Contribution to Anatomy of the Central Nervous System of the Japanese

XI. Upon the Vermal Arbor Vitae

By

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As a result of a detailed observation on 50 adult human cerebella, 29 males and 21 females, a considerable number of variations on the features of the vermal arbor vitae* or the branching forms of the medullary branches were found, and the typing and classification of them was performed.

After the stripping of the pia mater and blood vessels by means of careful manipulation, the boundary fissures between the lobules of vermis and both hemispheres were identified, and then the median sagittal section was made in the vermal portion in the most exact manner. Hereupon the right half of the cerebellum was put into an intensively diluted carmin solution for a night. Finally the clearly tinged arbor vitae was mapped on section paper by a special drawing apparatus.

The outlines of the median sagittal sections of cerebella are usually pentagonal. I named their five sides and five edges as follows: (fig. 1)

1. anterior side (the vermal base or petroventricular surface),
2. cranial side,
3. posterosuperior side,
4. posteroinferior side,
5. caudal side,

1. cranial edge,
2. superior edge,
3. posterior edge,

* Sincere thanks to Prof. T. Ogawa for his valuable revision.
* Since 1944 the term “arbor vitae” has been omitted from Nomina anatomica japonica.
Fig. 1. Standard lines at the observation of vermal section. The vermal pentagon and vermal axial line.

4. inferior edge and
5. caudal edge.

I drew a vertical line to the vermal base through the fastigium, and named it "the vermal axial line". This line is important as a standard line and passes almost horizontally through the central part of vermis at the upright posture of the body.

In most cases (35 out of 50) the vermal axial lines passed just on or slightly below the posterior edges (the axial position). Sometimes (13 out of 50) the lines passed considerably above the posterior edges (the infraaxial position), and rarely (2 out of 50) they passed considerably below the posterior edges (the supraaxial position).

The following table (fig. 2) shows the miniature photographs of all examined-objects. Nos. 1 to 29 are male and Nos. 30 to 50 are female respectively in age order.
I. The central medullary substance and primary medullary branches (ray) (fig. 3)

The central medullary substance is more or less triangular in shape (the medullary triangle) and the chief part of it is situated above the vermal axial line (the supraaxial part). The base side of the triangle represents an inclined line to the vermal axial line (ca. 30 degrees). The most cranial or the first primary medullary branch (Bolk’s ray I or the lingula branch) arises from the anterior base angle of the triangle. The posterior base edge of the triangle extends beyond the vermal axial line downward (the infraaxial part). The infraaxial part appears rather in a club-form (the medullary club). The most caudal medullary primary branch (Bolk’s ray A or the nodule branch) arises from the central medullary substance and extends to the inferior medullary velum along the posterior roof of the ventricular fastigium.

1) The supraaxial part of the central medullary substance (the anterior medullary body or the medullary triangle)

From the apex of the triangle a heavy stalk arises as the principal offshoot or the erecting stem (Bolk’s ray III and IV or the culmen tree). In usual cases another relatively heavy stalk (Bolk’s ray II or the central lobule branch), sometimes two and rarely three stalks arise from the anterior side of the triangle.

The medullary branches arising from the medullary triangle are separated from the branches arising from the medullary club by the superior anterior fissure (Kuithan’s fissura primaria).

2) The infraaxial part of the central medullary substance
(the posterior medullary body or the medullary club)

The branches which arise from the infraaxial part of the central medullary substance are usually (31 out of 50 cases; 1., 2. and 3. in fig. 3) divided into two parts by the anterior inferior fissure or Smith’s fissura secunda (A-type).

A heavy stem grows backwards as the direct continuation of the medullary club (the common lying stem or Bolk’s ray C) and a weak branch grows downwards (the proper falling branch, Bolk’s ray B or the uvula branch).

The common lying stem is divided into two branches. One is thicker and represents the direct continuation of the common lying stem (Bolk’s ray C₂) and the other is lighter (the intermediate branch, Bolk’s ray C₁ or the pyramis branch). Both are separated by the inferior posterior sulcus or prepyramidal sulcus.

