic testing of the conditional mutations in the X chromosome (cross of $(X)_n$/*In(1)Muller-5* female × $(X)_{n+1}$ male).

Mutant female strain no	Daughter *B*/+	Daughter+/+	Son *M-5*	Son+	Total number of progenies	Of them, number of progenies with morphoses	
						Total	Share of the progeny (%)
1	129	47	147	109	432	37	8.6
2	208	76	229	272	785	58	7.4
3	51	27	46	48	172	8	5.7
5	227	163	253	270	913	72	8.9
6	354	115	203	270	942	21	2.3
7	93	27	87	100	307	16	5.2
8	224	126	153	212	715	34	4.8
9	227	126	176	241	770	33	4.3
10	192	97	178	235	702	37	5.3
11	251	162	204	195	812	37	4.6
27	169	68	170	176	583	45	7.7
29	96	34	89	103	322	24	7.5
30	152	86	133	176	547	24	4.4
31	161	111	144	210	626	19	3
32	62	40	44	50	196	2	1
33	77	33	92	70	272	5	1.8
34	58	50	43	42	193	7	3.6
35	144	91	135	136	506	15	3

quency depends on a particular mutation, type of the culture used for maintaining a mutation, and age of the stock. The share of progenies carrying morphoses may reach several tens of percent. Table 1 lists the frequencies of morphoses in the progenies of the females tested for crossover [30].

The frequencies of morphoses shown in Table 1 are calculated according to the number of the progenies carrying morphoses. In some cases a mass emergence of morphoses was observed. Identical morphoses in the progeny of the same mated pair were regarded as a single case. In total, five cases of mass morphosis emergence have been recorded in the experiment on crossover and each of them contained several tens of abnormal individuals. High frequencies of morphoses were recorded in a large experiment with diallelic crosses of conditional mutations (Table 2).

The process of emergence of morphoses in mutant stocks was not a monotonic one although the causes underlying the change in the rate of morphosis emergence are still vague. A general impression is that a cross with other stocks stimulates emergence of morphoses. The crosses between mutant stocks lead to the same effect. It looks as if the emergence of morphoses during maintenance of the stock cultures carrying conditional mutations abates with time. However, we have not focused on studying this issue in more detail.

For systematization, all morphoses were divided into two large classes, namely, “plus tissue” and “minus tissue”. Figures 1 and Figure 2 show examples of both classes. It is difficult to find any part of the fly body that avoided changes by morphoses, multiplication, or elimination. For example, half head, eyes, arista and antenna, bristles on the head and thorax, half thorax, haltere, the whole wing or its parts, abdominal segments (tergites), sternites, legs (one, two and all three from one side), individual parts of the leg (femur, tibia, and tarsus), and the overall anal and genital complex could be absent.

A separate class of morphoses is the combined morphoses, which concurrently carry the changes of a “plus tissue” or “minus tissue” in one body region and a change in another body region. For details, see our earlier paper [23]. This paper gives samples of wing (Figure 3) and leg (Figure 4) morphoses as examples of the morphoses of individual fly body parts.

A progeny of a pair may contain either a single individual with a morphosis or a number of individuals. In some cases, the overall progeny reaching several tens of individuals carry morphoses (note that their form is most frequently the same). Figure 5f and Figure 5g shows two cases of morphoses identical in their form.

The presence of a conditional mutation guarantees emergence of morphoses in successive generations. This fact has been reliably traced during long-term maintenance of the stocks carrying conditional mutations. However, the form of morphoses is not inherited. For example, once a morphosis in the first generation involved the wings, it can in the second generation affect the legs or some other body part. On the other hand, the cases when progenies carry absolutely identical morphoses have been recorded, as is illustrated in Figure 5f, Figure 5g.

Morphoses in the progeny of a conditional mutation emerge following the pattern of a parental effect (maternal, paternal, of concurrently both). In other words, emergence of a progeny with a morphosis does not require the presence of a conditional mutation in this progeny: The presence of the conditional mutation in one of the parents is sufficient. In terms of the parental effect, emergence of morphoses does not differ from any other manifestations of conditional mutations (for details, see [10,17,31]).

