THE JUNCTIONAL COMPLEX ASSOCIATED BODY
OF HUMAN ECCRINE SWEAT GLAND

S. S. SPICER, B. J. MARTIN, and J. V. SIMSON. From the Department of Pathology, Medical University
of South Carolina, Charleston, South Carolina 29401

INTRODUCTION
The junctional complex connecting epithelial cells
at their luminal pole consists of a complex of
highly specialized structures which provide attach-
ment (5-7) and communication (10) between cells.
This junctional complex includes the zonula oc-
cludens, the underlying zonula adherens and, at
intervals, the subjacent macula adherens or desmo-
some. Although this complex of fine structures
occurs very generally as the structural basis for the
joining of epithelial cells at their apices (5-7, 10),
little is known about the origin or maintenance of
its components. Ultrastructural examination of a
series of human skin biopsies has disclosed in the
secretory coil of the sweat gland a cytoplasmic
body which differs from recognized organelles of
this (1-4, 8, 9, 11-13) or other sites (6). As will be
described, the characteristic location and fine
structural features of this body and its related
structures suggest a relationship to the biogenesis
of the zonula adherens of the junctional complex.

MATERIALS AND METHODS
Small skin ellipses taken from the margin of abdomi-
nal or thoracic incisions of eight patients at the time
of surgery were processed for examination by routine
procedures. Specimens were fixed 90 min in cacody-
late-buffered 6.25% glutaraldehyde, postfixed 60
min in collidine-buffered 2% osmium tetroxide,
dehydrated through graded alcohols, and embedded
in Epon. Thin sections, unstained or stained with
uranyl acetate followed by lead citrate, were exam-
ined in an AEI-EM6B or Hitachi HS-8-1 electron
microscope.

RESULTS
The ultrastructural features previously described
for the secretory coil of the sweat gland (1-4, 8, 9,
11-13) were observed in specimens examined in
this study. In addition, a majority of the biopsies
revealed an occasional cytoplasmic body which
differed from the known structures of the secretory
coil. Profiles of this body as a rule lay in close
proximity to or in contact with the zonula adherens
of a junctional complex at the intercellular canaliculus (Figs. 1-4); and approximately 5% of
the intercellular canaliculi revealed such a body.
Because of its characteristic location, the body is
referred to as the junctional complex associated
(JCA) body.

All of the JCA bodies observed were in the
secretory coil and many were in definitely identi-
fied clear cells. None occurred in cells which con-
tained secretory granules and, accordingly, could
be identified with certainty as dark cells. One cell
contained bundles of microfilaments near a JCA
body. This cell, however, lacked secretory granules
and thus could not be identified positively as a
dark cell since bundles of microfilaments, a promi-

ent feature of dark cells, occasionally occur in
clear cells.

One to several profiles of endoplasmic reticulum
characteristically bordered the JCA body, con-
forming to a large portion of its surface at a close
and constant distance, but never intervening be-
tween the body and the associated junctional
complex or canalicular plasmalemma (Figs. 1-4). Some profiles of JCA bodies were fully encircled by
cisternae of endoplasmic reticulum, whereas other
profiles, apparently because of the plane of section,
disclosed few or no such cisternae in their immedi-
ate vicinity. The endoplasmic reticulum envelop-
ing the body often consisted of one to several
elongated and collapsed segments (Figs. 1, 2) or a
chain of closely approximated small round units
(Fig. 4) or both long, flattened and short, round
segments.

Ribosomes adhered to a variable portion of
cisternae neighboring JCA bodies but were gen-
erally bound only to the cisternal membrane distal
to the body (Figs. 1-4). The membrane proximal
to the JCA body in ergastoplasmic cisternae bor-
dering these bodies lacked ribosomes and often
appeared thicker than the opposite ribosome-
studded membrane (Figs. 1-4). Frequently, free
ribosomes also neighbored some portions of the
membrane distal to the body in areas where bound
ribosomes were either present or lacking (Figs. 1,
2, 4). Small profiles of granular reticulum often
lay randomly oriented at a slight distance from the
reticulum conforming to the surface of the JCA.
These figures illustrate junctional complex associated (JCA) bodies at the intercellular canaliculus in clear cells of the secretory coil. The specimens were fixed with a glutaraldehyde-osmium tetroxide sequence, and the thin sections were stained with uranyl acetate followed by lead citrate.

