K. Oshio, Y. Iwasaki, S. Morita, Y. Osana, S. Gomi, E. Akiyama, K. Omata, K. Oka and K. Kawamura,
Database of Synaptic Connectivity of *C. elegans* for Computation,
Technical Report of CCeP, Keio Future, No.3, Keio University (2003).

The format of data in "`White_Fig`" directory (folder)

CCeP (Cybernetic *Caenorhabditis elegans* Program),
December 28, 2003.

1 INTRODUCTION

This document provides detailed information of the format of data in "`White_Fig`" directory (folder). The database is constructed under the following policies.

(a) There should be one-to-one correspondence between information provided by the original papers and that described in various files in the database.

(b) The database should provide necessary information so that everybody can reconstruct the illustration in the original papers up to topology.

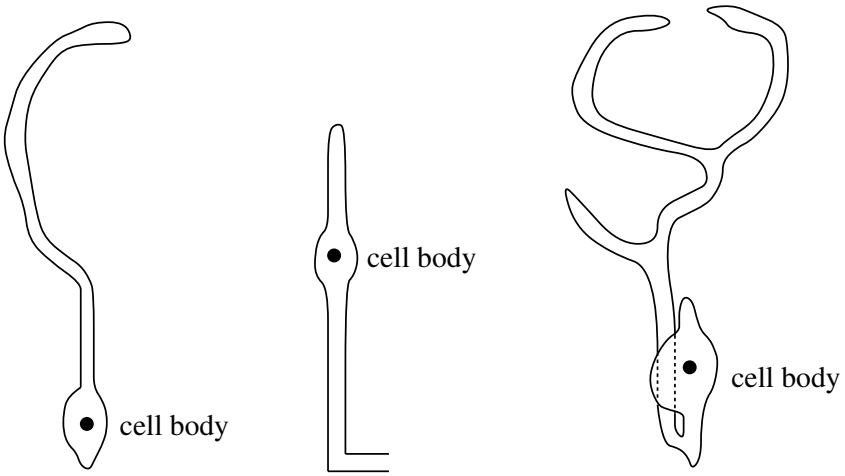
(c) The database should provide sufficient information for any user to edit their own data file according to their peculiar request.

In section 2, two points associated with the format of data are noted. One is on morphology of neurons and is associated with the policy (b). The other is on ambiguous or questionable descriptions in the original figures and is associated with the policy (c). In section 3, the format of data is described in detail following the policy (a). In section 4, an imaginary example of data is shown.

2 SYNAPTIC DATA IN THE ORIGINAL FIGURES

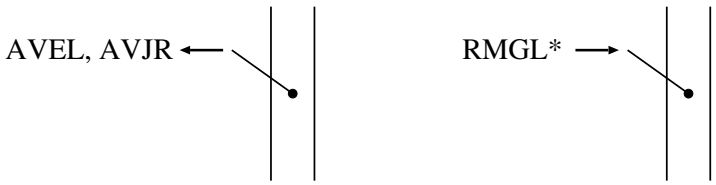
2.1 Morphology of neuron

In the figures in White *et al.* (1986), synaptic contacts are illustrated on processes of neurons. While most neurons of *C. elegans* have unbranched morphology, some of them have branched one. Examples of morphology of neurons are shown in Fig. 1. The AIAL neuron in Fig. 1a has an unbranched process that runs from the cell body. The AS11 neuron in Fig. 1b has two processes that run anteriorly and posteriorly from the cell body. In the case of unbranched neurons, the geometrical information of synaptic contact is easily expressed into text format. Synaptic contacts are only listed in thier positional order. In contrast to unbranched neurons such as AIAL and AS11, RIH neuron in Fig. 1c has branched processes. To represent the synaptic contacts on such branched processes, each process should be distinguished. Therefore indices not only for the synaptic contact but also for the process are introduced in the database (see section 3 for details).



(a) AIAL (b) AS11 (c) RIH

Figure 1: Examples of morphology of neurons (White *et al.*, 1986).