Secondary mutations: Secondary mutations are a rarer and a solitary event; typically, the mutants have a phenotype known from the description of *D. melanogaster* mutations in catalogs [1], including a *white*-type eye color, *Bar*-type eyes, *black*-type cuticle color, and so on. The observed phenotypes display *a bilaterally symmetric manifestation.* The mutations detected over several generations have been cultivated and are inherited as typical recessive mutations with a visible manifestation. Eight cases of secondary mutations are shown in Figure 5, namely, the mutations *speak, cabin, short legs, dumpy, black, white-apricot,* and *Bar.* The mutation *yellow* (Figure 5g) is not a secondary mutation; it emerged in a strain with a conditional mutation

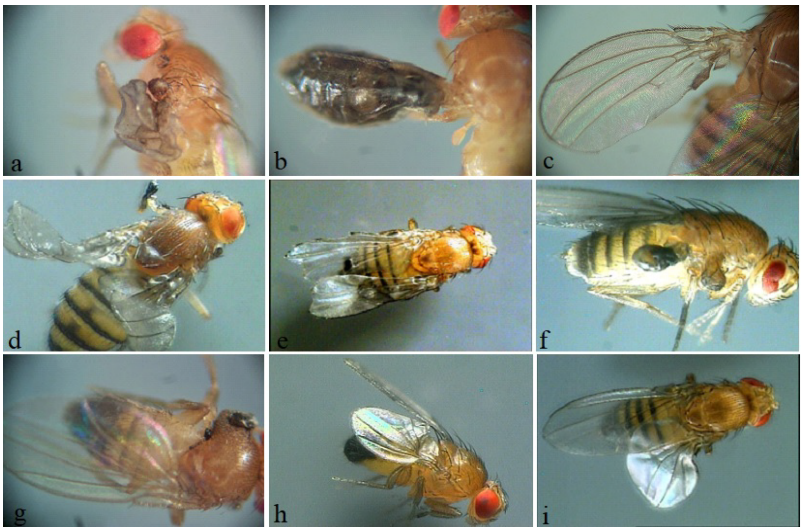

Figure 3: The morphoses of the wing: a) Rumpled left wing; b) The left wing filled with a melanotic substance; c) Reduced left wing with completely absent vein L5; d) An additional wing at the left side as a tube-like appendage; e) Reduced wings with asymmetric *Notch*-type indentation at the wing edge; f) The right wing is replaced by two bag-like projections with bristles; g) Absent the left wing with changes in the thorax and necrotic (black) regions; h) Shortened right wing with an untypical round shape; and i) Changes in wing shape on the right side.

