Collagen–tri-epsilon helical strands

Robert William Whitby
14 February 2004
http://homepage.mac.com/whitby/

http://web.me.com/whitby/Octahedron/Welcome.html

Reference

1. Bruce Alberts et al, *Molecular Biology of the Cell*, Garland Publishing, Inc., New York, 1983.
2. Lubert Stryer, *Biochemistry* 2d ed., W. H. Freeman and Co., San Francisco, 1981
3. Octahedron1stEd.pdf
4. ProteinFold.pdf

Introduction

This file extends the work on collagen shown in *Octahedron* [Ref. 3, chapter COLLAGEN, page 389]. It shows more extensively how the main chain units form the epsilon helical turns which combine to form the collagen strand. It looks at the orientation of the sidechains and how they form joins between the strands.

It takes an extensive look at the relationships between the strands of adjoining layers in tadpole skin and chick corneas which is suggested by an electron micrograph attributed to Jerome Gross [Ref.1, Fig. 12-48, page 699]

Figures 1, 2, and 3 show the assembly of the tri-helical turn of collagen strand from the male end of the strand axis;

Figures 4, 5, and 6 show the same assembly from the female end of the axis.

Figure 7 shows how the main chain units are arranged in layers of three units each from an axial view.

Figure 8 shows the same layers from a radial view.

Figure 9 shows the completed tri-axial strand both axially and radially.

Figure 10 shows how the oxygen atom might be joined to two likely proline residues to form hydroxyproline.

Figure 11 shows possible hydroxylysine residues based on the lys1-residue [Ref. 4, page 10].

Figure 12 shows some of the other peptides which are found in collagen [Ref. 2, Fig. 9.2, page 186]. All the peptides are shown in the orientation which they would have if they were viewed parallel to the collagen strand axis.

Figure 13 shows a tri-helical turn with lysine sidechains attached to the available main chain units viewed axially from the male end.

Figure 14 shows the same assembly viewed axially from the female end.

Figure 15 shows an hexagonal assembly of parallel tri-helical strands linked by their lysine sidechains.

Figure 16 shows a triangular assembly of three of the hexagonal rings shown in Figure 15.

Figure 17 shows the axial relationships between strands in adjoining parallel layers of an assembly which occurs in tadpole skin and chick corneas [Ref.1, page 699].

Figure 18 shows the orientations of the sidechains of the strands in adjoining parallel layers.

Figure 19 shows radial views of the main chain units and their helical assemblies in each of two adjoining layers.

Figure 20 shows an oblique view of a helical turn from the male end.

Figure 21 shows the an oblique view of a helical turn from the female end.

Figure 22 shows both axial and oblique views of helical turns from both male and female ends.

Figure 23 shows colinear sidechain joins between strands of adjoining layers

Figure 24 shows non-colinear sidechain joins between strands of adjoining layers

Figure 25 shows how the sidechain joins between strands of adjoining layers differ within the multi-layer assembly.

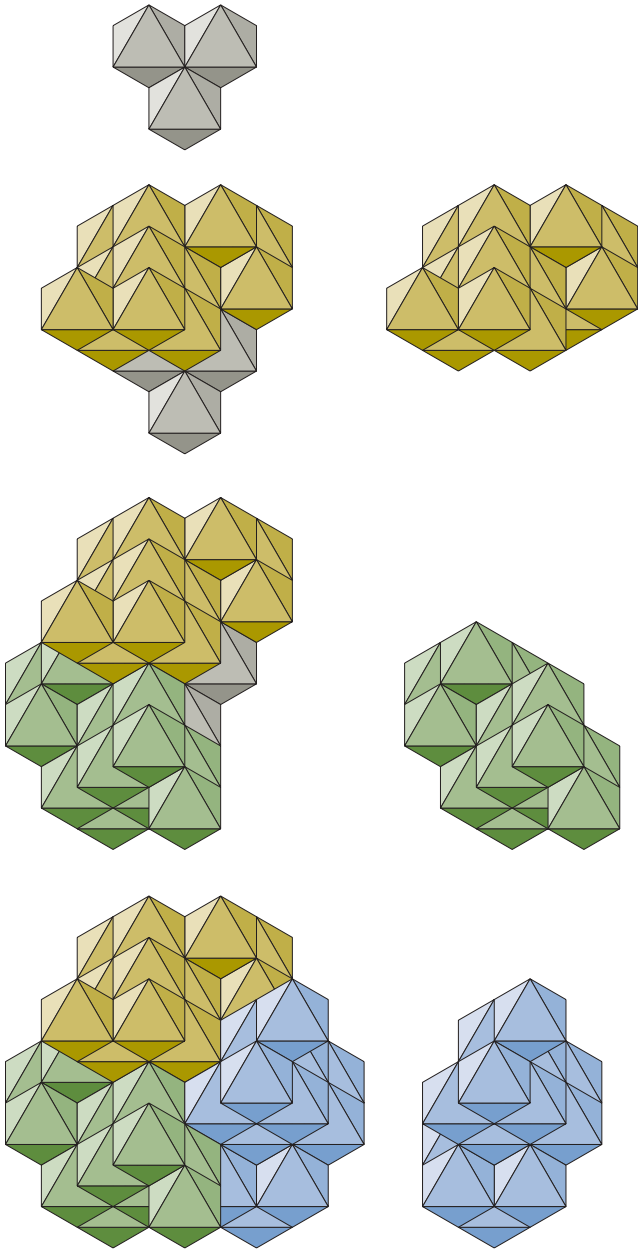


Fig. 1 Three epsilon helical main chain units joined by a C-atom, male end

The figure depicts how each of three main chain units can cleftly share the same C-atom as if it were its sidechain. The three main chain units on the right are identical except for a rotation of one-third turn about the normal to the graphical plane. Each is oriented so that it is in one of the three orientations which occur in an epsilon helix viewed parallel to the helical axis. The colors of each main chain unit is used to identify its orientation in this and subsequent figures. The C-atom is shown at the top of the figure and is colored gray. The units in the right-hand column are added one by one to the assembly shown on the left. The complete assembly shows the relationship of the glycine residues which effectuate the join between the three epsilon helixes which make up the collagen molecule.

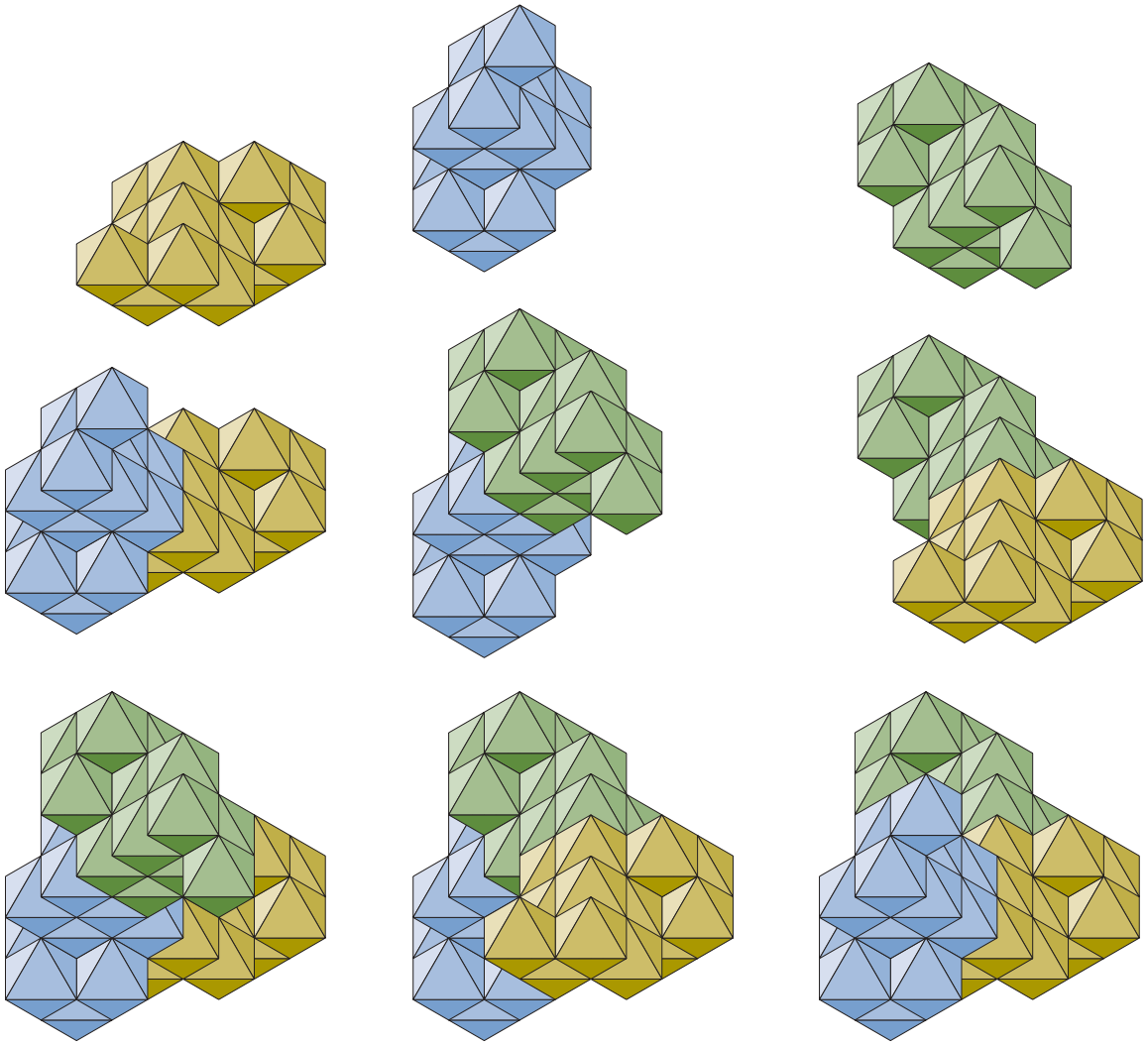
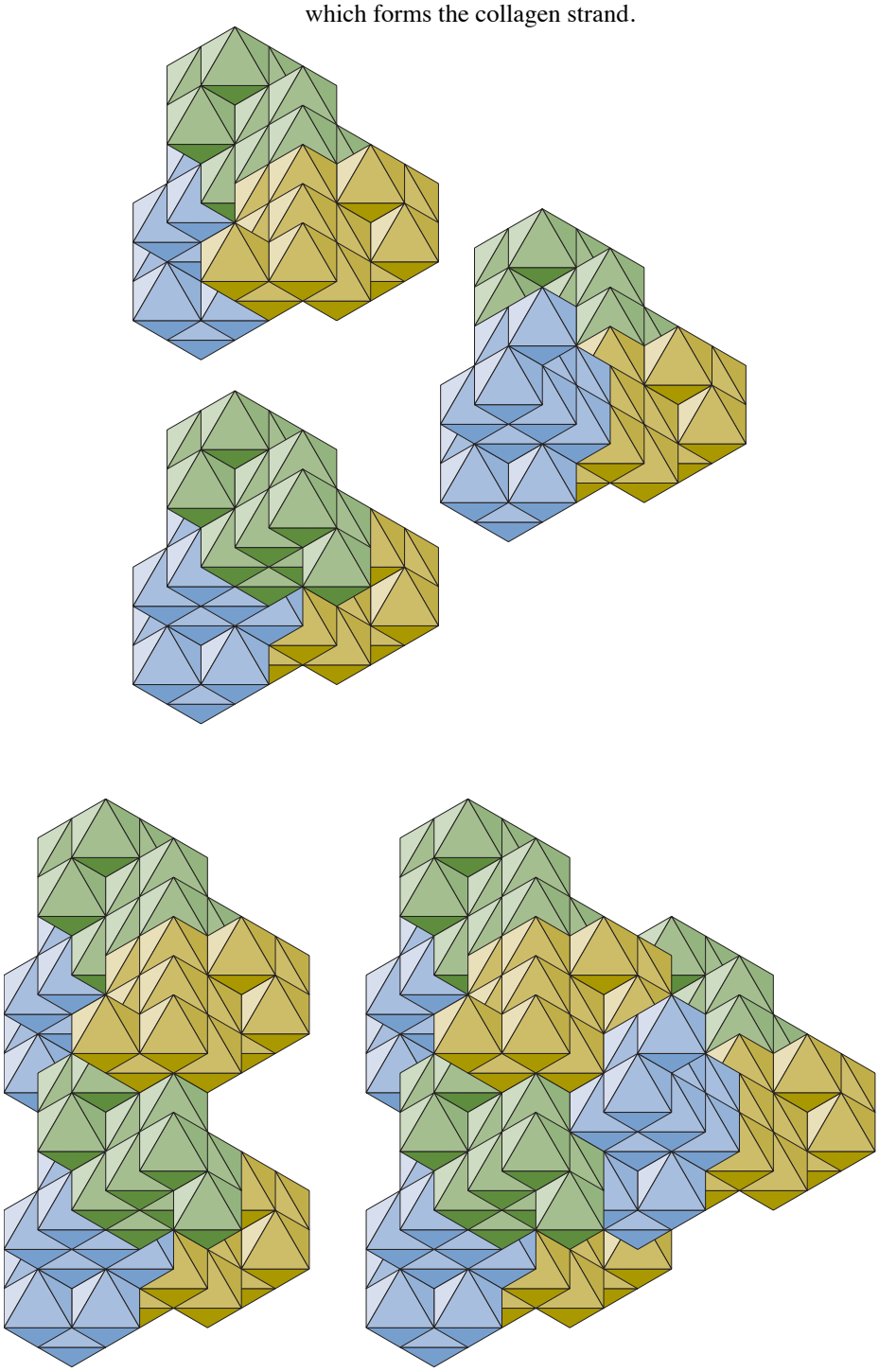