(a) Send (b) Receive

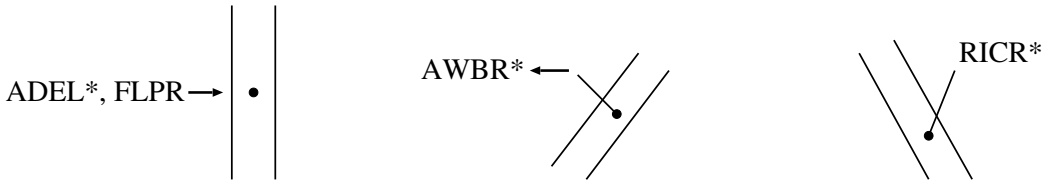
Figure 2: Expected descriptions of multiple chemical synapses in ADAL neuron.

2.2 Ambiguous or questionable descriptions

Several ambiguous or questionable descriptions have been unexpectedly found in the original figures. Most of them are associated with representation of a multiple chemical synapse. In the case of multiple chemical synapses, the names of partner neurons are denoted in the figure according to the following rules (White *et al.*, 1986).

- Rule (I): When the reference neuron is a presynaptic neuron, all partner (postsynaptic) neurons are shown (Fig. 2a).
- Rule (II): When the reference neuron to which the process belongs is one of several postsynaptic neurons to a single presynaptic neuron, the partner (presynaptic) neuron is shown with an asterisk "*" (Fig. 2b).

However some representations of the synaptic contacts are not following these rules. Examples of the ambiguous synaptic contacts are shown in Fig. 3. There are several possibilities for the interpretations of these synaptic contacts.



(a) Ambiguity in AVAL (b) Ambiguity in ADFR (c) Ambiguity in AVBR

Figure 3: Ambiguous descriptions of synaptic contacts.

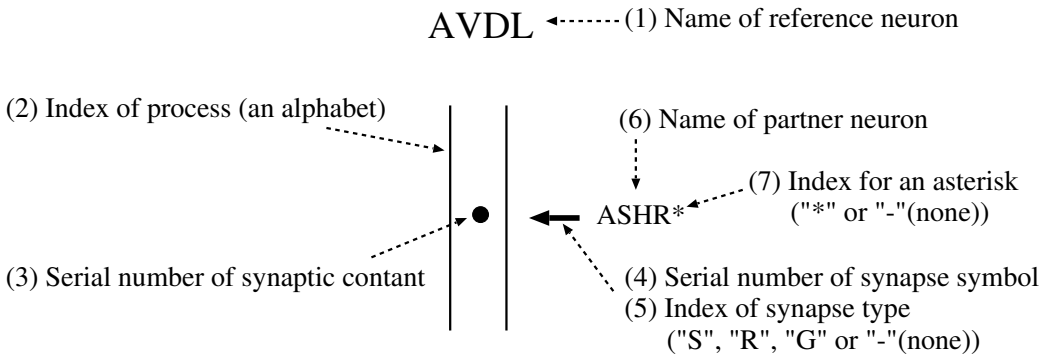


Figure 4: Data in the figure in White *et al.* (1986) and the items in the data files.

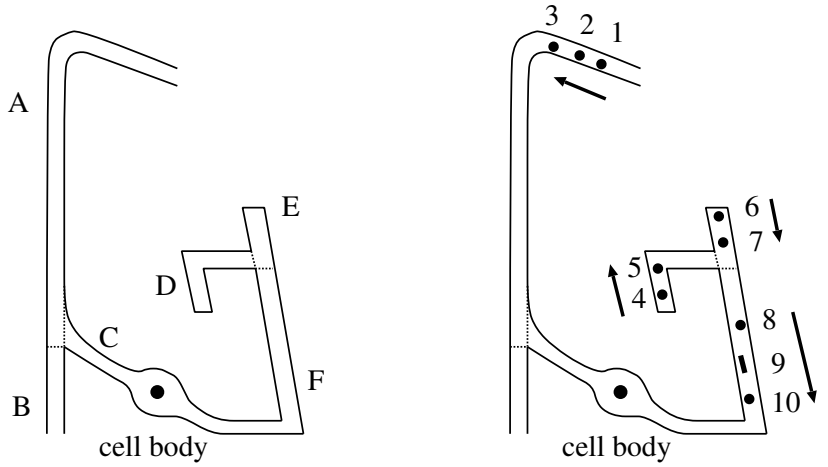
▷ Fig. 3a: (i) The multiple chemical synapses from ADEL and FLPR neurons exist, or (ii) the multiple chemical synapses from ADEL neuron and the single chemical synapse from FLPR neuron exist.

