The rat anococcygeus muscle and its response to nerve stimulation and to some drugs

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Commentary by

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Few discoveries in science are without antecedents and even fewer scientists have the opportunity to describe these given the pressure on publication space.. An opportunity such as this is sheer indulgence!

In the discovery of the anococcygeus the first step was take by a young research worker, Vernon Rayner, who came to work with me after a spell in Makerere University. I asked him to see if he could identify the internal anal sphincter in the rat by taking successive rings from the terminal colon and testing the response to various drugs particularly noradrenaline on the assumption that the inhibitory response would be reversed to motor. He did find reversal though not consistently, but I do remember him saying that he believed he could identify the region because of a thickening of the colon wall. In retrospect what he was describing was the ventral fusion of the two anococcygeus muscles close to the anus and their motor response to noradrenaline. Vernon moved on and the next visitor was a young doctor with an interest in gastroenterology, Gavin Maxwell. At that time I was investing considerable effort in the Falck and Hillarp fluorescent histochemical demonstration of noradrenaline and suggested Maxwell should look at the pylorus, the ileocolic junction and the terminal colon to see if he could identify the sphincteric regions by the presence of noradrenergic nerves in the circular muscle layers. This he did and described sharply-limited regions of adrenergic innervation in the pylorus and in the terminal colon. Closer examination however showed that while the nerves in the pylorus were indeed in the circular muscle, in the colon the innervated tissue was not only outside the circular muscle but outside the serosa. With this information, dissection of a rat revealed the twin anococcygeal muscles running on each side of the colon then joining in front of the colon just short of the anus. I still remember the satisfaction of that day's dissection. Sadly I did not identify the muscle with the retractor penis in other species. The long intrapelvic length of the anococcygeus, its close association with the anal region of the colon and its presence in both male and female mislead me into thinking of a funtion in the terminal colon. What was even less excusable was my ignorance of the work on the retractor penis by Langley and others early in this century.. In 1895 and 1896, Langley and Anderson published a brilliant description of the autonomic innervation of the pelvic viscera. Indeed in my PhD thesis in 1955 I included, with acknowlegments, their illustration of the arrangements in the rabbit. To my chagrin when I looked at it many years later long after the publication of this article I found they had identified the anococcygeus, though calling it the caudo-anal muscle along with the adjacent caudo-cavernosus muscle. Though it is not clear from the text I believe from the names they used for these two muscles that they too imagined the function of the caudo-anal muscle to be with the alimentary canal and only the caudo-cavernosus muscle was associated with the penis. The beautiful work by Klinge and Sjöstrand beginning in 1974 on the retractor penis in many species finally established the correct link.

The paper reproduced here expressed the hope that the muscle would prove useful for both teaching and research. At the time this was based on biological features, parallel muscle fibres, little impediment to diffusion a useful receptor population and an interesting innervation. Today one more might be added, low cost. For older pharmacologists and physiologists it is a source of sadness that student 'hands-on' laboratory experience is steadily diminishing to be replaced by demonstrations and computer based "experiments". Excellent methods of learning, but no substitute for the experience of hand and eye which the laboratory provides. Perhaps the rat or mouse anococcygeus may offer a cheap and instructive continuation of direct personal experimental work.

In research, the most interesting outcome has been the identification of nitric oxide as a neurotransmitter in the peripheral autonomic nervous system. In this research chance has allowed me to finish my career with the solution to the problem with which it started. When I was a young research student Professor Robert Garry asked me to look at the variable responses of the stomach and colon to autonomic nerve stimulation which had been reported by many research workers particularly Langley and Anderson (1898) and Bayliss and Starling (1899). In the cat stomach vagal stimulation usually caused contraction, but if muscle tone was high or high frequencies of stimulation used, this was reversed to relaxation. We studied an *in vitro* preparation of the rabbit colon in which both sympathetic and parasympathetic nerves could be separately stimulated. We were unable to demonstrate reversal under any circumstances but did find a difference in frequency-sensitivity of the two outflows so that if the two were simultaneously stimulated motor, inhibitor or mixed responses could be produced. Our rather dull conclusions were that previous investigators had probably stimulated a mixture of sympathetic and parasympathetic fibres. If we had but tried the immediately adjacent smooth muscle, Langley's caudo-anal, our results and conclusions would have been so different. Twenty years later the rat anococcygeus provided just that opportunity though it took another fifteen years before we and Mike Rand's group in Melbourne were able, independently, to provide the evidence for the involvement of nitric oxide.

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