Fig. 2 Epsilon helical turns, male end

Three identical main chain units which differ by a rotation of one-third turn about a normal to the plane of the figure are shown along the top of the figure. Each has been colored to distinguish it from the other two orientations. Each heads one of three columns of drawings which show the assembly of three turns of an epsilon helix which differ from one another by a rotation of one-third turn about a normal to the plane of the figure. These three turns can be joined to form the minimal axial unit of a collagen strand. Each element of the figure is viewed from the male end of the epsilon helical axis.

Fig. 3 Collagen strand, male end

Three identical turns of an epsilon helix are shown in a triangular grouping at the top of the figure. Each differs from the others by a rotation of one-third turn. Each consists of three main chain units each of which has been colored according to its orientation. The yellow units have the same orientation in each of the three turns as do the blue and the green. The two turns on the left are joined in the lower left. On the lower right, the third turn has been added to form the tri-helical unit which forms the collagen strand.



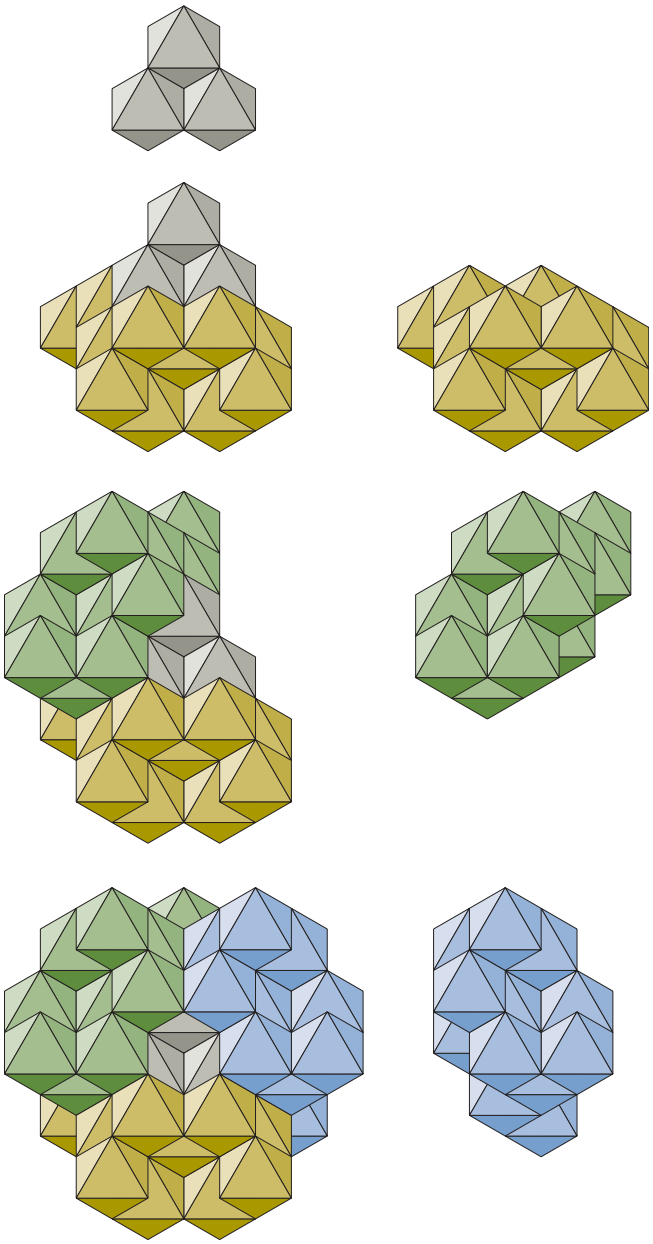


Fig. 4 Three epsilon helical main chain units joined by a C-atom, female end
The figure shows main chain units in the three orientations required to form an epsilon helix viewed from the female end of the helical axis.

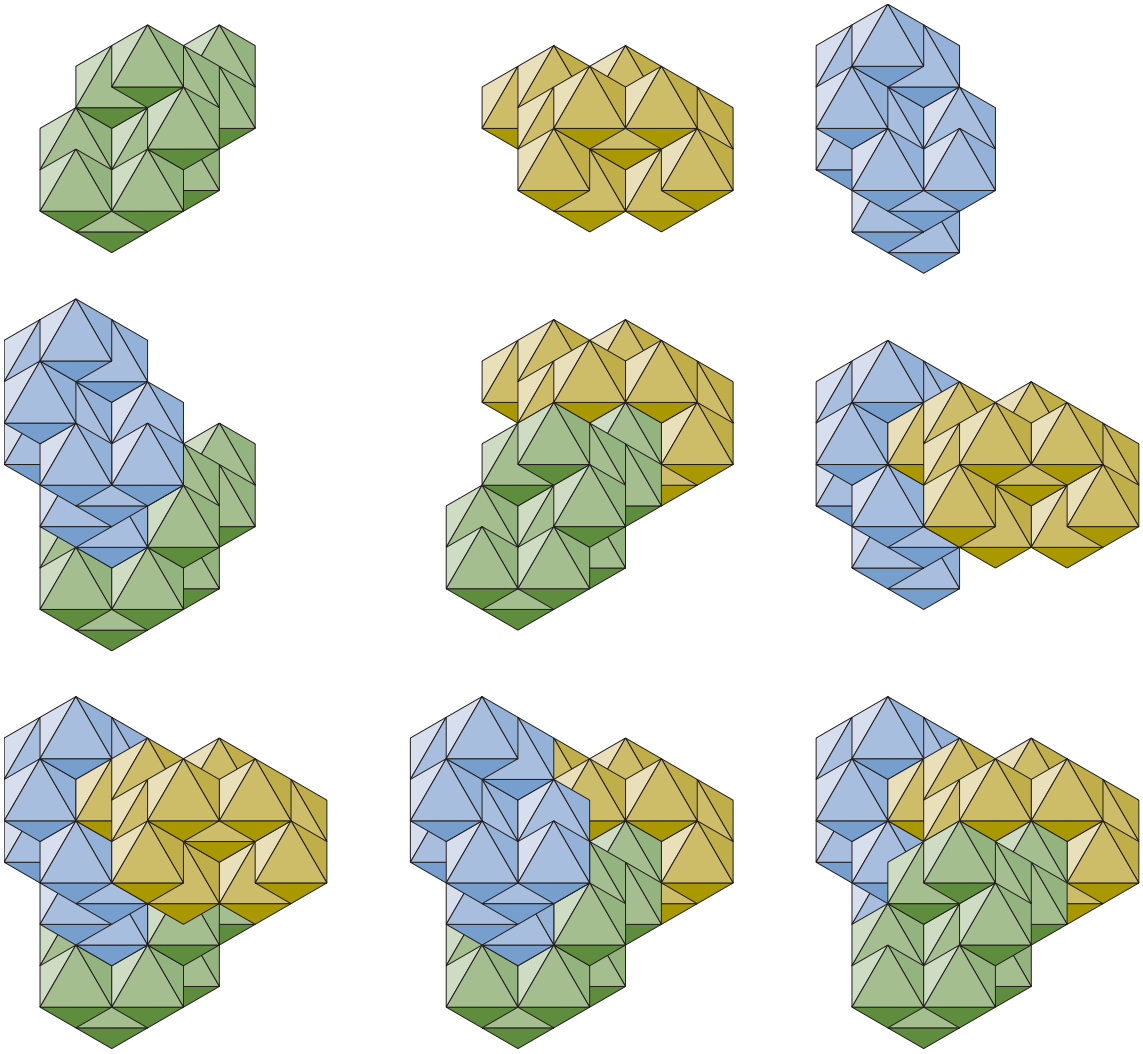


Fig. 5 Epsilon helical turns, female end

The figure shows three turns of epsilon helix from their female ends. The strands are identical except for a one-third turn difference in their orientations.

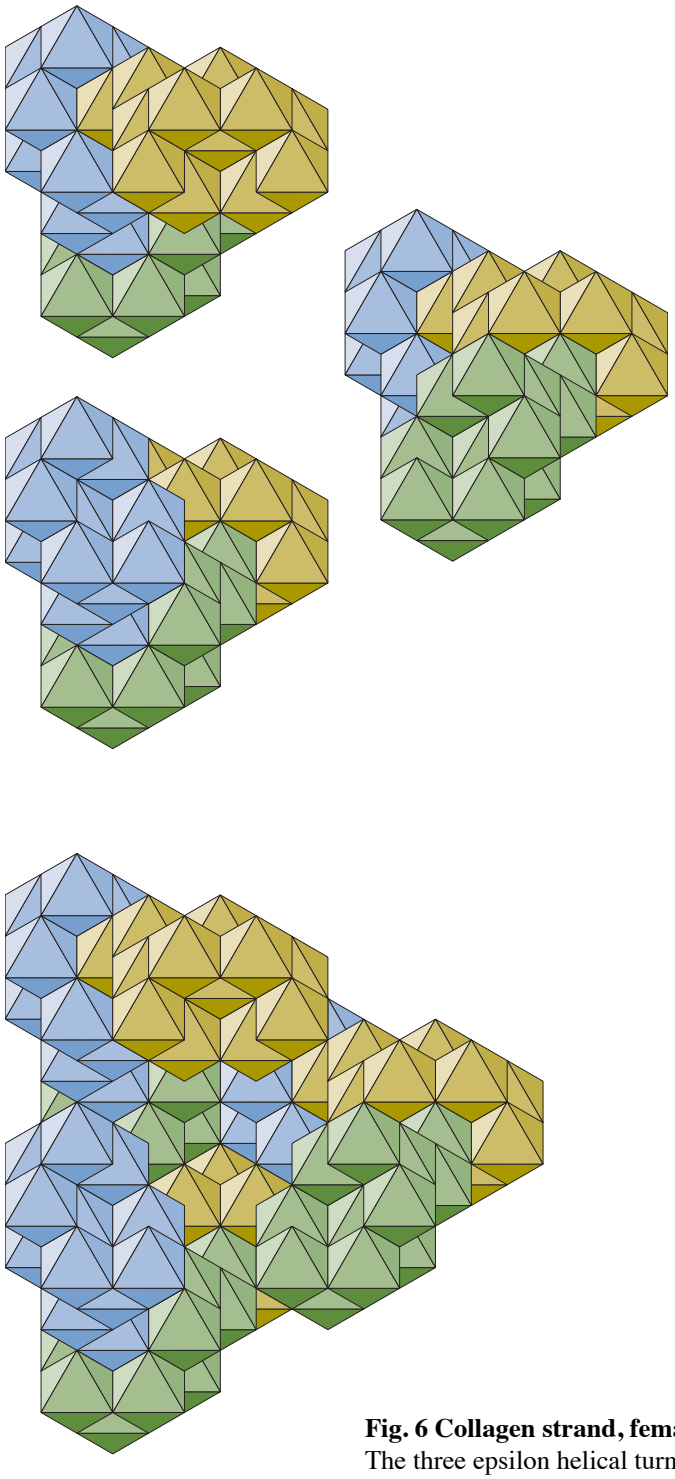


Fig. 6 Collagen strand, female end

The three epsilon helical turns at the top of the figure are joined to form the turn of collagen strand at the bottom.