▷ Fig. 3b: (i) The multiple chemical synapses from ADFR to AWBR neurons exist (against the rule (II) of the asterisk "*"), or (ii) "send" ("←") is mistaken for "receive" ("→") (the direction of the arrow is opposite).

▷ Fig. 3c: A symbol of synapse type ("→", "←" or "⊣") is lacked in the figure. Therefore this connection can not be identified whether it is a chemical synapse or a gap junction.

3 FORMAT OF DATA

To exactly list the synaptic connectivity shown in the figures in the original paper, we describe a synapse by the seven items shown in Fig. 4. In addition to the seven items, we introduce the comment index to point out ambiguous or questionable descriptions in the original paper. Corresponding to these eight items, the data files consist of eight columns as follows.



(a) Index of process (b) Serial number of synaptic contact

Figure 5: Priority in assignment of the index of process and the serial number of synaptic contact in FLPL neuron.

- **1st column: Name of reference neuron**

- **2nd column: Index of process**
  Each process of neuron is labeled with an alphabet. When a neuron has branched precesses, a process at the upper left-hand side of the original figure is given priority in assignment of the index (Fig. 5a). Since the index is assigned to the process without a synaptic contact, the index does not always begin from the alphabet "A" in the database. Refer to the PDF file "`process_WF.pdf`" for the correspondence between the index and the process.

- **3rd column: Serial number of synaptic contact**
  All the synaptic contacts (illustrated with a dot "•" or a bar "|" in the original figures) on the process are numbered. Consecutive numbers are used in a given reference neuron. In the same process, a synaptic contact far from the cell body is given priority in numbering (Fig. 5b). From a combination of the 2nd column (the index of process) and the 3rd column (the present number), location of contacts on the process is known up to topology.

- **4th column: Serial number of synapse symbol**
  All the symbols of synapse type (arrows "→", "←" and T lines "⊣" in the original figures) are numbered. Consecutive numbers are used in a given reference neuron. Even when several partner neurons are listed after a symbol of synapse type, the same number is used for them (see Fig. 7 and Table 1).

- **5th column: Index of synapse type**
  Synapse type is illustrated with an arrow (a chemical synapse) or a T line (a gap junction) in the original figures. In the case of chemical synapse, furthermore, "send" or "receive" is distinguished by the direction of the arrow. We use four indices, "S", "R", "G" and "-" to describe the synapse type.

"S": The reference neuron sends chemical synapse to its partner neuron.
"R": The reference neuron receives chemical synapse from its partner neuron.
"G": A gap junction connects the reference neuron with its partner neuron.
"-": A symbol of synapse type is missing.

- **6th column: Name of partner neuron listed in "`name_neurons.txt`" or others listed in "`name_others.txt`"**

- **7th column: Index to indicate that an asterisk is attached to the partner neuron**
  When a reference neuron receives multiple chemical synapses, only one of its presynaptic partner neurons is explicitly denoted with an asterisk "*" in the original figures. We use two indices, "*" and "-". In the case of chemical synapse, therefore, multiple chemical synapses are distinguished from a single chemical synapse by this index. In the case of gap junction, the index should be "-".

  "*": An asterisk is attached to the name of partner neuron.
  "-": No asterisk is attached to the name of partner neuron.