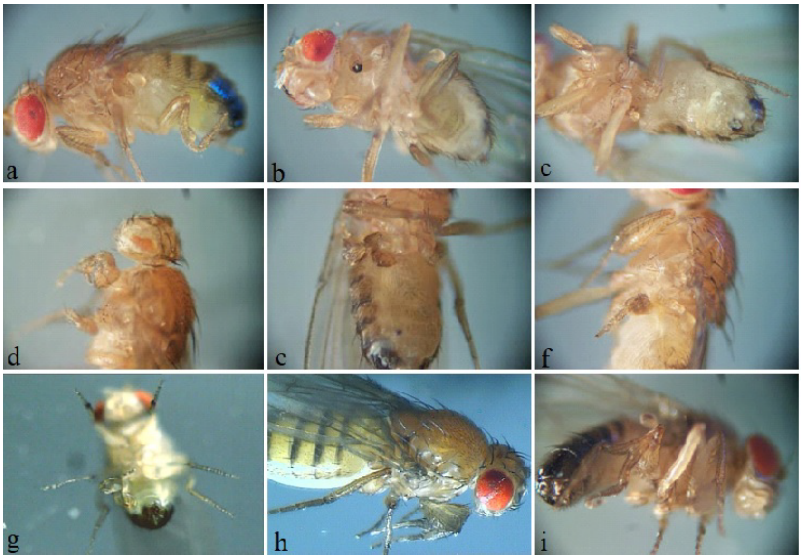

Figure 4: The morphoses of the leg: a) Deformed femur, tibia, and tarsus of the left metathoracic leg; b) Absent left prothoracic leg; c) Absent right metathoracic leg; d) The left prothoracic leg has the shape of a chela (bifurcated tarsus); e) A stump of the right metathoracic leg; f) Absent femur and tibia of the left metathoracic leg; g) Additional seventh leg (wound); h) Thickened tibia of the right prothoracic leg and bifurcated tarsus; and i) Bifurcated right metathoracic leg (tibia and tarsus).

as a result of a cross. The phenotypes of mutations are shown for comparison (see below, Section 3) in the flies carrying morphoses.

Modifications: Modifications emerge at a higher rate as compared with secondary mutations. In their phenotype, they resemble mutations but appear not in singles but rather in groups. Similar to secondary mutations, modifications are bilaterally symmetric (Figure 6). The attempts to obtain a culture of an individual with a mutant phenotype allows for confirming whether a particular variant is a modification. The crosses of closely related individuals for several generations lead to a rapid increase in the occurrence of "mutant" phenotypes but their number abruptly drops in a certain progeny down to several individuals or the mutants just disappear. The attempts to obtain the culture from an emerged phenotypic variant have always failed.

Asymmetry of morphoses

A specific feature of the emerged morphoses is their asymmetry. The morphoses

Figure 5: Secondary mutations and morphoses: a) *Speak* mutation; b) *Cabin* mutation; c) *Plexus* mutation; d) *Bar* mutation (an eye as a band) in the *short legs* strain and a morphosis of the left wing; e) *Dumpy* mutation (obliquely cut wings) and a morphosis (absent right wing); f) *Black* mutation on the left side and a morphosis of the right wing (its shortening and a bubble on it); g) A morphosis (bifurcation of the thorax and a bubble-like left wing) in *yellow* strain; h) *White-apricot* mutation and a morphosis (absent half thorax and the left wing); and i) *Bar* mutation and a morphosis (a decreased second head instead of the left eye; the eye on the small head copy has the same phenotype as on the main head).

of a "plus tissue" type (Figure 1) or "minus tissue" type (Figure 2) emerge at either the left or the right side of the body, for example, on one wing (Figure 3) or one leg (Figure 4). It looks as if morphoses cannot be symmetric at all. Here we speak about the morphoses of the same form. A mutant fly can carry not only a single morphosis, but also several morphoses different in their form; in this case, morphoses may reside at both sides of the fly's body.

Symmetry of mutations versus asymmetry of morphoses

A unilateral manifestation of morphoses (Figure 1, Figure 2, Figure 3 and Figure 4) contrasts to a bilateral manifestation of modifications (Figure 6) and secondary mutations (Figure 5). The contrast with regard to symmetry is especially evident in the individuals that carry the defects of different natures. In Figure 5, the same individuals carry both secondary mutations and morphoses but these morphological defects manifest themselves according to their specific features. Morphoses are unilateral in all cases, whereas mutants reside at both sides of the fly's body. The eight mutations shown in Figure 5 are secondary mutations formed in the stocks of conditional mutants. The mutation *yellow* is a standard Mendelian mutation that appeared in the flies carrying a conditional mutation as a result of crosses.

Noteworthy is the case of a bilateral manifestation of a Mendelian mutation, *Bar,* in combination with a fractal-type morphosis, namely, an additional small head instead of the left eye (Figure 5i). The fly heterozygous for the Mendelian mutation *Bar* carried this mutation at both sides of its body: On the right side, instead of its eye and on the left side, instead of the "secondary" eye of the morphosis in the form of additional head. This demonstrates that the defects of a morphosis type and a Mendelian mutation type manifest themselves independently.