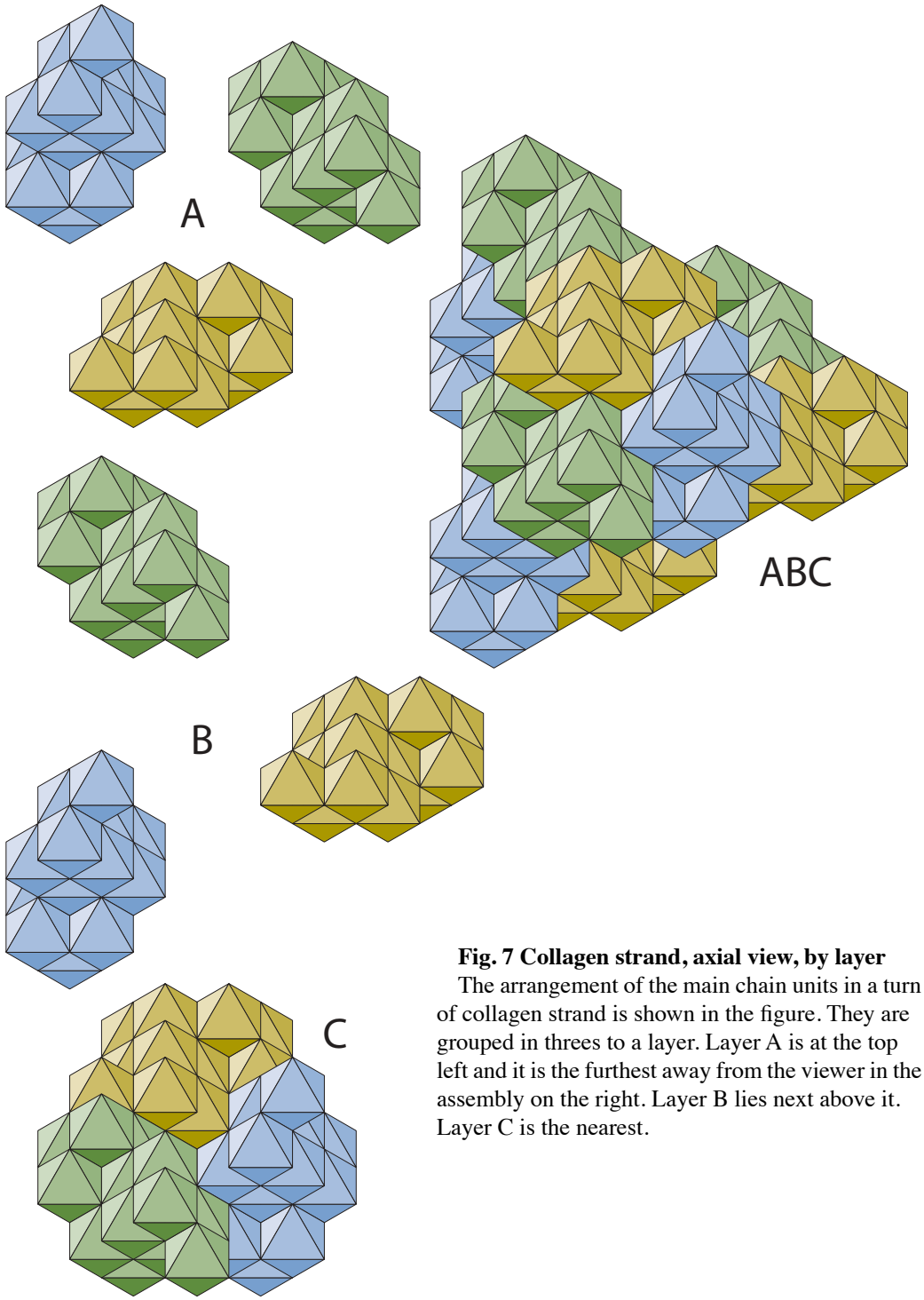


Fig. 7 Collagen strand, axial view, by layer

The arrangement of the main chain units in a turn of collagen strand is shown in the figure. They are grouped in threes to a layer. Layer A is at the top left and it is the furthest away from the viewer in the assembly on the right. Layer B lies next above it. Layer C is the nearest.

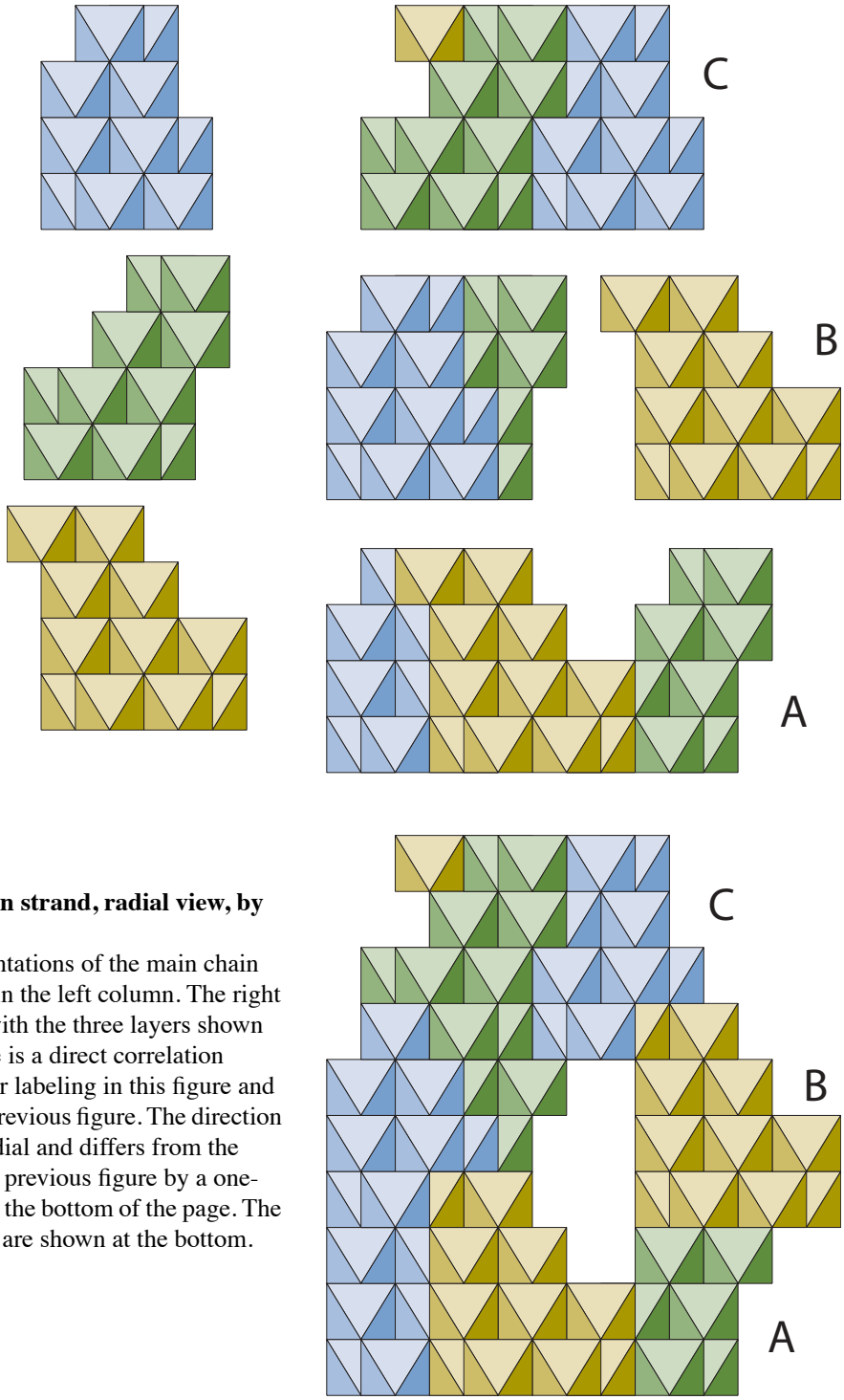


Fig. 8 Collagen strand, radial view, by layer.

The three orientations of the main chain units are shown in the left column. The right column begins with the three layers shown separately. There is a direct correlation between the layer labeling in this figure and that used in the previous figure. The direction of the view is radial and differs from the axial view of the previous figure by a one-fourth turn about the bottom of the page. The combined layers are shown at the bottom.

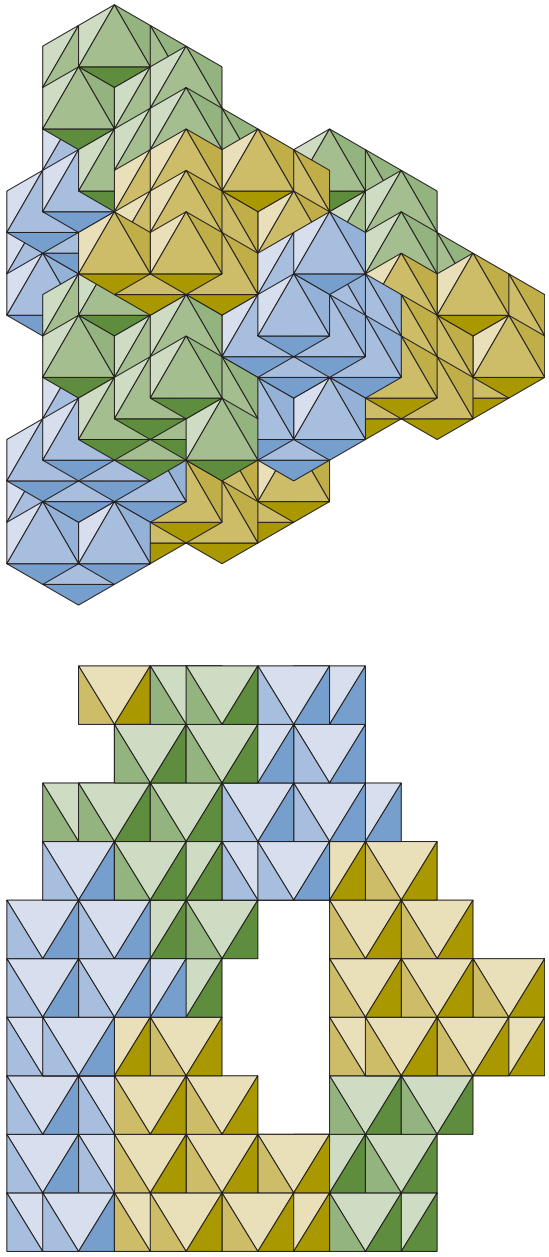


Fig. 9 Collagen strand, viewed both axially and radially

The figure shows a collagen strand viewed parallel to its axis at the top. Below it is a radial view. The difference between the two view is a one-fourth turn about the bottom edge of the page.