Fig. 3. The central medullary substance and the primary medullary branches (diagrammatically). The Roman numerals and alphabets in brackets are Bolk’s nomenclature.
1) No. 17 in fig. 2; 2) No. 46 " " ; 3) No. 14 " " ;
4) No. 8 " " ; 5) No. 10 " " .
In some instances (13 out of 50) the proper lying branch arises immediately from the medullary club (B-type of the branching form of the medullary club; 4. in fig. 3), and the proper falling branch is confluent with the intermediate branch and makes the common falling stem, which is separated again into the intermediate branch and the proper falling branch.

Rarely (6 out of 50) all three branches (the proper lying branch, the intermediate branch and the proper falling branch) arise directly from the medullary club as the individual primary medullary branches (C-type of the branching form of the medullary club; 5. in fig. 3).

The proper lying branch is subdivided into three branches: (see p. 219).
1. the dorsal or ascending branch (the declive branch),
2. the middle or straight branch (folium branch), and
3. the ventral or descending branch (the tuber branch). 1. and 2. are separated by the superior posterior sulcus, and 2. and 3. by the horizontal sulcus.

According to the above mentioned facts and the Elliot Smith's descriptions I classify the branches of the arbor vitae as follows:
1. the anterior arbor vitae (corresponding to the anterior lobe):
   1) the most cranial branch which surmounts the superior medullary velum (the lingula branch).
   2) the branch arising from the anterior side of the medullary triangle (the central lobule branch).
   3) the culmen tree.
2. the posterior arbor vitae (corresponding to the posterior lobe):
   The common lying stem sends two branches:
   1) the proper lying branch which sends three small branches (the declive, folium and tuber branch).
   2) the intermediate branch (the pyramis branch).
3. The inferior arbor vitae (corresponding to the inferior lobe):
   1) the proper falling branch which arises from the medullary club (the uvula branch).
   2) the most caudal branch which extends onto the inferior medullary velum (the nodule branch).

II. The anterior arbor vitae (fig. 4)

1) The lingula branch (L)
In some cases (16 out of 50) the lingula branch represents only a
stem without branching which surmounts the superior medullary velum ("a" type; 5., 6., 7. and 8. in fig. 4). In usual cases (21 out of 50) the lingula branch sends 3 to 6, mostly 5 small branches or the medullary cores ("b" type; 2. and 4. in fig. 4). In 13 out of 50 cases the apex of the stem is detached from the velum and the stem sends 2 to 3 little twigs ("c" type; 1. and 3. in fig. 4).

As a rule the lingula branch extends toward the hemispheres as the vincula lingulæ, but sometimes the extension to the vincula is entirely absent. In such cases the vincula is made by the double lingula (see page 217). The lingula branch is limited caudally by the postlingular* sulcus.

2) The branches arising from the anterior side of the medullary triangle

There are three types (fig. 3).

The type 1 shows only one medullary primary branch (the central lobule branch: Ce). This is the most usual form (32 out of 50; 1., 4. and 5. in fig. 3). This branch proceeds toward the cranial edge

* The postlingular sulcus is customarily called the postlingual sulcus, which, according to Prof. T. Ogawa is an inadequate name.
of the vermal pentagon and its terminal branches make up the surface foliation on the cranial side. Its branching form shows three variations:

Generally (23 out of 32) the branch is monopodic and sends a number of the secondary small side branches (“a” type; 2. in fig. 4). Sometimes (6 out of 32) it is bifurcated (“b” type; 3. in fig. 4), and rarely (3 out of 32) it consists of a strong stem and two light side branches with their tertiary end sprays (“c” type; 1. in fig. 4). The central lobule branch is bounded caudally by the postcentral sulcus.

Type 2 represents two primary branches arising from the anterior side of the medullary triangle (17 out of 50; 2. in fig. 3). Among them two different forms are distinguishable:

a) The double central lobule branches (9 out of 50; 5. in fig. 4). The hemispheral part of these branches makes the ala lobuli centralis. The cranial one of them is designated as the anterior or first central lobule branch (Ce₁) and the caudal one as the posterior or second central lobule branch (Ce₂). As a rule the second branch develops more extensively than the first.

b) In cases where the hemispheral district of the cranial branch represents the vincula lingulae, the branch is named as the second lingula branch (L₂; 6. in fig. 4). In the double lingula branches the proper lingula branch (L₁) appears surmounted the superior medullary velum and lacks in the vincula (8 out of 50).