- **8th column: Comment index**
  When descriptions in the original figures are questionable, we have commented in this column. We have classified the comments into 33 types, and distinguish them by the following indices. Indices "wf1-5" are due to deviations from the rules (I) and (II) of the original paper.

  "-": Nothing to comment.
  "wf1": This is a presynaptic chemical synapse ("Send"), but an asterisk is attached to the partner neuron in the original paper against the rules (I) and (II) (Fig. 3b).
  "wf2": This is a postsynaptic chemical synapse ("Receive") with two or more names of partner neurons. This may mean a multiple receive synapse (Fig. 3a).
  "wf3": This is a gap junction, but multiple names of partner neurons are denoted in the original paper against the rule (I) (Fig. 6a).
  "wf4": This is a gap junction, but an asterisk is attached to the partner neuron in the original paper against the rule (II) (Fig. 6b).
  "wf5": This is a gap junction between "*L" and "*R" neurons in the same class (Fig. 6c). In the figure, the names of the two neurons are denoted for the identical symbol of synapse type which is common to the two neurons. The database of each neuron has two lines for this connection, however, it means a gap junction between contralateral neurons in the same neuron class.
  "wf6": This is a gap junction between processes within the same neuron.
  "wf7": No symbol of synapse type is attached in the original paper (Fig. 3c).
  "wf8": No symbol of synapse type is attached in the original paper, but the synaptic contact is illustrated with a bar "|" that often represents a gap junction (Fig. 6d).

"wf9": The symbol of synapse type is illustrated with a left-right arrow "↔".

"wf10": Multiple symbols of synapse types are corresponding to an identical synaptic contact.

"wf11": "wf10" and "wf3".

"wf12": "wf10" and "wf7".

"wf13": Comment peculiar to RIPL. Boundary between RIPL and RIPR is not clear in the original figure. It is possible that the synapse lies on the process E of RIPR.

"wf14": Comment peculiar to RIBR. A symbol of this synaptic contact is drawn over the boundary of two neurons. It is possible that the synapse lies on the process F of RIBL (or RIBR).

"wf15": Comment peculiar to RIBL. From the same reason as above, it is possible that the synapse lies on the process F of RIBR (or RIBL).

"wf16": Comment peculiar to SMBVL. Location of the synaptic contact is erroneous. It is possible that the index in column 5 is "R".

"wf17": The index of synapse type ("Send" or "Receive") is questionable because the guiding line is ended between the symbol of synapse type and the name of partner neuron in the original figure (Fig. 6e).

"wf18": "wf2" and that the index of synapse type ("Send" or "Receive") is questionable because the guiding line is ended at the end of the name of partner neuron in the original figure (Fig. 6f).

"wf19": The guiding line does not clearly point to the synaptic contact in the original figure.

"wf20": "wf19" and "wf5".

"wf21": The name of partner neuron is not clearly printed in the original figure.

"wf22": The asterisk is not clearly printed in the original figure.

"wf23": This synapse might be "NMJ" which is a special cases of chemical synapses, however, the symbol of synapse type is illustrated with that for "Gap junction".

"wf24": Comment peculiar to RMDR. The name of partner neuron "SVPL" does not exist. It should be read "PVPL" or other names of neurons.

"wf25": Comment peculiar to RMGL. The name of partner neuron "RMVDL" does not exist. It should be read "RMDVL" or other names of neurons.

"wf26": When distances of the several synaptic contacts from the soma seem to be the same, the left (leftmost) synaptic contact is assigned the smaller (smallest) serial number. Refer to explanation of 3rd column in page 3.

"wf27": The serial number of synaptic contact is not definitive, because distances from the soma are not distinguishable due to gap junctions usually marked with a bar "|" along process (Fig. 6g).

"wf28": "wf27" and "wf2".