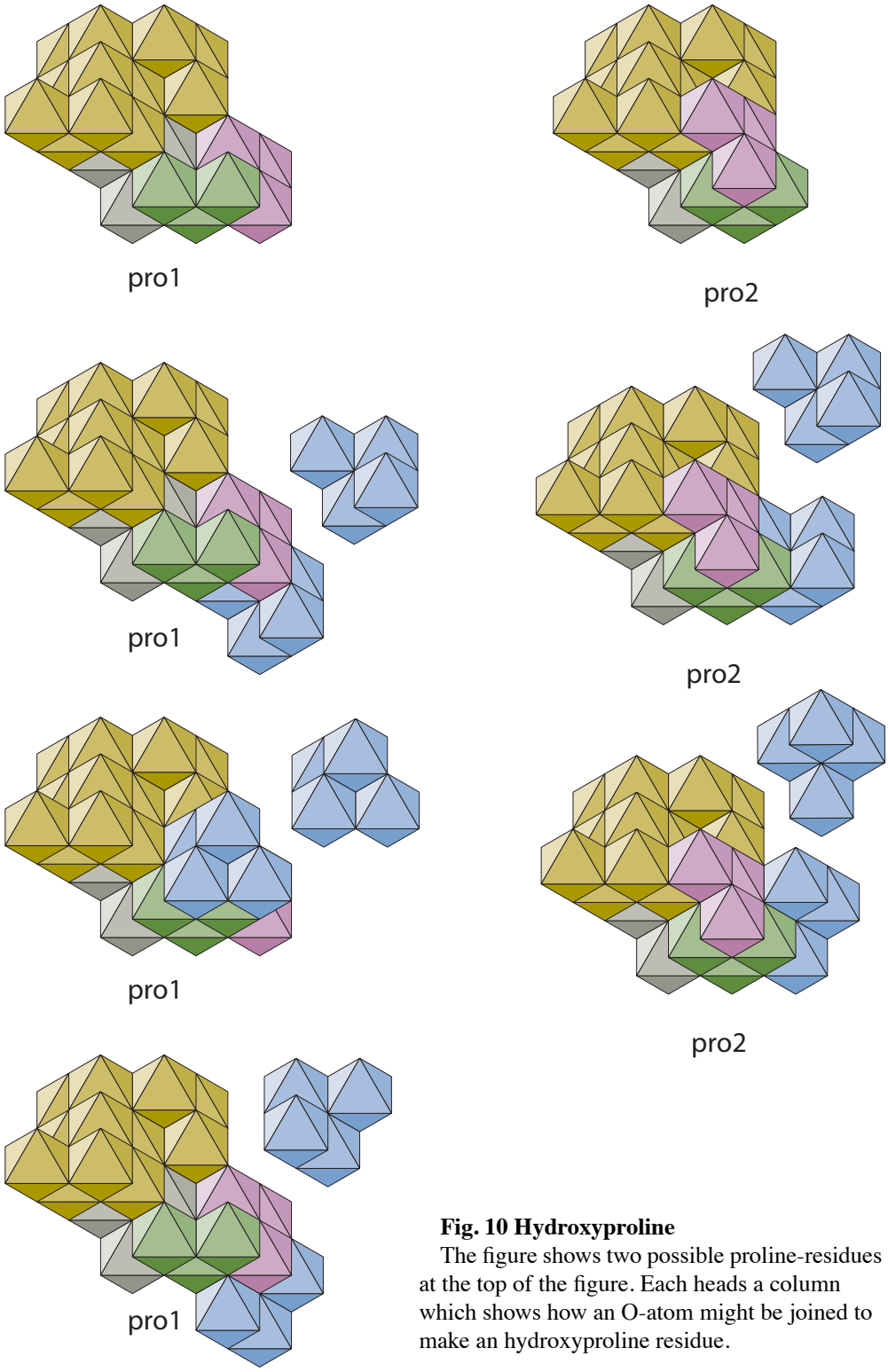


Fig. 10 Hydroxyproline

The figure shows two possible proline-residues at the top of the figure. Each heads a column which shows how an O-atom might be joined to make an hydroxyproline residue.

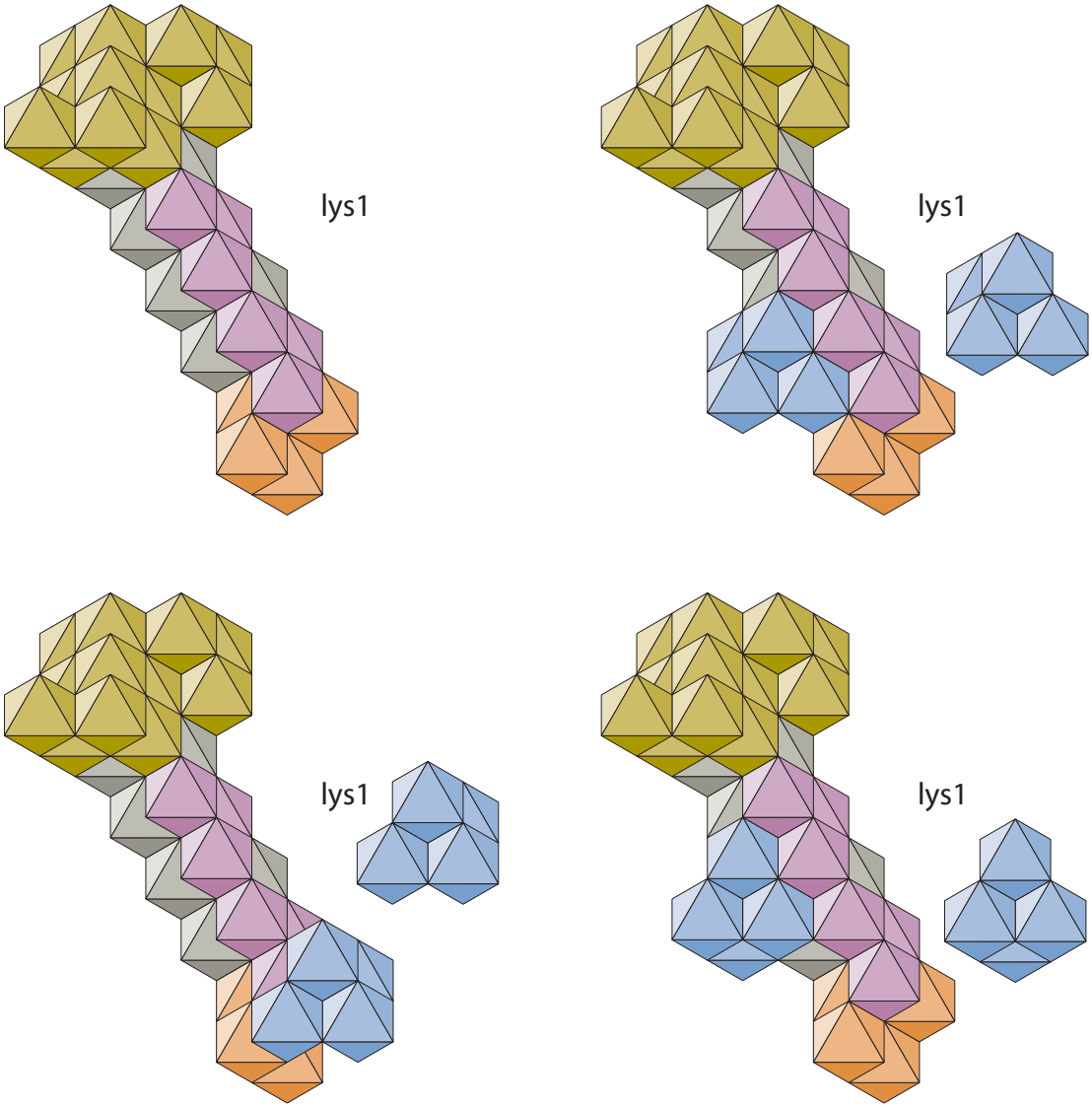


Fig. 11 Hydroxylysine–possible locations and orientations of O-atom

The lys1-residue is shown at the upper left. To the right, an O-atom colored blue is joined to the lys1-residue to produce an hydroxylysine-residue. On the lower right, an O-atom with a different orientation has been added to a lys1-residue to produce another type of hydroxylysine-residue. A third placement for an O-atom is at the extreme end of the lys1-residue's sidechain. It is shown at the lower left.

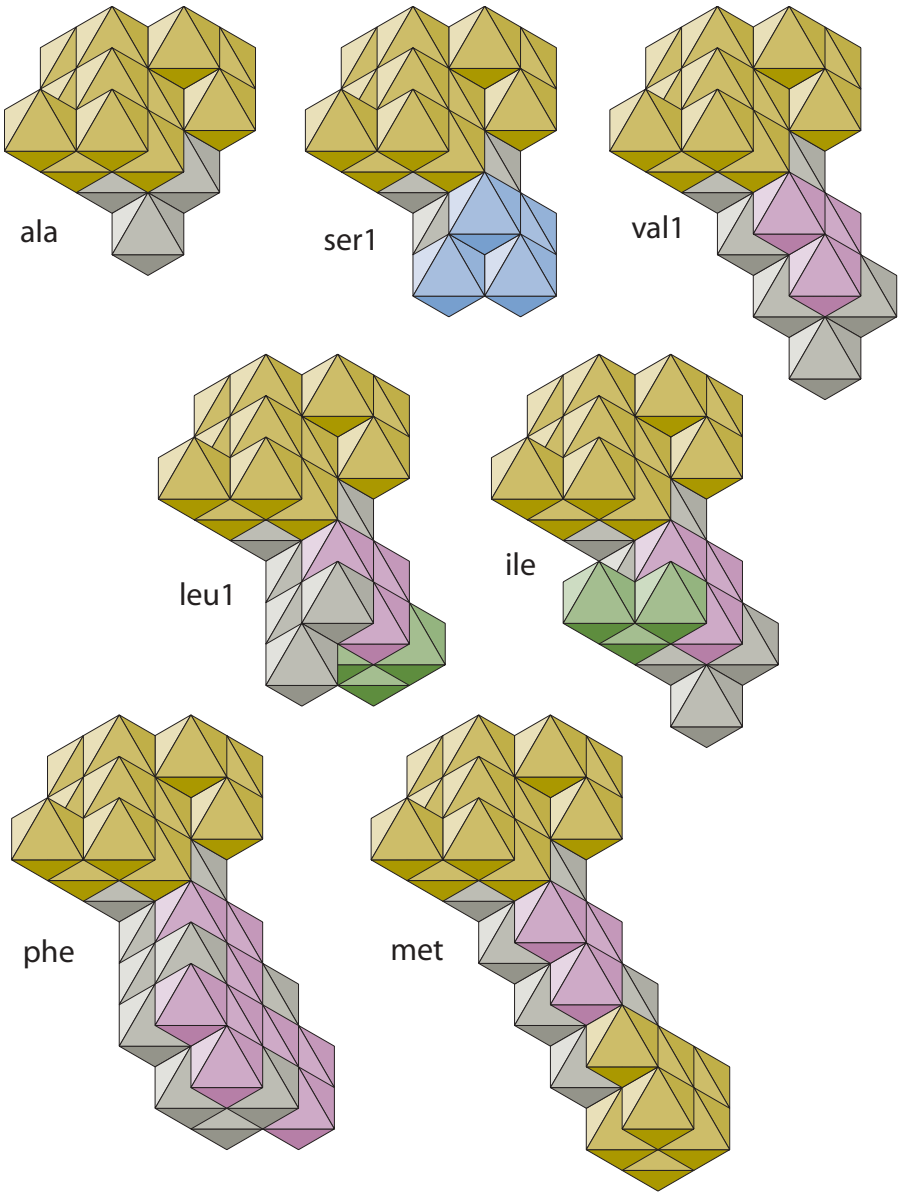


Fig. 12 Collagen peptides–axial view

The peptides shown in the figure are found in the α1(I) chain of collagen.[1] Each is viewed parallel to the fibril axis.