Type 3 represents three primary branches arising from the anterior side of the medullary triangle (3. in fig. 3 and 7. in fig. 4). This type is very rare (only 1 out of 50) and the combination of the double lingula and the double central lobule branches (L₂, Ce₂).

In cases where the supernumerary branches arise from the anterior side of the medullary triangle, the feature of the corresponding hemispheral parts are not constantly symmetrical on both sides. Therefore in this study the right hemispheres only are observed.

3) The culmen tree (Cu)

The principal stem of the culmen tree proceeds almost parallel with the cranial side of the vermal pentagon and bifurcates into the anterior and posterior end branch. The anterior one runs for the superior edge of the pentagon (4. in fig. 4). It is sometimes dichotomic or trigeminic (1. and 2. in fig. 4). Each branch makes up the surface end sprays. The posterior one proceeds for the cranial half of the posterosuperior side of the pentagon and becomes dichotomic or trigeminic to terminate with end sprays (3. and 4. in fig. 4).
The principal stem gives off one or two relatively heavy stem branches from its anterior side. The anterior stem branches proceed for the cranial side of the vermal pentagon and make up the peripheral end sprays.

a) In 32 out of 50 cases the culmen tree has only one anterior stem branch ("a'" type of the culmen tree; 1. and 2. in fig. 4).

b) In 16 out of 50 cases the culmen tree has two anterior stem branches ("b" type of the culmen tree; 3. and 4. in fig. 4).

The peripheral end sprays of the anterior stem branches extend for the middle part of the cranial side of the vermal pentagon. The hemispheral part of the anterior stem branches is usually separated from the hemispheral part of the end branches of the culmen tree by a fissure and makes a sublobule. Therefore the branching district of the culmen tree is separated into two parts: one of them represents the district of the anterior stem branch and the other the district of the end branches of the culmen tree. The district of the anterior stem branches may be comparable with Bolk's ray III, and the district of the end branches with Bolk's ray IV.

Two more weak branches arise from the caudal side of the culmen stem. They are concealed in the anterior wall of the fissura primaria without distributing to the vermal surface.

c) In 2 out of 50 cases the anterior stem branch is entirely absent ("c" type of the culmen tree; 8. in fig. 4). In these cases the branch arising from the anterior side of the medullary triangle is supernumerary. It may be regarded that the anterior stem branch is moved to the anterior side of the medullary triangle.

III. The posterior arbor vitae (fig. 5)

The posterior arbor vitae consists of the medullary common lying stem and its branches. The stem sends two branches which are separated from each other by the inferior posterior sulcus. One is thicker (the proper lying branch; Bolk's C₂) and the other is thinner (the intermediate branch; Bolk's C₁). (1., 2., 4., 6. and 7. in fig. 5; 1., 2. and 3. in fig. 3).

1) The proper lying branch (Bolk's C₂)

The proper lying branch proceeds generally (39 out of 50) slightly below the vermal axial line and almost parallel to it (1., 2., 3., 4. and 7. in fig. 5) and sometimes (11 out of 50) considerable below the line and somewhat inclined (5. and 6. in fig. 5).
The branch sends again following three branches:

- the declive branch (D),
- the folium branch (F), and
- the tuber branch (T).

The folium branch is bounded cranially by the superior posterior sulcus and caudally by the horizontal sulcus.

According to developmental studies these sulci appear bilaterally on both hemispheres, gradually extend toward the medial portion and at last meet on the vermis. Usually the similar sulci are confluent on the vermis (the homonymous confluence), but often they become confluent with a different sulcus of the other side (the heteronymous confluence). Occasionally the sulci are interrupted on the vermis without confluence.

The above mentioned facts cause various appearances of the folium formation in section surface.

(1) The folium branch (F)

The folium branch represents the least sprig. The folium is very small but it corresponds to the large hemispherical parts, the superior semilunar lobules. Mostly (41 out of 50) the folium appears as a single
sprig (the single folium), but often (9 out of 50) as two sprigs (the double folium). Therefore 50 examined cerebella have 59 folium branches. There are three branching forms of the folium sprig. One represents the direct continuation of the proper lying branch (proper folium; 13 out of 59). The other two arise from the declive branch (declivofolium; 25 out of 59) or from the tuber branch (tuberofoilium; 21 out of 59).

