nitic shells may be more advantageous to free-moving bivalves, because aragonite is harder, has greater strength as a structural material, and is less prone to breakage by cleaving than calcite. On the other hand, calcitic shells may be more advantageous to bivalves permanently immobilized in certain environments, because calcite is more stable and much less subject to leaching in the sea water and because calcite can be secreted more economically than aragonite. Secreted calcite fills a larger volume per mole than aragonite. Adult oysters need a thick shell for defense against predators.

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Femoral Expansion in Aging Women: Implications for Osteoporosis and Fractures

Abstract. *In femoral radiographs of 2030 aging women, the diameter of the midshaft periosteum increased as cortical thickness declined. Since the cortical area enlarged, periosteal accretion exceeded endosteal resorption. Since the section modulus increased more than did cortical area, the ratio of flexural failure resistance to crush resistance increased, in apparent contrast to the changes observed in the femoral neck.*

The great extent to which the human skeleton involutes with age is apparent in the high incidence of spontaneous vertebral and femoral fractures in elderly women. In studying the correlation between vertebral and femoral atrophy we obtained unexpected results in respect to femoral dimensions. These results are reported briefly here.

Standard anteroposterior radiographs of femurs were obtained in a study of 2030 women, aged 45 to 90 years. All were ambulatory outpatients or hospital personnel; none had skeletal disease and each entered the survey voluntarily. Cortical thickness and the periosteal diameter of the left femur were measured with a transparent plastic rule. Measurements to the nearest 0.5 mm were made at the point along the shaft where, in the anteroposterior projection, cortical thickness is maximal and femoral diameter is minimal. This position, roughly pear-shape in cross-section, approximates the mid-shaft (*1*) and corresponds closely to section 40 of Koch (*2*). Cortical thickness, as used here, represents the sum of the two projected cortices. To test the reliability of the measurements, 50 replicate readings of randomly selected radiographs were made 9 months apart, the sites for measurement being reselected. Reliability for cortical thickness was 0.93 and for diameter, 0.93.

Table 1. Dimensions and calculated derivatives for the femoral midshafts of subjects in different age groups.

Age group	Observed data: No. of subjects (2030)	Observed data: Periosteal diameter† (mm)	Observed data: Cortical thickness† (mm)	Calculated data*: Endosteal diameter (mm)	Calculated data*: Cross-section cortical area (mm^2)	Calculated data*: Section modulus (mm^3)
45–49	286	31.32 ±0.15	18.67 ±0.17	12.65	644	2935
50–54	303	31.60 ±0.15	18.69 ±0.14	12.91	653	3010
55–59	501	31.86 ±0.13	18.17 ±0.12	13.69	652	3065
60–64	424	32.12 ±0.14	17.96 ±0.14	14.16	653	3129
65–69	291	32.85 ±0.16	18.08 ±0.16	14.77	678	3336
70–74	162	33.03 ±0.23	17.32 ±0.22	15.71	661	3355
75–90	63	34.74 ±0.32	17.68 ±0.37	17.06	718	3875

* Based on group means of observed data. † Mean ± standard error.

The difference between the periosteal diameter and cortical thickness was recorded as the inner or endosteal diameter. Cross-sectional cortical areas were calculated from equation $\pi/4(2cd - c^2)$ where c is cortical thickness, d is periosteal diameter, and section shape is assumed to be circular. As a measure of bone volume, the cortical area is a determinant of resistance to longitudinal compression forces (stress equals force divided by area). To obtain a rough index of resistance to flexural failure, section moduli were calculated from the equation

$$Z = \frac{\pi}{2} \times \frac{\left[\frac{d}{2}\right]^4 - \left[\frac{d-c}{2}\right]^4}{d}$$

by appropropriate substitution of c and d for R_1 and R_2, the outer and inner radii of a tubular structure, in the conventional equation

$$Z = \frac{I}{Y_{max}} \text{ or } \frac{\pi}{4} \times \frac{R_1^4 - R_2^4}{R_1}$$

where Z is the section modulus or measure of applied bending moment required to gain a given level of stress in outermost fibers, I is the area moment of inertia, and Y_{max} is the distance of maximal stress from the neutral line. Chemical composition, porosity, and microstructure were assumed to be similar in all age groups. Cross-sectional areas and section moduli were calculated with mean measurement values for 5-year age groups; the percentages of change were computed, the data of the 45 to 49 age group being used as reference.

As shown in Table 1, the mean periosteal diameter increased successively by 0.2 to 0.3 mm per 5 years through age group 60 to 64, then by increments of 0.7, 0.2, and 1.7 mm to an overall 3.4 mm gain. Changes in cortical thickness were less, with reductions of 1.4 and 1.0 mm for the two oldest groups. By variance analyses of all data, the p value was $<< .001$ both for diameter and for cortex. Since periosteal diameter increased and cortical thickness decreased, endosteal diameter expanded faster with a gain of 4.4 mm (35 percent) between the youngest and oldest groups. These progressive increases in diameters result in similar gains in theoretical surface areas, 11 percent for periosteal and 35 for endosteal. In addition, an overall gain of 74 mm^2 in cortical area was found to be the net result of 177 mm having been added periosteally while 103 mm were resorbed endosteally. Expressed as rates, the outer accretion of femoral bone was 1.7 times faster than inner resorption. Finally, from gains in periosteal diameter and cortical area, the section modulus increased progressively, totaling 32 percent for the oldest femurs.