---

1. Ref. 2, Fig. 9-2, page 186

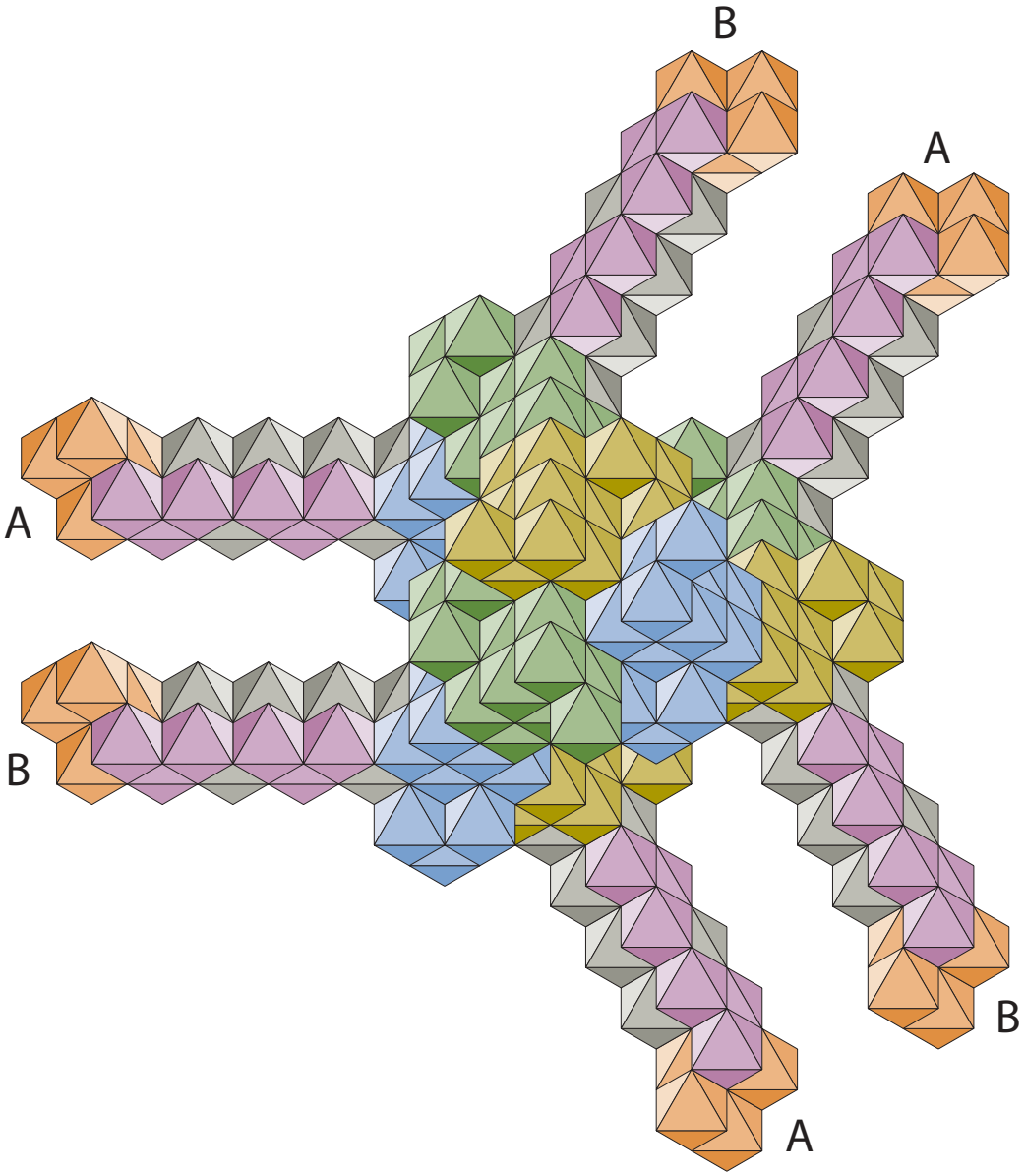


Fig. 13 Collagen strand with lysine sidechains, axial view, male end

Each epsilon helical turn of the three turn assembly has two residues which can accept a sidechain. A lysine chain has been added to each of these six residues. The identifying letter at the outer end of each of the sidechains identifies the layer to which its peptide belongs.

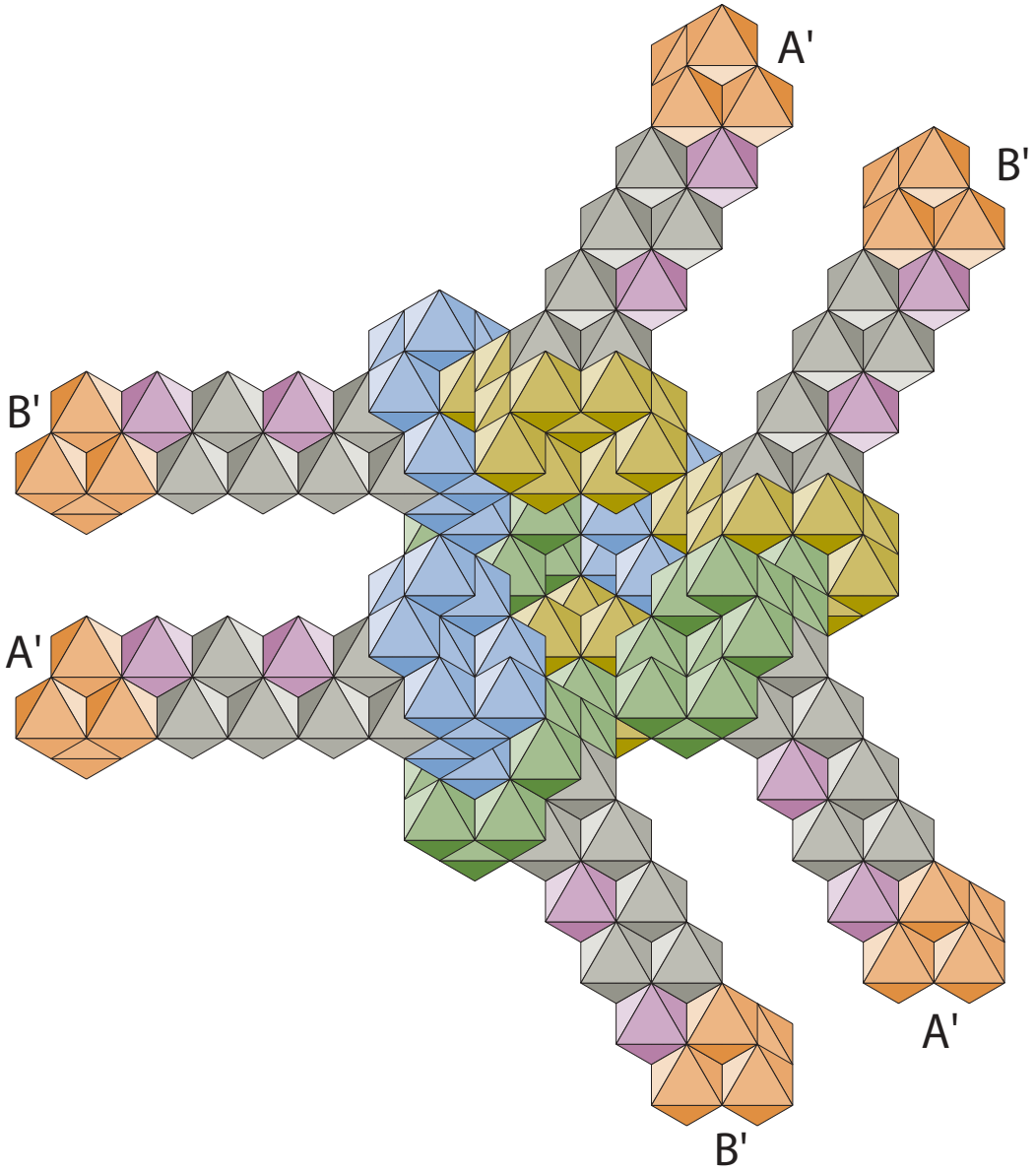


Fig. 14 Collagen strand with lysine sidechains, axial view, female end
This is simply the assembly of the previous figure viewed from the opposite direction.

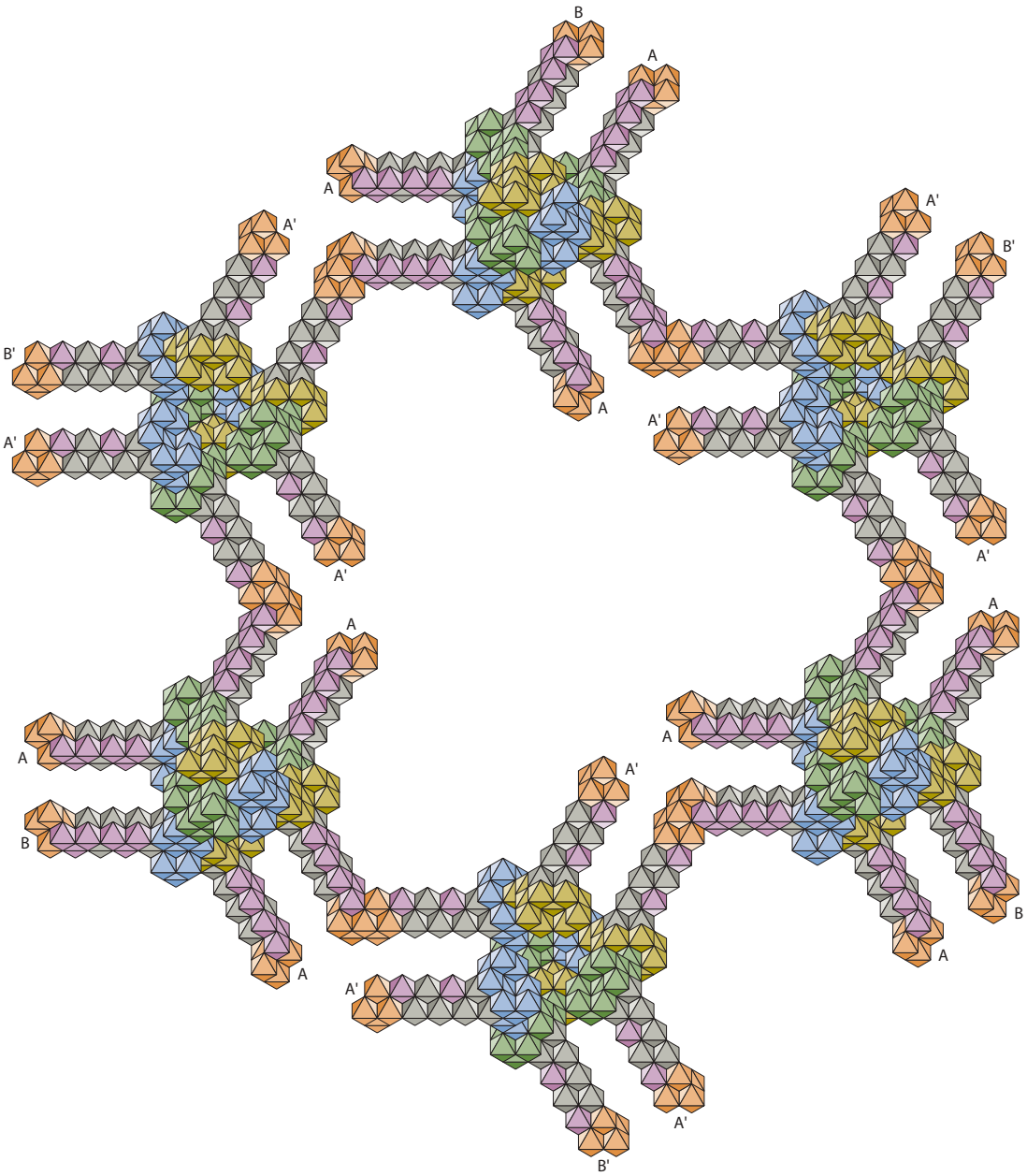


Fig. 15 Collagen strands, axially parallel, linked by lysine sidechains.
The figure shows an hexagonal assembly of identical tri-helical strands linked by their B-layer lys1-sidechains. Adjoining strands are inverted one to the other.