It is not rare (9 out of 50) to find that the folium is entirely concealed to outside view (1. and 6. in fig. 5).

When both pairs of the boundary sulci of the folium are homonomously confluent with each other, the folium formation is simple and clear, but it is more complicated in heteronymous confluences.

The folium formations are classified into the following 4 types and 18 forms (fig. 6):

Type I. The homonymous and contemporaneous confluence of the superior posterior sulci (sp) and the horizontal sulci (h):

- a form: h is deeper than sp (8 cases out of 50 cerebella; 1. in fig. 6).
- b form: sp and h are similarly deep (2 cases; 2. in fig. 6).
- c form: sp is deeper than h (7 cases; 3. in fig. 6).

Type II. A pair of sulci (sp or h) is homonymous and the other is not:

- a form: sp is homonymous.
  1. left and right h are both interrupted (3 cases; 4. in fig. 6).
  2. left h joins to a subdividing furrow on the inferior semilunar lobule; right h is interrupted (1 case; 5. in fig. 6).
- b form: h is homonymous.
  1. left sp is interrupted and right sp joins to a subdividing furrow on the left posterior lunate lobule (6 cases; 6. in fig. 6).
  2. right deep sp joins to a subdividing furrow on the left posterior lunate lobule and left sp makes an incision on the vermis (4 cases; 7. in fig. 6).
  3. right sp is interrupted and left sp joins to a subdividing furrow on the right posterior lunate lobule (1 case; 8. in fig. 6).
  4. left sp is interrupted and right deep sp joins to a subdividing furrow on the left posterior lunate lobule (1 case, 9. in fig. 6).
  5. left sp makes a complete incision on the vermis, while right sp joins to a subdividing furrow in the left posterior lunate lobule (1 case; 10. in fig. 6).

Type III. Left sp is heteronomously confluent with right h (diagonal
Fig. 6. The classification of the folium formations.

\[\\text{1, joins to the superior semilunar lobules on both sides;};\\text{2, joins to the right superior semilunar lobule;}\\text{3, joins to the left superior semilunar lobule;}\\text{4, homonymous confluence;}\\text{5, heteronymous confluence;}\\text{6, interrupted;}\\text{7, horizontal sulcus;}\\text{8, superior posterior sulcus;}\\text{9, left, r, right;}\\text{D, declive branch;}\\text{F, folium branch;}\\text{T, tuber branch.}

- a form: deep left h joins to a right subdividing furrow on the inferior semilunar lobule, while right sp joins to a left subdividing furrow on the posterior lunate lobule (1 case; 11. in fig. 6).
- b form: shallow left h joins to a subdividing furrow on the right inferior semilunar lobule, while right sp joins to a subdividing furrow on the left posterior lunate lobule (4 cases; 12. in fig. 6).
- c form: deep right sp joins to a left subdividing furrow on the
posterior lunate lobule, while shallow left h joins to a subdividing furrow on the right inferior semilunar lobule (2 cases; 13. in fig. 6).

**d form**: left sp is diagonally confluent with right h and makes the double folium with a deep fissure (4 cases; 14. in fig. 6).

**e form**: similar as d. form, but the fissure is more shallow (1 case; 15. in fig. 6).

**f form**: deep right sp joins to a subdividing furrow on the left posterior lunate lobule and left h is interrupted (1 case; 16. in fig. 6).

**Type IV. The fortuitous connections.**

**a form**: deep left sp joins to a subdividing furrow on the right inferior semilunar lobule, while right sp joins to the left posterior lunate lobule. And both h are interrupted (2 cases; 17. in fig. 6).

**b form**: right sp and h joins to a subdividing furrow on the left posterior lunate lobule, while left sp and h are inrerrupted (1 case; 18. in fig. 6).

In the cases of heteronymous confluence, the left anterior fissure limiting the folium constantly joins to the right posterior fissure.

(2) The declive branch (D)

There are two branching forms. One is the pure declive branch and the other is the combined form with the folium sprig. One is observed almost as frequently as the other (26:24).