A unilateral (left or right) manifestation of a phenotypic defect is the most frequent but not the only disturbance of symmetry in the progenies of a conditional mutant. The second in frequency is multiplication of an abnormal or a normal structure that is normally singular. Doubling of wing structures is shown in Figure 1c and Figure 3g, Figure 3f, and Figure 7g; of the genitals, in Figure 1f; and of parts of the leg, in Figure 4d, Figure 4h, and Figure 4i. Thus, the symmetry emerges in the cases when it is normally absent.

The direction of the symmetry axes may remain close to the norm (anteropos-

Figure 6: Modifications: a) Inserted head capsule regions in the eye); b) A “triangle” eye; c) Defects of the eye shape; d) Narrow wings; e) Pulled apart wings; f) Reduced unspread wings; h) Altered shape of the wings with bubbles and abnormal venation; and i) Interruptions of wing veins L4 and L5.

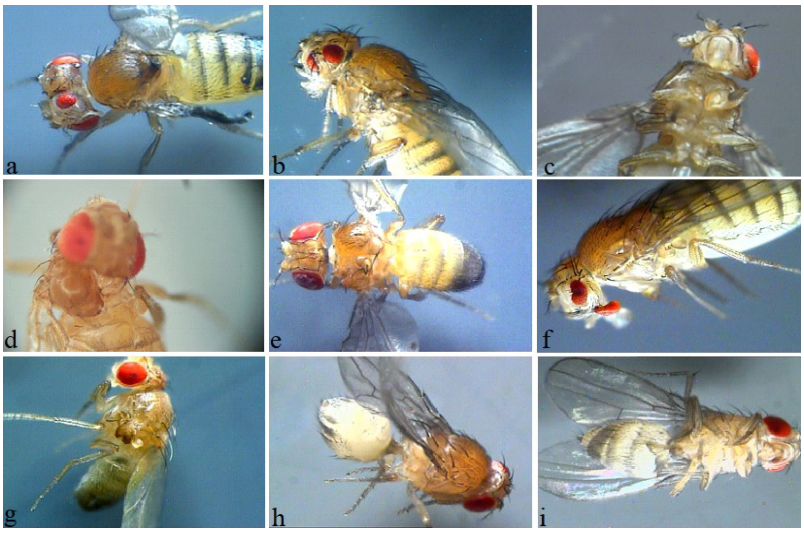

Figure 7: Doubling of structures and new symmetry axes in the individuals carrying morphoses: a) Two heads with appendages on one neck; the anteroposterior axis of the fly’s body is normal; b) The left eye is replaced by a small head with appendages and two red eyes; c) Part of the head and eye on the right side are absent; arista and antenna are doubled; d) The right thorax is absent; a symmetric thorax of a small size is formed of the left thorax; e) A symmetric thorax of a small size is formed instead of the right thorax; f) The left eye is represented by two symmetric fragments; g) Two symmetric projections with hairs replace the left wing; h) Rotation of the abdomen by 180° (top view); and i) The same case of the abdomen rotation (bottom view); (b-g) new symmetry axes emerge at an angle to the fly’s main (anteroposterior) symmetry axis.

terior) as in the cases of doubling of the head (Figure 7a) and genitals (Figure 1f) but it in most cases differs from the normal direction. The morphoses, such as an additional small head replacing the eye (Figure 7b), doubling of arista-antenna complex (Figure 7c), and doubling of the eye (Figure 7f), have unusual symmetry axes that are directed at an angle to the general anteroposterior axis of the fly’s symmetry. These facts suggest that the local development spins out of the general control over the fly development. An extraordinary case of the development program disturbance is a 180° rotation of the fly’s abdomen, when the dorsal and ventral parts of the abdomen, as well as the left and right parts, interchange (Figure 7h and Figure 7i).