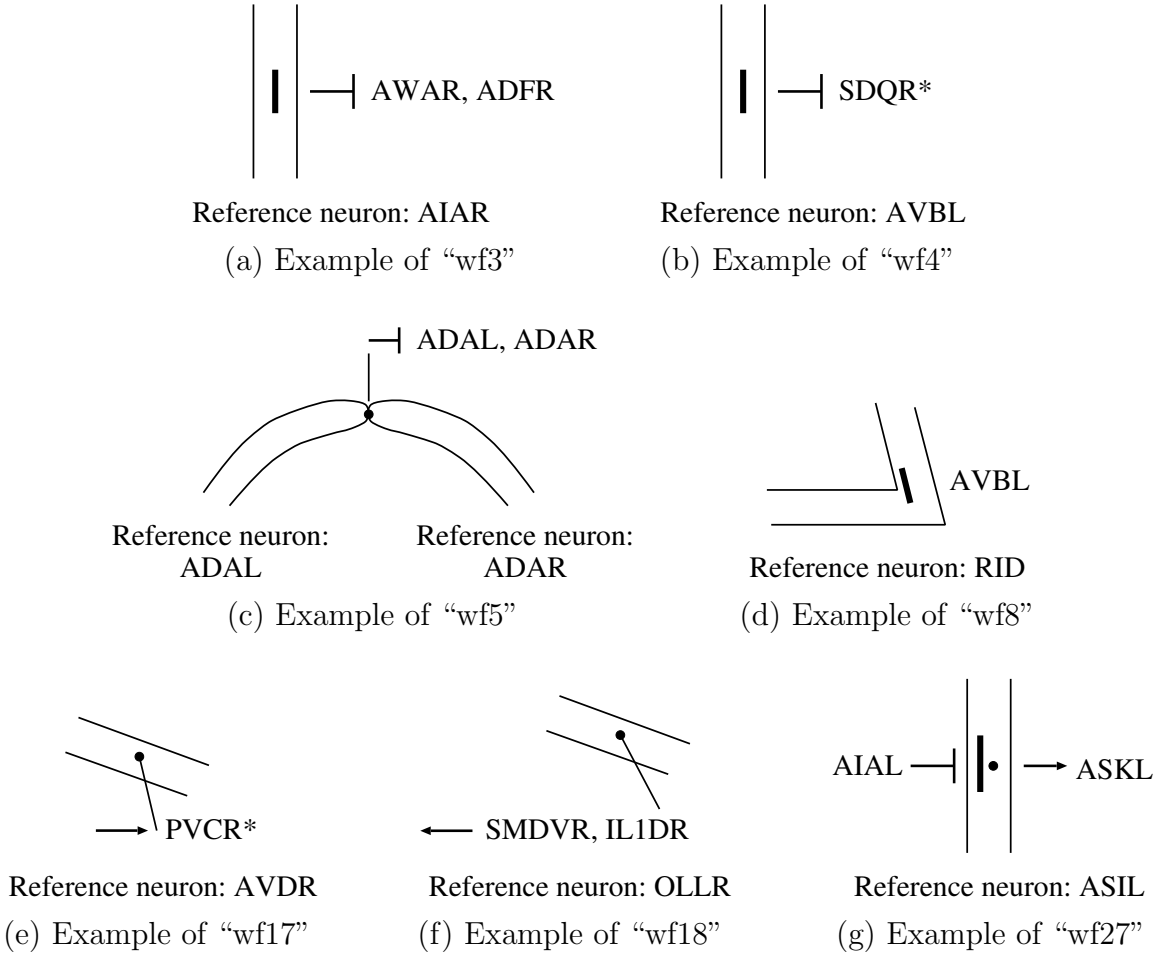
"wf29": "wf27" and "wf3".

"wf30": "wf27" and "wf10".

"wf31": The N2U reconstruction of RMF (RMFL/R) neurons. The data is included in "`synapse_WF.txt`".

"wf32": The JSH reconstruction of RMF (RMFL/R) neurons. The data is not included in "`synapse_WF.txt`".

"wf33": "wf32" and "wf21".



(a) Example of "wf3" (b) Example of "wf4"

(c) Example of "wf5" (d) Example of "wf8"

(e) Example of "wf17" (f) Example of "wf18" (g) Example of "wf27"

Figure 6: Examples of the comment indices in the database and the corresponding figures in White *et al.* (1986).