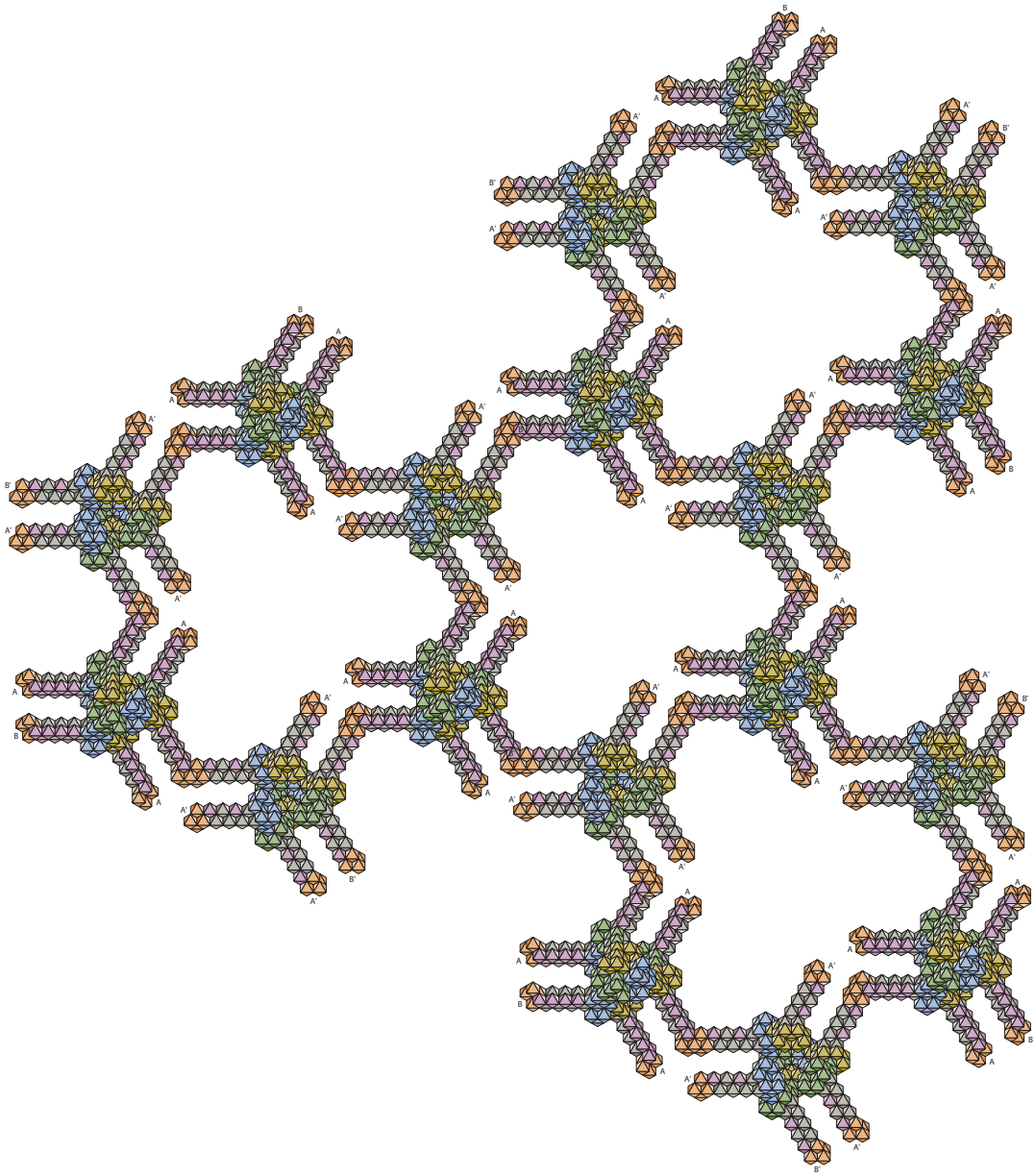


Fig. 16 A triangular assembly of hexagonal collagen rings

The figure shows a triangular assembly of three hexagonal collagen rings. Each ring is joined to the other two rings in the same manner. The ring-to-ring join is identical to the strand-to-strand join of the ring. Each ring contributes two strands to form the central ring.

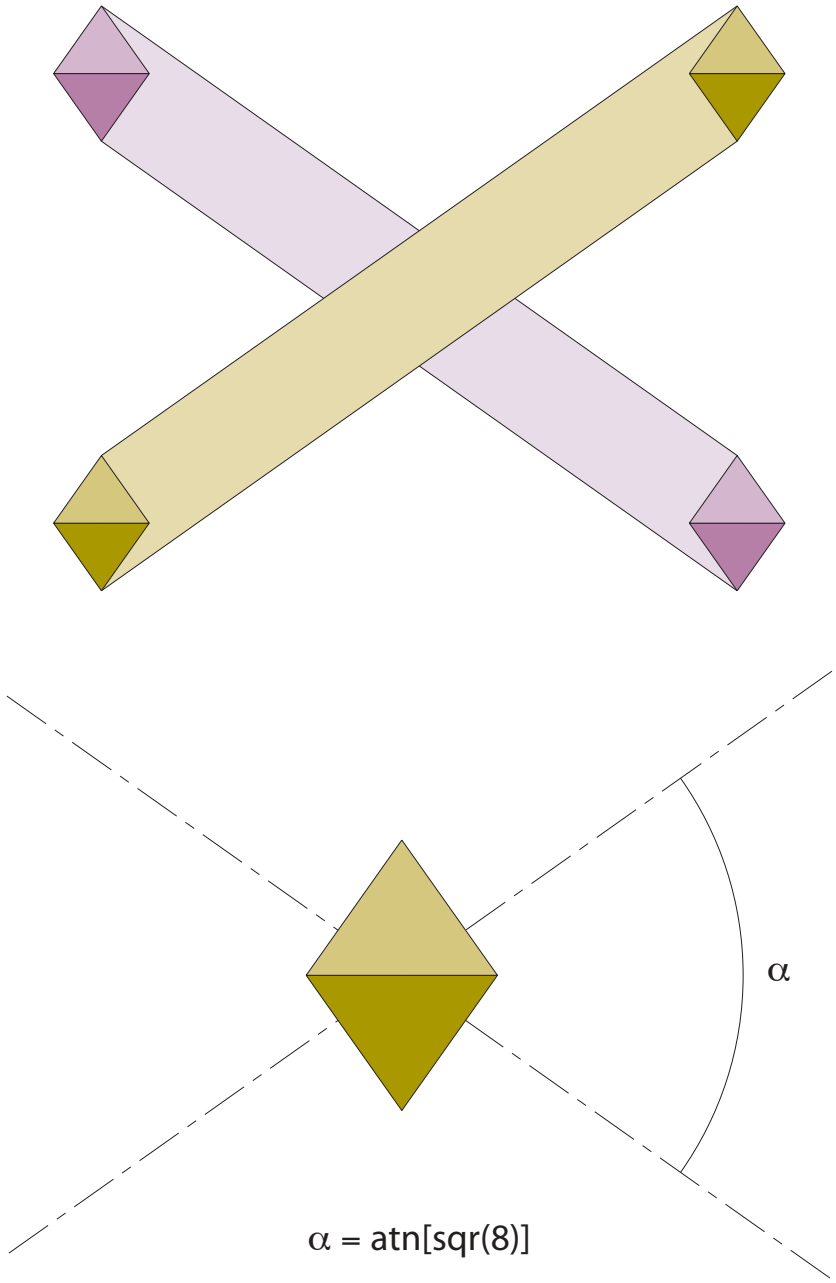


Fig. 17 Collagen fibrils lying in parallel planes

In tadpole skin and chick corneas, the axis of each collagen fibril within a layer is parallel to the axis of each of the other fibrils. Each axis is also parallel to the boundary between its layer an adjoining layer. The axis of a collagen fibril in one layer makes an angle of atn(sqr(8)) with the axis of a collagen fibril in an adjoining layer. It follows that the axis of a collagen fibril in one layer is parallel with the axis of a collagen fibril in each of the alternate layers. The top figure shows the relationship between fibrils in adjoining layers. Each band represents a fibril within an adjoining layer. The lower figure shows how the fibril axis in one layer compares with the fibril axis in an adjoining layer.

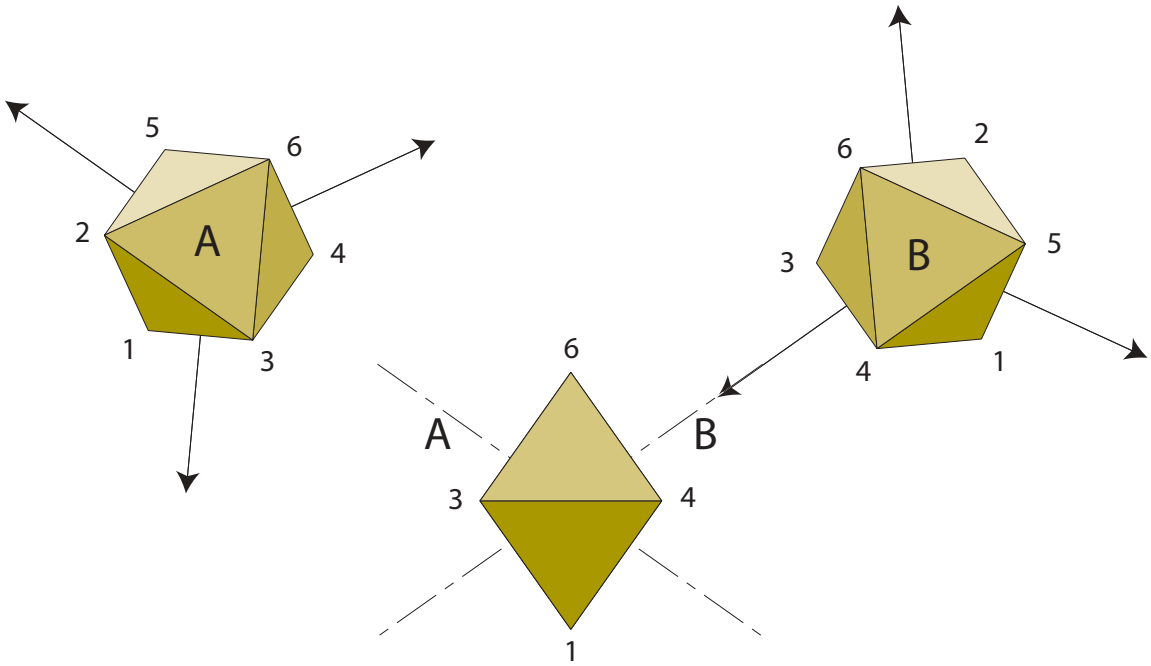
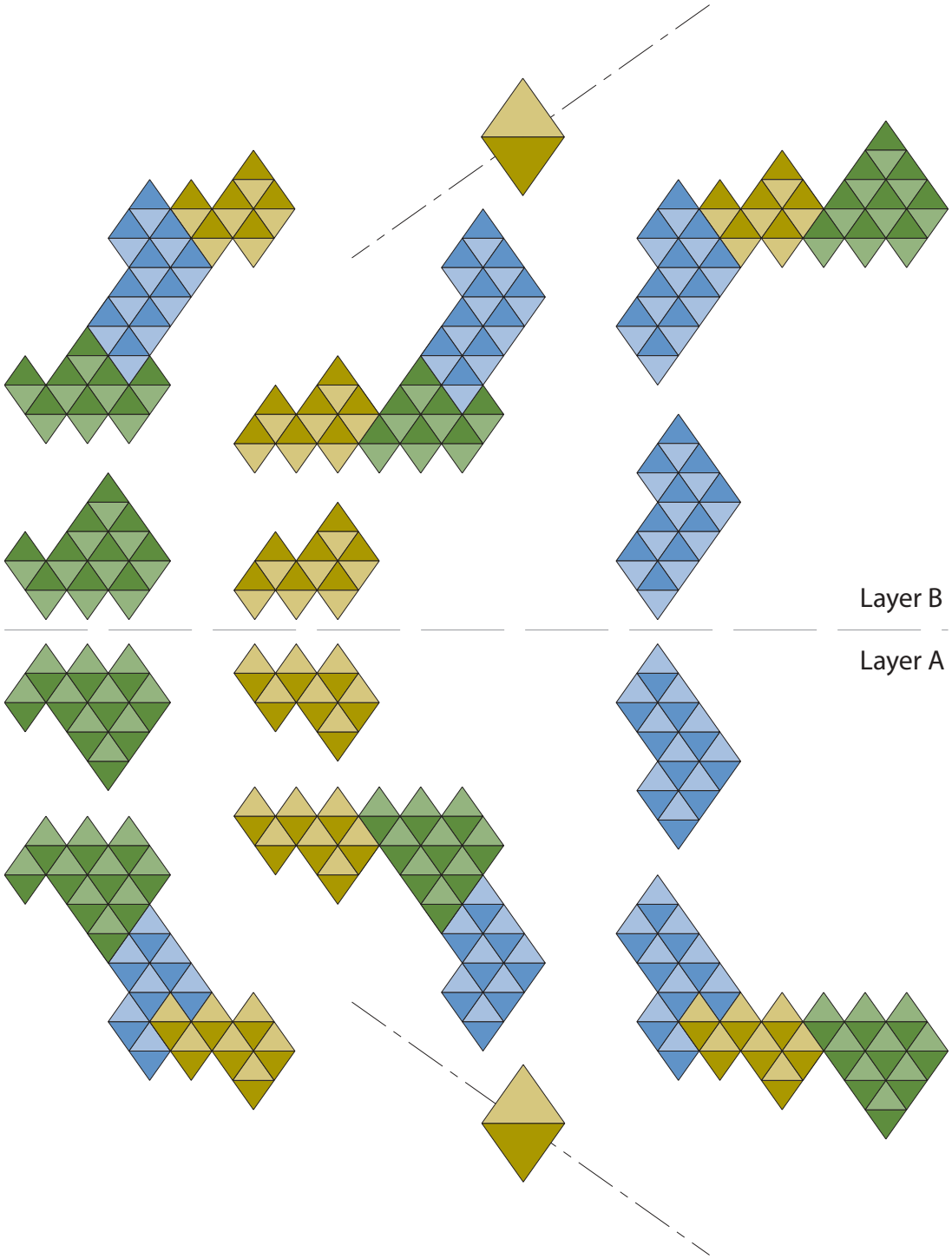