Discussion

The phenomenon of symmetry is inherent in different types of matter, the living matter included [32-34]. A genetic determination of the living nature suggests in-

volvement of genes in its symmetry. However, universality of symmetry contradicts this assumption since the symmetry in the universe does well without any genes. The *disturbances in a bilateral symmetry of drosophila caused by conditional mutations,* described here, *clearly show the role of genes in development of symmetric structures of a living organism.* Further discussion will clarify how this contradiction is resolvable.

A genetic nature of the bilateral symmetry disturbances in a living organism

The following events were regarded as disturbances of a bilateral symmetry in *drosophila*: 1) The absence on one side of the fly's body of a structure that is normally present on both sides; 2) The presence of an unusual structure on one side of the body with the concurrent presence of a normal structure on the other side or its absence; and 3) A change in the direction of the symmetry axis of some structures relative to the general symmetry axis. Two types of events are observed in these cases: The alteration of symmetry and a change in the local morphology. Earlier, the attention was mainly focused on the latter type of events, namely, on the emergence of unusual structures and the absence of normal ones. In the literature, both types of events are referred to as morphoses (monstrosities) [27,28].

Until recently, morphoses have been regarded as nonhereditary morphological abnormalities emerging as a result of the impacts of extreme environmental factors on the organism [28,35,36]. In the *Glossary of Genetics,* morphosis is defined as a nonadaptive and typically unstable variation of individual morphogenesis associated with environmental changes and the morphoses that repeat the phenotypes of known mutations are referred to as phenocopies [37]. The emergence of monstrosities in response to the impact of mutagens is regarded as a teratogenic effect of mutagens [26]. Ashburner in his handbook on *drosophila* genetics [25] devoted a chapter ("Phenocopies") to the nonhereditary abnormalities. A potential role of monstrosities in the evolutionary process is frequently considered and discussed [38,39]. Morphoses emerge in the interspecific hybrids and their appearance depends on the direction of crosses [40].

The results of our study clearly demonstrate a genetic nature of morphoses. Morphoses 1) Emerge in the progeny of the genetic mutations of a specific type, namely, conditional mutations; 2) The individuals carrying morphoses display the specific features characteristic of conditional mutations [12,17,31]; 3) The event of emergence of a morphosis is reproduced in successive generations (although a particular form of the morphosis can be different); and 4) The presence of a morphosis is successfully used as the test for the presence of a conditional mutation [41].

The fact that disturbances of a bilateral symmetry are local (affect only individual organs and structures) also makes them similar to common genetic mutations. As is known, genes are discrete units of heredity and their damages appear as disturbances of individual traits, organs, and functions. Despite a global nature of the very phenomenon of symmetry, the symmetry of the living entities, as is evident from our data, is the sum of the symmetries of individual organs and structures. The figures demonstrate that the symmetry is broken on a local level, affecting individual organs and structures (wing, head, leg, thorax, and so on) rather than the overall body.

Why the Mendelian mutations do not interfere with a bilateral symmetry versus the other type of mutations (conditional mutations) that break the symmetry

The world collection of *drosophila* genetic mutations is wide and diverse [1]. The discovery of the mutations that interfere with the symmetry of the fly's body has made it clear that all mutations collected before unintentionally possess an opposite property, the symmetry of manifestation. Thus, it is now necessary to explain not only the cause underlying the disturbance of symmetry in conditional mutants, but also the cause allowing for the retention of symmetry in the case of Mendelian mutations. The situation becomes clear when analyzing the very term "bilaterally

symmetric trait".

A bilaterally symmetric trait consists of two structures-the right and the left ones. In their appearance and location, they look quite similar; however, this similarity is not complete and it is impossible to replace the right one with the left and vice versa. It is also impossible to assemble the whole entity of two same parts (two left or two right ones). In other words, two symmetric structures display not only similarity, but also difference. *The difference consists in that the members of this pair are diverse in their spatial orientation.* The two structures representing a symmetric pair can be superimposed only by moving them in space taking into account the so-called *symmetry axis.* There is one more important detail of the entity defined as a symmetric structure: The members of the pair are not independent objects, being two *complementary parts of the whole.* Two wings are necessary to fly, an even number of legs is necessary to walk, and so on.