**Figure 1** A JCA body and the zonula adherens of a junctional complex appear almost continuous and consist of similar material. Numerous ribosomes lie near or attached to flattened profiles of endoplasmic reticulum conforming closely to the surface of the body. The ribosomes are distributed only on or near the side of the reticulum opposite the body. They are bordered on the right by a mitochondrion. The JCA body also borders the intercellular canaliculus (IC) closely. × 36,650.

**Figure 2** A JCA body like that of Fig. 1 and its related structures are illustrated at two planes. In Fig. 2a, continuity between cytoplasm and the discrete area of similar low density in the JCA body (arrow) suggests that the dielectronic areas in the bodies represent invaginations of ground cytoplasm. × 15,750. In Fig. 2b, from an adjacent section, the discrete focus of lower density in the JCA body lacks continuity with the cytoplasm. × 12,900.

body, and ribosomes on this reticulum often appeared to exceed in size those on the reticulum adjacent to the body (Figs. 1, 4).

One to several mitochondria commonly lay close to or in contact with the agranular and granular reticulum and associated ribosomes on the aspect farthest removed from the JCA body (Figs. 1–4). Mitochondria also often bordered the small profiles of granular reticulum lateral to that marginating the body.

Profiles of the JCA bodies varied somewhat in contour but were usually round or ellipsoid (Figs. 1, 2, 4). A flattened region of the surface, on occasion, coincided with a nearby intercellular canaliculus, ergastoplasmic cisterna, or zonula adherens (Fig. 3b). Infrequent bodies disclosed a contour heavily indented by cytoplasm which enclosed several membrane-limited vesicles (Fig. 3a).

The bodies varied also in size, in part at least according to the plane of section. The largest, 30% of all the bodies observed near the intercellular canaliculus, measured, on the average, 1.39 µ in length and 1.15 µ in width. This group presumably included those most nearly sectioned in an equatorial plane.

The JCA bodies lacked a limiting membrane. Their periphery was sharply delimited from the cytoplasm, however, at a regular boundary which was occasionally interrupted by surface projections. Viewed in either stained or unstained thin sections, the JCA body consisted mostly of uniform material with the same high electron opacity and fine grainy texture as that in the cytoplasmic densification comprising the lateral part of the zonula adherens of the junctional complex. Except for the zonula occludens and desmosomes of the junctional complex and the dense type of lipoid body (12), the JCA body and zonula adherens comprised the sites of greatest inherent density in clear cells in stained or unstained thin sections.

The homogeneous dense material constituting
FIGURE 3  A single JCA body is shown at four levels. Proceeding from Figs. 3 a–3 d, the body becomes more closely associated with a zonula adherens on the left in Fig. 3 b, appears midway between this and a zonula on the right in Fig. 3 c, and fuses with the right hand zonula in Fig. 3 d. Endoplasmic reticulum, marginated in areas by bound and free ribosomes, borders the surface of the body not adjacent to the zonula; and mitochondria lie slightly more peripherally. The largest discrete area of lower density in the body in Fig. 3 b is probably continuous with that which in Fig. 3 a represents an indentation from the cytoplasm. The cytoplasm indenting the body encloses a small vesicle. × 17,500.

FIGURE 4  A JCA body illustrated at two planes of sectioning does not appear to have a relationship with a junctional complex in Fig. 4 a, but at the level of Fig. 4 b it borders a zonula adherens. At either level, a chain of closely approximated segments of endoplasmic reticulum closely marginates the surface of the body distal to the canaliculus and zonula. Small profiles of granular reticulum (arrow), amid the free ribosomes near the reticulum which conforms to the JCA body, possess larger ribosomes than those on the latter cisternae. Fig. 4 a, × 17,500. Fig. 4 b, × 23,750.
the major portion of the JCA body commonly
enclosed one to several, sharply delimited foci with
a density and structure comparable to that of
surrounding cytoplasm (Figs. 1–4). These dielec-
tronic foci varied widely in size, were usually
round, and sometimes enclosed a more dense core,
moderately dense small particles, or crystal-like
rods. In occasional profiles cytoplasm extended
into an invagination of the surface of the body
(Figs. 2, 3 a), suggesting that the discrete, trans-
lucent foci in JCA bodies represent cytoplasmic
invaginations which probably are continuous with
the cytoplasm or may have become pinched off
and separated from cytoplasm.