4 EXAMPLE OF DATA

An imaginary example of synaptic connectivity and the corresponding record are shown in Fig. 7 and Table 1, respectively.

When the index of synapse type (shown in 5th column) is "R" (Receive), the malutiplicity of chemical synapse is indicated by an asterisk "*" in the 7th column. In Table 1, the example for this case are shown in the 7th, 9th, 12th and 13th lines. When the index of synapse type is "S" (Send), on the other hand, the multiplicity is indicated by the serial number of synaptic contact (3rd column) together with the serial number of synapse symbol (4th column). In Table 1, an example for the case is shown in the 1st line (AIBL) and the 2nd line (AVEL). Since the records in the 3rd and 4th columns are the same in these lines, we find that the chemical synapse is multiple.

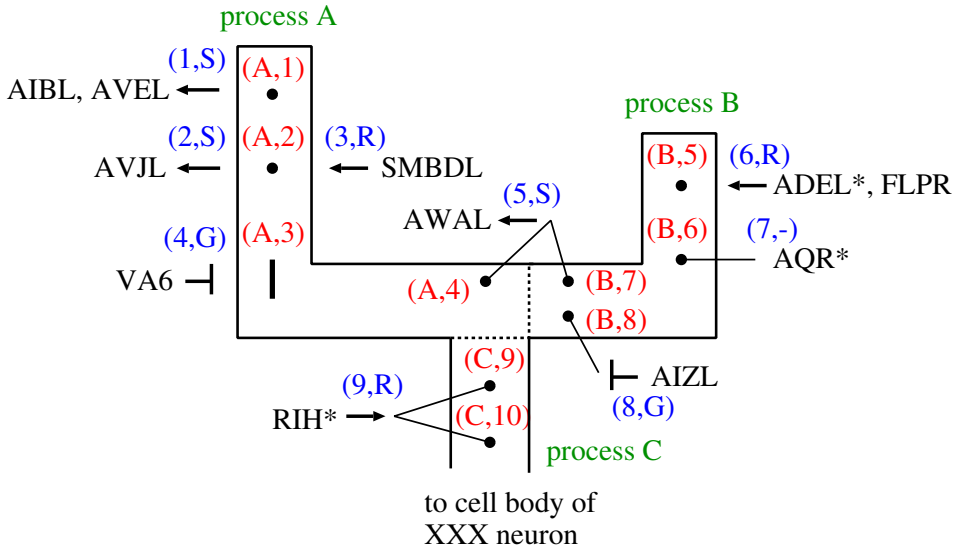


Figure 7: An imaginary example of synaptic connectivity. The branched processes are divided into three elements which are labeled with the indices of process "A", "B" and "C". A combination of the index of process and the serial number of synaptic contact is represented by red color. On the other hand, a combination of the serial number of synapse symbol and the index of synapse type is represented by blue color.

Table 1: The corresponding record to Fig. 7.

line \ column	1	2	3	4	5	6	7	8
1	XXX	A	1	1	S	AIBL	-	-
2	XXX	A	1	1	S	AVEL	-	-
3	XXX	A	2	2	S	AVJL	-	-
4	XXX	A	2	3	R	SMBDL	-	-
5	XXX	A	3	4	G	VA6	-	-
6	XXX	A	4	5	S	AWAL	-	-
7	XXX	B	5	6	R	ADEL	*	wf2
8	XXX	B	5	6	R	FLPR	-	wf2
9	XXX	B	6	7	-	AQR	*	wf7
10	XXX	B	7	5	S	AWAL	-	-
11	XXX	B	8	8	G	AIZL	-	-
12	XXX	C	9	9	R	RIH	*	-
13	XXX	C	10	9	R	RIH	*	-

References

White, J. G., Southgate, E., Thomson, J. N. and Brenner, S. (1986). The structure of the nervous system of the nematode *Caenorhabditis elegans*, *Phil. Trans. R. Soc. London* **B 314**, 1–340.