To de novo create an entity referred to as a symmetric structure means to create two structures simultaneously being similar and different. One generator (a gene) cannot create two opposite (different and similar) entities. Correspondingly, there must be two generators (genes) and the processes they generate must be different. Thus, *the fact of existence of a trait with a symmetric manifestation means that the genes of two types control development of the trait.* The genes implement two different processes. One process is named already: This process provides a spatial orientation of the developed structures. As for the other one, it is not difficult to guess. This is the synthesis of proteins, the chemical substances that form the background of all living organisms.

Most traits in an organism with a bilateral symmetry are bilaterally symmetric. In addition, the performed analysis of the concept of symmetric structures demonstrates that development of the majority (if not all) of the traits of living entities requires a certain process that would provide their arrangement (orientation) in space and, consequently, demands existence of the genes responsible for the orientation in space. It is necessary to emphasize here that these genes are different from the genes responsible for similarity and supplementary to them.

The current view of the morphogenesis states four successive events that lead to formation of a living structure, or, in other words, a *trait:* 1) cell division; 2) cell orientation in space after the division; 3) triggering of protein synthesis in the cell by regulators of synthesis; and (4) The very template-directed protein synthesis. The above named process of spatial orientation of the developing symmetric structures is implemented during events (1) and (2) and the protein synthesis, during event (4), having the same name. Events (1-3) must be controlled by ontogenes and event (4), by Mendelian genes.

The process of development of a trait is schematically describable as follows. Ontogenes trigger cell divisions and drive the spatial orientation of the formed cells. In the case of symmetric structures, ontogenes form two subpopulations of cells that continue their development according to the rules of symmetry. The specific features of symmetric structures are considered above. Thus, the symmetry appears at the stage when a cell massif is formed and transformed. The activity of ontogenes creates the general *body plan* (known in morphology as the *Bauplan*) [42-44]. In other words, the ontogenes may be referred to as *Bauplan genes and the conditional mutations, as Bauplan mutations.* The mutations in ontogenes (*Bauplan genes*) will lead to distortion of symmetry, which is discussed above.

The second task of the ontogenes is to control the switch-on of Mendelian genes. The mutations in Mendelian genes will lead to synthesis of altered proteins. The resulting Mendelian mutations may alter the appearance of an individual in an arbitrary manner but will never interfere with the Bauplan created for the individual by ontogenes. In the case of a normal Bauplan, all Mendelian mutations will appear in a symmetric manner versus the case of an altered Bauplan, when the mutations will manifest themselves according to the altered Bauplan.

Thus, there are Mendelian traits, which are the traits that exclusively depend on proteins. Mendelian mutations are associated with the abnormal chemical structure of proteins, acting either as a construction material or as a regulator. All remaining traits are formed with involvement of ontogenes. The mutations in ontogenes change the work of the genome as early as the gametogenesis. The majority of these mutations are lethal as early as the state of zygote [16,17]. In the case when the lethality barrier is overcome, the mutations in ontogenes appear as unilateral morphogenetic abnormalities, i.e., morphoses.

Hypothesis on the mechanism of Bauplan implementation with the help of ontogenes

The existence of the genes of a new category (ontogenes) was inferred after the discovery of conditional mutations in *drosophila* [24]. The same conclusion is made as a result of the theoretical analysis of the phenomenon of a symmetric trait. The specific features of ontogenes are also evident from this analysis, namely, that their activity (1) is directed to provide cell spatial orientation and (2) is not associated with the template-based DNA synthesis. The latter specific feature is confirmed by the "indifference" of the Mendelian genes towards symmetry. Thus, the problem arises to define this *type of gene activity*, at least in general outline, which quite unexpectedly appeared on the genetic horizon and *categorically has nothing to do with chemical synthesis.*