Fig. 18 Sidechain orientations of collagen fibrils lying in parallel planes.
The figure shows the orientations of the sidechains of the peptides which make up each of the epsilon helical turns for two adjoining parallel layers of collagen fibrils. The orientation of the fibril axes within each layer is shown in the edgially viewed octahedron in the middle of the figure. The facially viewed octahedra labeled A and B are auxiliary views of the middle octahedron. These are axial views and the three arrows which are parallel to edgial diameters of their respective octahedra show the directions of the three sidechains relative to each helical axis. Each vertex of each of the three octahedral views is consistently labeled from view to view. Each of the facial views is an orthographic projection of the middle octahedron.

Fig. 19 Collagen fibrils in parallel planes–epsilon helical turns, radial view

The figure shows the main chain units and the three epsilon helical turns formed by them for two adjoining collagen layers. Each turn is viewed radially. The octahedra of which their atoms are composed have but one orientation. The axes of each set of three turns are parallel to a different facial diameter of that octahedron. That relationship is shown at the top of the figure for one set, and at the bottom of the figure for the other set.



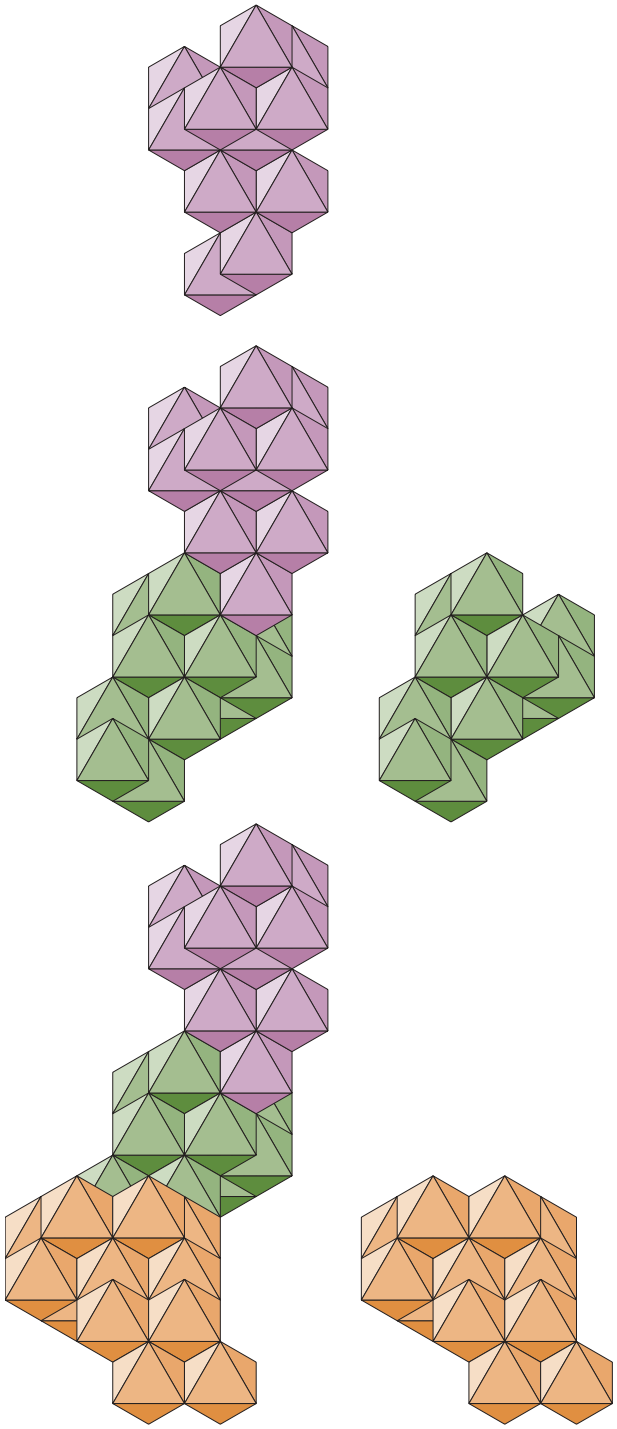


Fig. 20 Epsilon helical turn, assembly of, oblique view, male end

The assembly of the epsilon helix begins at the top with the violet main chain unit. The green is added first, followed by the orange. The complete helical turn is shown at the bottom of the left hand column. The three orientations of the main chain units accounts for half of the total number of orientations within its layer.

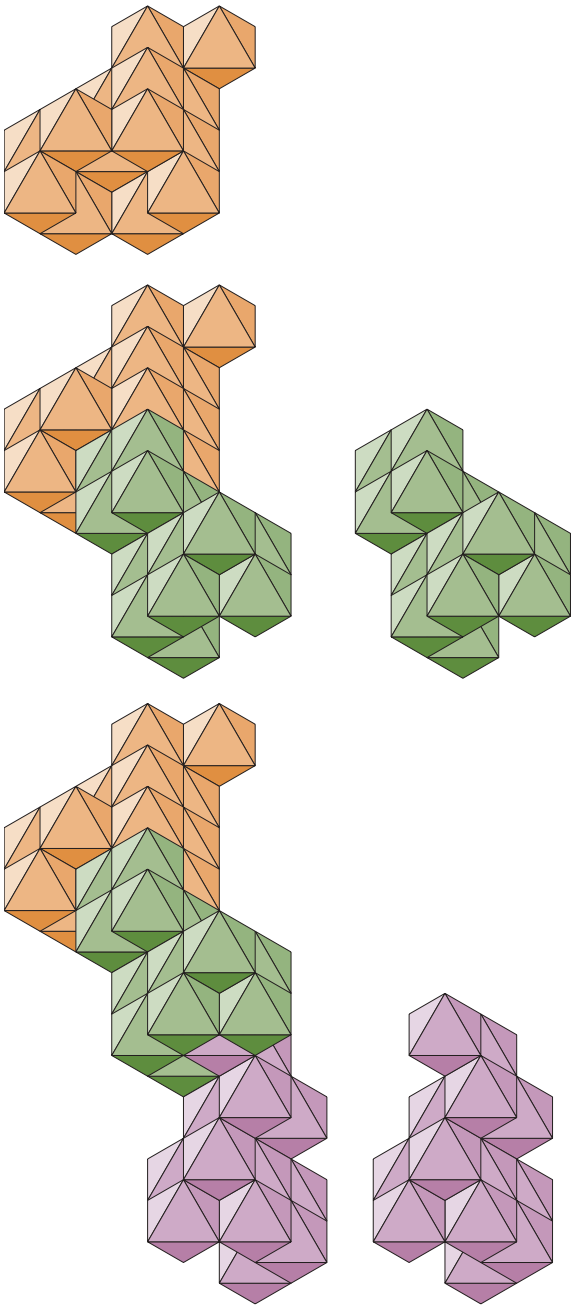


Fig. 21 Epsilon helical turn, assembly of, oblique view, female end

The figure shows the assembly of an epsilon helical turn viewed obliquely to its axis. The assembly begins with the orange main chain unit at the top. It is joined with the green residue at the next step. The turn is completed with the addition of the violet unit. This helical turn and each of its three units is identical to that of the previous figure excepting for a rotation of one-half turn about the bottom edge of the page.

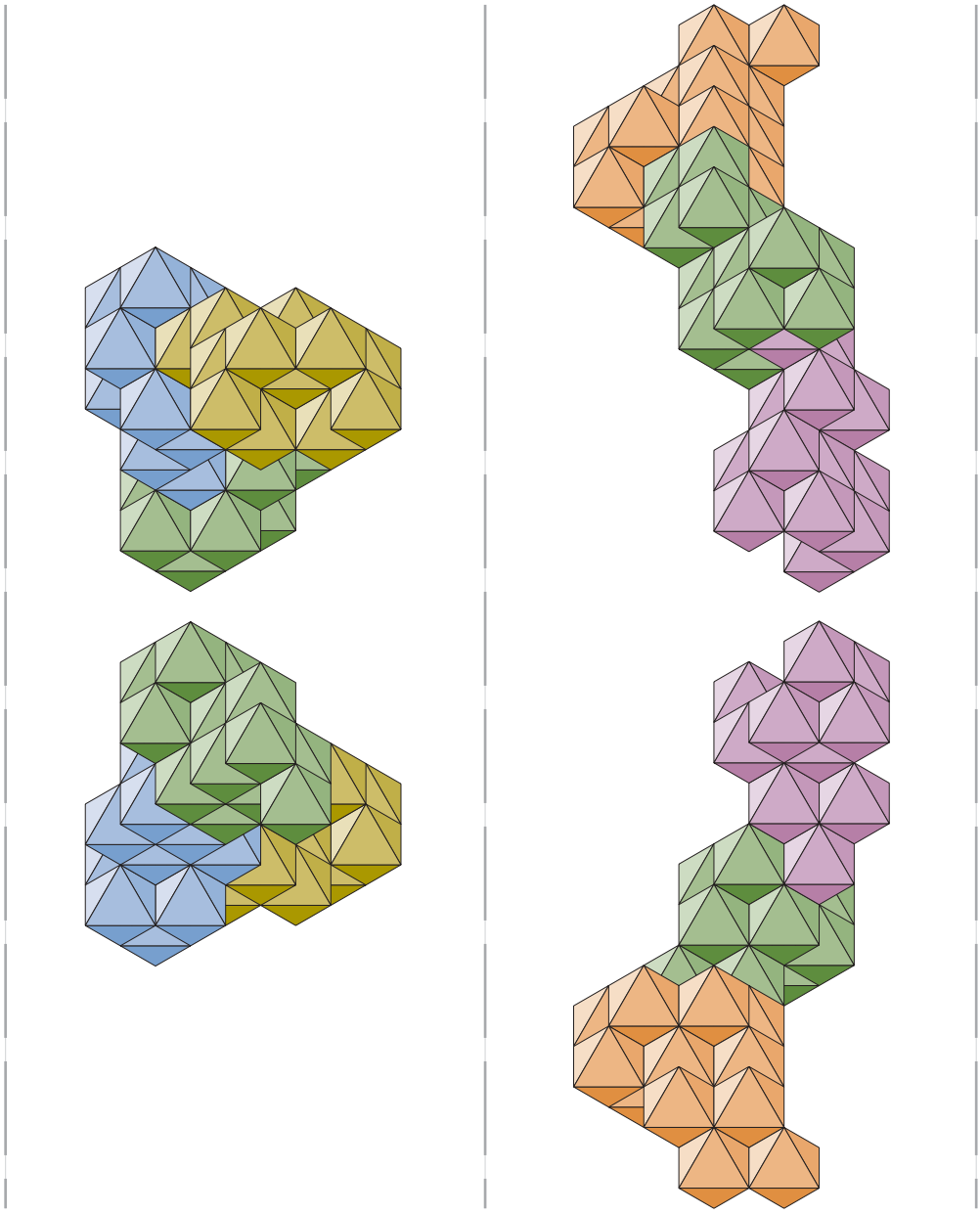


Fig. 22 Epsilon helical turns from collagen fibrils in adjacent parallel layers of tadpole skin
The figure shows epsilon helical turns as they would be oriented in adjacent layers of a structure which has been noted in both chick cornea and tadpole skin [Ref. 1, page 699]. The turns are shown from both male and female ends. The dashed lines represent the boundary planes of the layers.