DISCUSSION

The JCA bodies differ in their location, lack of a
limiting membrane, and internal structure from
familiar cytoplasmic dense bodies of the sweat
gland such as the secretory granules of dark cells
(1–4, 8, 9, 11, and 12) or the small acid phospha-
tase–positive (13) lysosomal bodies present in both
dark and clear cells of the coil and in duct cells.
Since bodies with these characteristics have not to
our knowledge been encountered previously, their
physiological significance is not understood. Con-
finement of the JCA body to the region of the
intercellular canaliculus or apical plasmalemma
suggests that its function might relate to activities
presumed to occur at the membrane of the cana-
lliculus or lumen, such as transport of fluid and
electrolytes.

However, a number of observations point more
precisely to a morphological and, presumably, also
a functional relationship between the JCA body
and the zonula adherens of the junctional complex.
For example, the observed JCA bodies often con-
tacted the zonula adherens broadly, bordered it
closely, or lay connected to it across a short dis-
tance by material of similar morphological charac-
ter. This spatial association, along with the striking
similarity in density and texture between the JCA
body and the dense periphery of the zonula ad-
herens in both stained and unstained thin sections,
is consistent with the possibility that the JCA body
contributes material to the lateral part of the
zonula, functioning in its biosynthesis or replenish-
ment. Notably, when a moderate distance sepa-
rated the body from the zonula, only filamentous
cytoplasm with no organelles intervened between
the two structures; and endoplasmic reticulum
bordering the body invariably lay on the side away

from the zonula. It also appeared that the lateral
region of zonulae adjacent to a JCA body often
was depleted relative to that in other zonulae (Figs.
2, 3).

Both the JCA body and the zonula adherens
represent relatively unique cytoplasmic structures
in that they consist of material which remains
discretely aggregated without an intervening mem-
brane to prevent its diffusion into surrounding
hyaloplasm. The interface between the JCA body
and cytoplasm accordingly resembles that between
the zonula adherens and cytoplasm. The content
of the zonula adherens in these sweat gland speci-
mens did not have the filamentous structure which
characterizes the comparable region of the desmo-
some and which, presumably, is anchored to the
cell membrane. Instead, the cohesiveness of the
JCA body and zonula adherens might reflect a
gel-like concentration of protein which is non-
diffusible because of extensive cross linking be-
tween protein chains rather than linkage to an-
other structure. In its sharp membraneless border
with less electron-opaque ground cytoplasm and
its invagination by the latter, the JCA body re-
sembles rather closely the nucleolus in its relation
to nucleoplasm.

The JCA body generally occurred not as a
single isolated entity but rather as part of a discrete
cytoplasmic complex which also included inti-
mately associated cisternae of endoplasmic retici-
ulum, free and bound ribosomes, and mitochondria.
This association of organelles raises a question
whether the granular reticulum of the complex
might function in biosynthesis of protein compris-
ing the JCA body. Such a process would constitute
an exception to the general view of rough endo-
plasmic reticulum as an organelle for synthesis of
protein for export. Protein delimited by the cis-
ternal membrane presumably would reach the
JCA body only through dissolution or disruption
of the agranular membrane proximal to the body,
unless the membrane had unusual permeability.
Alternatively, the free ribosomes commonly found
in the vicinity of the JCA bodies could serve pri-
marily in the synthesis of protein for the body, in
which case the association of the JCA bodies with
profiles of endoplasmic reticulum and the frequent
interposition of the reticulum between the body
and the free ribosomes remain unexplained. The
juxtaposition of mitochondria with the reticulum
enveloping or neighboring JCA bodies suggests a
functional relationship and possibly implicates

BRIEF NOTES  585
these mitochondria as a source of energy or metabolites for biosynthetic reactions of the reticulum.