A bilateral symmetry is the result of development of two structures similar in their pattern (1) in a synchronous manner and (2) in specially (mirror-like) oriented spatial planes. For this purpose, (1) there must be a certain "vectorized space" (field); (2) the cells must "be able" to create such field; and (3) each individual cell must be able to orient itself in this field. To construct a symmetric structure, *a certain group of genes must be able to physically interact with this vectorized field that is created by dividing cells.*

Ontogenes can be these particular genetic structures capable of creating and sensing this field. The morphogenetic field in question may be an electromagnetic field, known in physics. The specific features of this field, such as the creation of a driving electromagnetic force, dependence of the directions of the field force lines and electric current in a conductor, and right-hand and left-hand rules, look most appropriate for the construction of the symmetric structures of cells. Regions of DNA double helix may well be the sources of gene electromagnetic fields as well as their receptors. Their configuration in the form of solenoids can change depending on the degree of chromatin condensation.

The idea of morphogenetic field in biology [45,46] has a long history. It is yet untimely to discuss this in detail in the context of the data that are not of a physical nature. However, the hypothesis on a physical field is very much to the point in our particular case when the fact of existence of symmetric structures is unexplainable by the effect of classical genes involved in protein synthesis. The protein synthesis is unrelated to space and is a cyclic process versus the ontogenesis, which is in general an acyclic process with a spatiotemporal arrangement [47]. A spatiotemporal pattern "demands" the existence of a field.

This work suggests the entities responsible for electromagnetic regulation, namely, the DNA regions within the ontogenes. Our data support and contribute to the hypothesis on existence of a field in the living entities. An autonomous *biochemical mechanism* underlying the development of the living and comprehensively mastered by the current genetics can be most likely supplemented with still understudied *biophysical mechanism.*

Utilization of the idea on an electromagnetic field leads to the understanding of the cause underlying a global character of the phenomenon of symmetry. Electromagnetic field may well be the particular reality underlying the symmetry of the overall universe. The contradiction between a universal scale of the phenomenon of

symmetry and the use of specific tools, genes, for construction of symmetry in the living entities is thus resolved. As is assumed, the genes in order to create the symmetry make use of electromagnetic interaction, one of the four types of interactions in the universe, with all its specific features.

Conclusions

A large-scale sequencing of the human genome has shown that the protein-synthesizing Mendelian genes account for only several percent of the genome DNA [48]. The discovery of a new category of mutations, named conditional mutations, suggests that the major part of the genome may be represented by ontogenes, the genes supervising the ontogenesis at many stages, and protein synthesis is only one of them. The very need in the presence of "some other" (non-Mendelian) genes in the genome means that morphogenesis for its implementation requires certain genes that function in the way other than chemical synthesis along with the genes implementing protein synthesis.

The manifestation of ontogenes in many respects differs from the manifestation of Mendelian genes [10,20,22] but this paper focuses on only one difference. The Mendelian genes are not involved in the development of a bilateral symmetry of a trait, whereas the ontogenes are involved in this process. The mutations in Mendelian genes do not interfere with a bilateral symmetry of the *drosophila* body, whereas mutations in ontogenes broke this symmetry. The fact of this difference suggests that the symmetry of a biological trait emerges in the process of cell propagation and their arrangement in space. These processes are controlled by ontogenes. Symmetry is one of the variants how certain elements can be arranges in space (field). In order "to perform the task of creation of a symmetric structure", the ontogenes of some cells must create a *vectorized field* and the ontogenes of the other cells must respond to this field.

It is assumed that electromagnetic field can be such vectorized field. The DNA helix and the electric processes along its length are the prerequisites for the existence of this field. The proposed hypothesis focuses on the search for regulatory genetic phenomena of an electromagnetic nature and the data on a physical aspect in the function of ontogenes.

Acknowledgement

The authors thank the Institute of Cytology and Genetics, Russian Academy of Sciences, for financial support of this work (budget project no. 0324-2019-0042).

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