

Among the effects of friction, we may notice the standing of a stone arch. For each of the vaulting stones of an arch is a truncated wedge; and though a collection of such stones might be so proportioned in their weights as to balance exactly, yet this balance would be a tottering equilibrium, which the slightest shock would throw down, and which would not practically subsist. But the friction of the vaulting stones against one another prevents this instability from being a practical inconvenience; and makes an equilibrated arch to be an arch strong for practical purposes. The *Theory of Arches* is a portion of Mechanics which has been much cultivated, and which has led to conclusions of practical use, as well as of theoretical beauty.

I have already spoken of the invention of the Arch, the Dome, and Groined Vaulting, as marked steps in building. In all these cases the invention was devised by practical builders; and mechanical theory, though it can afterwards justify these structures, did not originally suggest them. They are not part of the result, nor even of the application of theory, but only of its exemplification. The authors of all these inventions are unknown; and the inventions themselves may be regarded as a part of the Prelude of the science of mechanics, because they indicate that the ideas of mechanical pressure and support, in various forms, are acquiring clearness and fixity.

In this point of view, I spoke (Book iv. chap. v. sect. 5) of the Architecture of the Middle Ages as indicating a progress of thought which led men towards the formation of Statics as a science.

As particular instances of the operation of such ideas, we have the *Flying Buttresses* which support stone vaults; and especially, as already noted, the various contrivances by which stone vaults are made to intersect one another, so as to cover a complex pillared space below with *Groined Vaulting*. This invention, executed as it was by the builders of the twelfth and succeeding centuries, is the most remarkable advance in the mechanics of building, after the invention of the *Arch* itself.

It is curious that it has been the fortune of our times, among its many inventions, to have produced one in this department, of which we may say that it is the most remarkable step in the mechanics of arches which has been made since the introduction of pointed groined vaults. I speak of what are called *Skew Arches*, in which the courses of stone or brick of which the bridge is built run obliquely to the walls of the bridge. Such bridges have become very common in the works of railroads; for they save space and material, and the inven-