A problem in proposing a developmental or functional relationship between JCA bodies and the zonula adherens is that many junctional complexes lacked associated bodies, and some of the bodies were not near a zonula adherens. The former probably reflects a low incidence of these bodies at the canaliculus, and the latter can be attributed to the plane of section sometimes missing either body or canaliculus. Indeed, some bodies unassociated with a junctional complex at one plane of section have been found to lie near or contact a complex at another (Figs. 3, 4).

SUMMARY

A unique cytoplasmic body in the secretory coil of the human sweat gland is described. This body has been observed in the clear cells but has not been found in dark cells. The organelle is designated the junctional complex associated (JCA) body, in reference to its close proximity to or contact with the zonula adherens of the junctional complex. Profiles of granular and agranular reticulum and free ribosomes consistently border a variable part of the surface of the JCA body facing away from the canaliculus or junctional complex; and a few mitochondria usually lie near these cisternae. JCA bodies generally exhibit a round or elongated contour; although lacking a limiting membrane, they have a sharp even border. The dense, principal component of the bodies has a density and texture like that of the material in the lateral part of the zonula adherens and encloses less dense foci, which apparently represent cytoplasmic invaginations.

The authors are grateful to Mr. J. P. Reynolds, Miss N. J. Wright, and Mrs. N. T. Thompson for skilled technical assistance.

This research was supported by National Institutes of Health Grants AM-10956 and AM-11028 and a grant from the National Cystic Fibrosis Foundation.

Received for publication 11 November 1971, and in revised form 14 January 1972.

REFERENCES

1. Charles, A. 1960. An electron microscope study of the eccrine sweat gland. J. Invest. Dermatol. 34:281.
2. Dobson, R. L. 1962. The correlation of structure and function in the human eccrine sweat gland. In Advances in Biology of Skin. W. Montagna, R. A. Ellis, and A. F. Silver, editors. Pergamon Press, Inc., Elmsford, New York. 4:54.
3. Ellis, R. A. 1962. The fine structure of eccrine sweat glands. In Advances in Biology of Skin. W. Montagna, R. A. Ellis, and A. F. Silver, editors. Pergamon Press, Inc., Elmsford, New York. 3:30.
4. Ellis, R. A. 1967. Eccrine, sebaceous and apocrine glands. In Ultrastructure of Normal and Abnormal Skin. A. S. Zelickson, editor. Lea & Febiger, Philadelphia. 132.
5. Farquhar, M. G., and G. E. Palade. 1963. Junctional complexes in various epithelia. J. Cell Biol. 17:373.
6. Fawcett, D. W. 1966. An Atlas of fine structure. In The Cell, its Organelles and Inclusions. W. B. Saunders Company, Philadelphia.
7. Fawcett, D. W. 1958. Structural specializations of the cell surface. In Frontiers in Cytology. S. L. Palay, editor. Yale University Press, New Haven. 19.
8. Hibbs, R. G. 1958. The fine structure of human eccrine sweat glands. Amer. J. Anat. 103:201.
9. Kurosuni, K., T. Kitamura, and K. Kano. 1960. Electron microscopy of the human eccrine sweat gland from an aged individual. Arch. Histol. Jpn. 20:253.
10. Lorwenstein, W. R. 1966. Permeability of membrane junctions. Ann. N. Y. Acad. Sci. 137:444.
11. Munger, B. L. 1961. The ultrastructure and histophysiology of human eccrine sweat glands. J. Biophys. Biochem. Cytol. 1:135.
12. Spicer, S. S., and W. H. Prioleau, Jr. 1971. Ultrastructure of lipid inclusions and dense bodies in the human eccrine sweat gland. In press.
13. Spicer, S. S., and Prioleau, W. H., Jr. 1971. The cytochemistry of lipid and acid phosphatase in the human eccrine sweat gland. In press.

*