These observations are pertinent to the causality and effects of osteoporosis which is evidenced so commonly in

women beyond middle life by vertebral and femoral fractures. The fractures appear to result from an age-related loss of bone mass, judged from the well-known reductions in cortical and trabecular thickness and from decreasing femoral density (total weight divided by total volume) (*3*). Reductions in mass of 25 to 50 percent have been estimated for osteoporotic spines of women in whom rates of calcium accretion have been found normal (*4*). To explain this discrepancy, increased resorption rates have been proposed (*4*), but seemingly relevant is our evidence in "averaged" aging femurs that remodeling occurs without apparent net loss of compact bone and that theoretical surface areas substantially increase. From the youngest to oldest groups, vertebral osteoporosis of significant degree increased from 19 to 90 percent (*5*). Thus, from mean data only, femurs of largest diameter and surface areas were found in the group with highest incidence of significant vertebral atrophy.

Our measurements were made at the section where the transverse diameter, although minimal, is less than the anteroposterior diameter which is enhanced by the prominent linea aspera. Dimensional changes of similar type and magnitude would not be expected in other sections of the femur with different stress-structural relationships. Indeed, as shown in Table 2, the increases in diameter with age were less at sections above midshaft, 1.8 mm at the section (circular) just below the lesser trochanter [section 24 of Koch (*2*)] and only 0.9 mm at the femoral neck section of minimal diameter.

This suggests that flexural stress with bowing, which is maximal at about midshaft, activates the periosteal accretion of bone. Meanwhile the trabeculated, nontubular and, thus, more rigid femoral neck undergoes a proportionately smaller increase with age. For older femurs at midshaft, gains in section moduli mean increased resistance to flexural forces. This has more significance for subjects in whom skeletal ingredients are diminished, since the resistance of the shaft to flexure can be maintained even with less bone provided it has been remodeled into a cortex of larger diameter.

However, this entire osteoporotic femur will bow less and store less elastic energy. With resistance to flexural forces being decreased in the neck relative to the shaft, the femoral neck becomes the most vulnerable site for fracture. Similarly, trabeculated, nontubular, rigid vertebrae become prone in later life to compression fractures from minimal flexural forces since there is no compensatory increase in vertebral diameter with age (*5*).

We have not shown that all femurs participate similarly in structural remodeling which, since mean data only are presented, could represent either a progressively differing population sampled for successive age groups or an increasing rate of "dropping out" of women with smaller femoral diameters. However, these two explanations seem untenable since the diameters of both the metacarpal and lumbar vertebrae remained constant despite significant cortical thinning (*5*). Whereas the mean diameters of adult radii are unchanged with age (*6*), rib diameters increase (*7*). If changes in the tibia and fibula are also found to parallel those of the femur, they may reflect a progressive adaptation to the erect state in which flexural and longitudinal compression forces on leg bones from lifelong weight-bearing decline proportionately less than do predominantly flexural forces on the arms and predominantly compression forces on the spine.

Table 2. Periosteal diameter of femurs at three sites. The subjects were selected at random from the oldest and the youngest groups.

Age group	No. of subjects	Periosteal diameter (mm)*		
		Midshaft	Subtrochanter†	Femoral neck‡
45–49	30	31.03 ±0.50	34.20 ±0.52	35.91 ±0.42
75–90	30	34.63 ±0.39	35.95 ±0.35	36.85 ±0.39
Increase		3.60	1.75	0.94
P		<.001	<.01	<.10

* Mean ± standard error. † Lesser; section 24 of Koch (*2*). ‡ At section of smallest diameter.

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Identification of Acetylcholine in Sympathetic Ganglia by Chemical and Physical Methods

Abstract. *Extracts of sympathetic ganglionic chains contain a substance which behaves like acetylcholine biologically, chromatographically, and electrophoretically. The melting point of the tetrachloroaurate salt of this substance is identical to that of acetylcholine tetrachloroaurate. No other choline esters have been detected in these extracts. Perfusion of sympathetic ganglia with C^{14}-choline indicates that C^{14}-acetylcholine is released.*

Acetylcholine was the first choline ester isolated from natural sources (*1*). More recently, a number of choline esters have been found in animal tissues (*2*). The choline ester in sympathetic paravertebral ganglionic chains is thought to be acetylcholine (*3*). This hypothesis is based on results obtained with nonspecific chemical tests, bioassay procedures, and classical pharmacological tests. In the investigation described here, more definitive techniques