The declive branch crosses over the axial line and ramifies in in dichotomy ("b" type; 9 out of 50, 5. in fig. 5), in trifurcation ("c" type; 24 out of 50, 2., 4. and 6. in fig. 5), or in repeated dichotomies ("d" type; 13 out of 50, 3. in fig. 5). Sometimes the principal declive branch proceeds toward the posterior edge of the pentagon as the direct continuation of the proper lying branch and separates off a dorsal side branch ("a" type; 4 out of 50, 1. in fig. 5). When the folium sprig is combined, it represents the first ventral side branch of the declive branch (2., 4 and 7. in fig. 5). In every case the the declive branch sends the surface end sprays to the caudal half of the posterosuperior side of the vermal pentagon.

(3) The tuber branch (T)

There are two branching forms. One is the pure tuber branch and the other is the combined form with the folium sprig. The former is more frequent than the latter (29:21). The tuber branch is generally monopodial and sends bilateral side branches ("a" type; 25 out of 50, 3. and 5. in fig. 5). Sometimes it is dichotomic ("b" type; 15 out of 50, 1., 2. and 7. in fig. 5) or trifurcated ("c" type; 10 out of 50, 4. in fig. 5).
When the folium sprig is combined, it comes out as the first dorsal side branch of the tuber branch (1. and 3. in fig. 5).

The tuber branch makes up the surface end sprays in the dorsal half of the posteroinferior side of the vermal pentagon. The peripheral surface district of the tuber branch is less wide than that of the declive branch.

2) The intermediate branch, Bolk's C₁ or the pyramis branch (P)

Mostly the pyramis branch proceeds monopodially toward the inferior edge of the vermal pentagon and splits off many side branches which are usually stronger to the ventral side of the pyramis branch (“a” type; 20 out of 50, 2., 4. and 7. in fig. 5) or similar strong to the ventral and the dorsal side (“b” type; 26 out of 50, 3., 6. in fig. 5).

Rarely the pyramis branch is dichotomic, repeatedly or not (“c” type; 4 out of 50, 5. in fig. 5).

The pyramis branch makes up the peripheral end sprays in the caudal half of the inferior side of the vermal pentagon. The surface district is slightly wider than that of the tuber branch and almost equal to that of the declive branch.

IV. The inferior arbor vitae (fig. 7)

1) The uvula branch (U)

The uvula branch arises usually from the medullary club as the proper falling branch, proceeds downward and spreads up in a peculiar branch formation (fig. 7).

The branches are sometimes dichotomic (“a” type; 4 out of 50, 1. in fig. 7) or trifurcated (“b” type; 10 out of 50, 2. in fig. 7), but more frequently they are divided in repeated dichotomy (“c” type; 18 out of 50, 3. in fig. 7) or pentamerous (“d” type; 18 out of 50, 4. in fig. 7).
The peripheral surface district of the uvula branch occupies the caudal parts of the caudal side of the vermal pentagon.

2) The nodule branch (N)

The nodule branch is the most caudal one of the primary branches arising from the central medullary substance and extends along the posterior roof of the ventricular fastigium. It proceeds toward the caudal edge of the vermal pentagon and generally gives off two or more dorsal and ventral side branches ("a" type; 28 out of 50, 2. and 4. in fig. 7). Sometimes the ventral side branches are fewer than the dorsal ones in number ("b" type; 11 out of 50, 1. in fig. 7) or missing entirely ("c" type; 11 out of 50, 3. in fig. 7).

V. Summary

The branching features of the vermal arbor vitae of fifty Japanese cerebella were observed in detail and the classification of each branch was performed.

The typings of all cases are summarized in the following table (table 1). There are no two types alike.

Table 2 shows the frequency of three vermal positions and of branching types of all medullary stems and branches.

Fig. 8 is obtained as the most common type of vermal arbor vitae.
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vermal position, the position of posterior edge of vermal pentagon, related to axial line; ax, axial position; ia, infraaxial position; sax, supraaxial position; L, lingula branch; L2, double lingula; Ce, central lobule branch; Ce2, double central lobule; Cu, culmen tree; D, decline branch; F, folium branch; T, tuber branch; P, pyramis branch; U, uvula branch; N, nodule branch.
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Abbreviations are same as table 1.
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