A previous article1 showed that the observations on which Starling based his famous paper were first made by François-Frank in 1877, corroborated and extended by Otto Frank's massive presentation in 1895 (subscribers to German journals were promised a fixed number of pages per year), and put into the form later called Starling's Law by Yandell Henderson of Yale in 1906. Starling's famous 1918 paper referred only to Otto Frank, and, of course, to his own fragmentary data.

The Law, as first promulgated, stated that muscle-fiber length determined the work of a muscle. But who can measure muscle fiber length in intact muscles, especially in a syncytium like the myocardium? Accordingly, the heart volume was taken as the index of muscle-fiber length, and Henderson used his outstanding competence in inventing gadgets to perfect a dog cardiac plethysmograph. François-Frank, 30 years earlier, had used a plethysmograph to study heart action in a patient with congenital absence of the pericardium, but of course, widespread use of this kind of device in man in vivo was impossible. Hence, the next step was taken which was to ignore measuring fiber length and heart volume and to state that the Law could be studied by measuring the ventricle filling pressure and its work, the latter usually measured by the intraventricular pressure.

From these fragmentary and tangential materials, a concept was created that was to influence the thinking of cardiac physiologists and some clinicians to a remarkable degree. This occurred despite the fact that, as reviewed elsewhere,1 the next half century saw the publication of voluminous data in relatively intact animals, and in man, all of which showed that the mechanisms of Starling's Law were not detectable except perhaps in denervated hearts.

Since that time, clinical studies in man have shown that the Starling mechanisms cannot explain the work of the heart in fever,4 in hemorrhagic shock,5 or in exercise in normal men.6,3 The Starling mechanisms may perhaps be detected in exercising patients with coronary artery disease.7 In patients with transplanted hearts, the organ is denervated, and according to earlier work,1 might be expected to show the action of Starling's Law. However, in such patients, the Starling mechanisms are detectable only early in exercise.6 In conscious intact dogs, the operation of Starling's Law is not detectable, according to the remarkable studies carried out in Vatner's laboratory.7

In what seemed to be a despairing effort to establish the validity of the Law, Sarnoff8 declared that there was no single curve to express the Law in any heart, but that there were families of curves that revealed its action. However, his view actually showed that what seemed to be the Law was really groups of phenomena that reflected the vasomotor state of the circulation as a whole and not the state of the myocardium. The filling of the ventricle is greatly influenced by the capacitance of the total vascular bed, and this is governed in large measure by the degree of generalized venous contraction.9 If anything, the existence of Sarnoff's 'families of curves' shows negligible importance, if any, of the Starling mechanisms of defining ventricular studies in any but isolated hearts.

Some comments by Louis Katz, that wise old physiologist of another day, are pertinent here. One comment, included in a paper on another matter, is admirable not only for its wisdom, but also for its wide applicability.10 He said,

Such factors as the rate and degree of ventricular filling, the variable effect of atrial systole, the time interval available for ventricular filling, coronary blood supply, humoral agents and neural impulses, etc, modify the interpretation of the Starling school that end-diastolic volume is the primary factor affecting cardiac output . . . Extensive discussion has recently delineated the role of a number of factors, other than the end-diastolic volume, in the intact open-chested animal and the completely intact animal—viz, the afterload against which the heart contracts, the neurogenic and humoral stimuli controlling the contractile power of the heart, the diastolic tone, the filling pressure, the filling time, the systolic pressure, etc. These, as well as the previously mentioned factors, modify significantly the application of the Starling relationship.

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444 Reflections on Starling's Laws of the Heart (Mark D. Altschule)
These gentle rebukes, expressed in the words of an earlier era, make it unjustifiable for Starling's Law of the Heart to be used in clinical medicine and in any but a very few physiologic research projects. This conclusion is supported by the fact that no studies in man, sick or well, have ever revealed the entire right half of the standard Starling curve. Thus, the Starling curve exists only in the imagination of certain authors, or pictured in the pages of theoretical discussions of cardiac physiology, which amounts to the same thing.

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