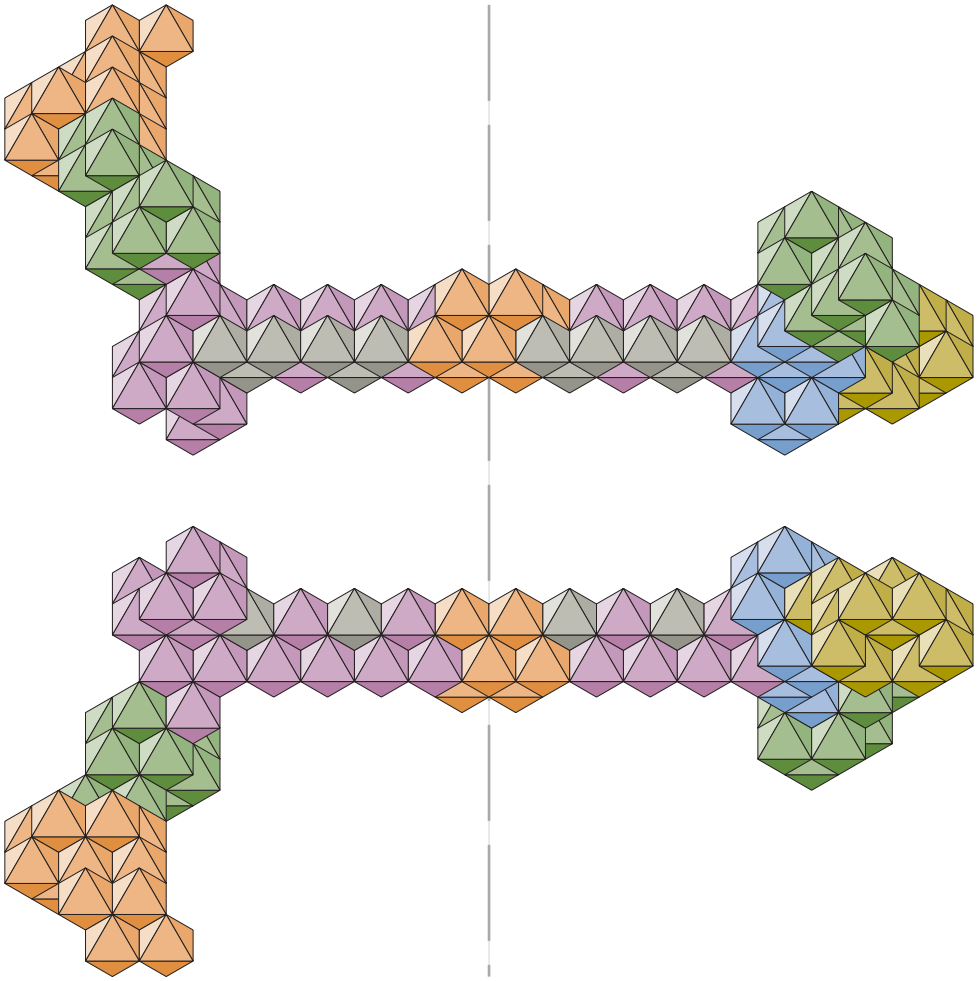


Fig. 23 Sidechain connections between adjoining collagen layers-colinear

The figure shows two sidechain joins which are effected between the N-atoms of lys1-residues. In each case, the violet residue of the helix on the left is linked to the blue residue of the helix on the right. The sidechains of the green and orange residues of the left helixes would be directed away from the layer boundary as would the sidechains of the green and yellow residues of the right helixes.

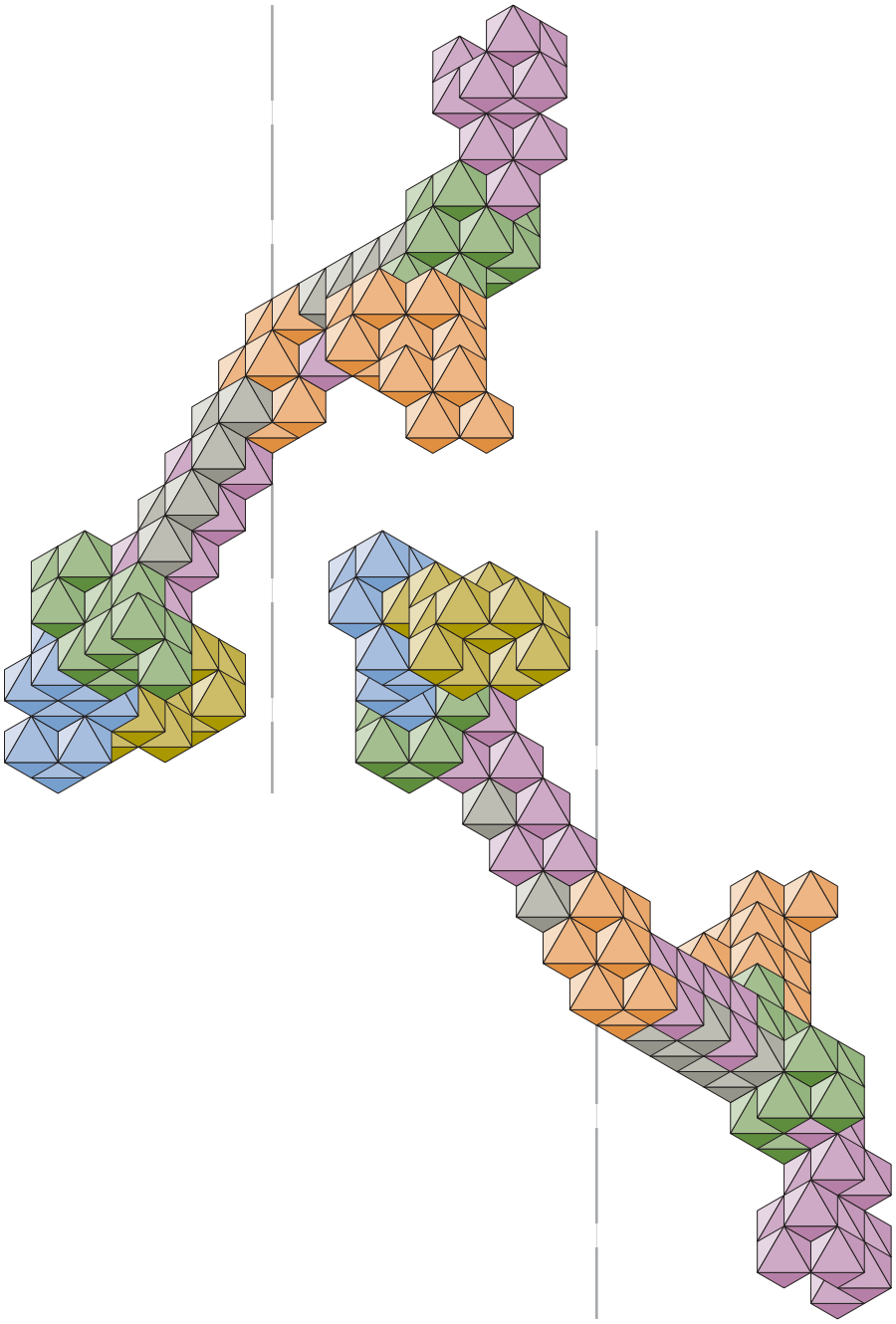


Fig. 24 Sidechain connections between collagen layers–non-colinear
The figure shows two non-colinear joins between the sidechains of residues across the layer boundary. At the top left, the sidechain of the green residue on the left of the boundary is linked to the side chain of the green residue on the right side of the boundary. At the bottom right, the same linkage occurs between inverted helices.

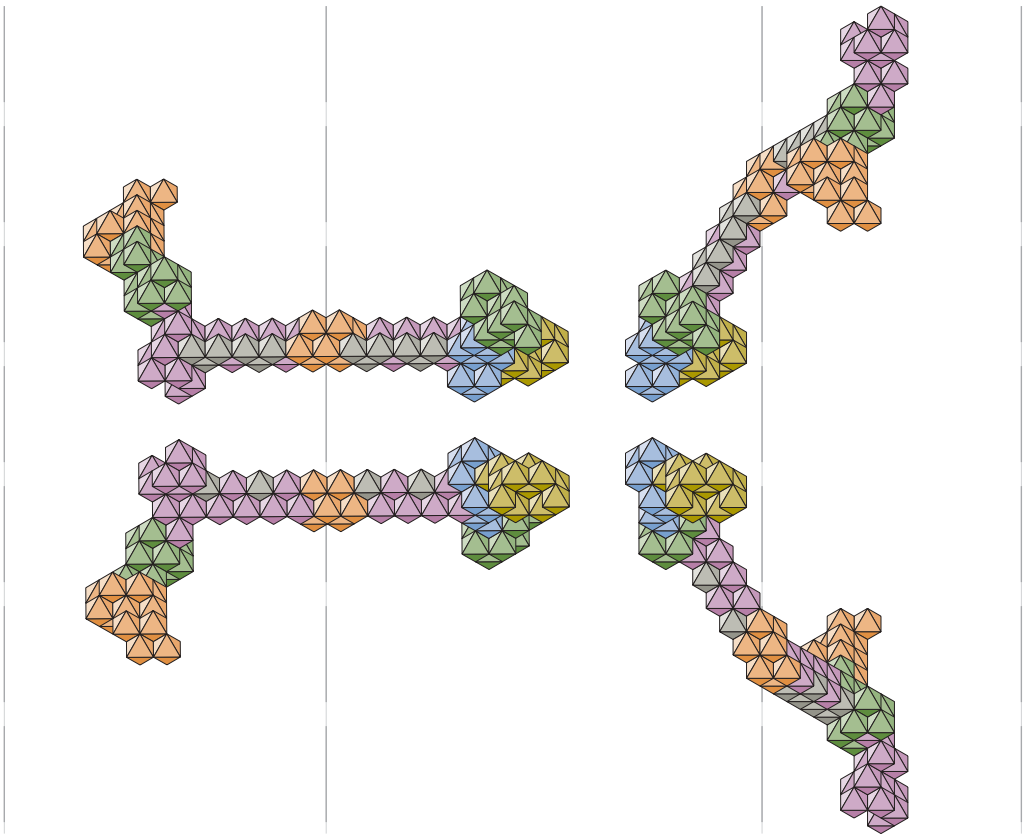


Fig. 25 Interlayer sidechain connections

The figure shows the interlayer connections between the central layer and the layers adjoining it. The axes of the helixes of the central layer are parallel to the viewing direction; the axes of the bounding layers at an oblique angle to the viewing direction. There are but three orientations for each main chain unit of each of two orientations of the helixes of the central layer which are colored green, yellow, and blue. There are but three orientations for the main chain units of each of the two orientations of the helixes of each of the two adjoining layers and these are colored violet, green, and orange. No matter how thick the layer, or how wide, or how deep, the orientations of the main chain units is fixed at six. Note, also, that there is but one orientation for each of the octahedra which compose each of the atoms in each helix of each tri-helical strand of each layer of the assembly. This is seen in the orientation of the He-octas of each of the main chain units. This alternating layer pattern is repeated in tadpole skin and chick cornea.[1]

1. Ref. 1, page 699, Fig. 12-48.

28 Collagen–tri-epsilon helical strands