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# This Week's Citation Classic™

**Reinert J.** Über die Kontrolle der Morphogenese und die Induktion von Adventivembryonen an Gewebekulturen aus Karotten. (The control of morphogenesis and induction of adventitious embryos in cell cultures of carrots.) *Planta* 53:318-33, 1959.
[Botanisches Institut, Universität Tübingen, Federal Republic of Germany]

Somatic carrot cell cultures were induced to form embryos on chemically defined nutrients. This 'embryogenesis *in vitro*' could be controlled by manipulation of the medium. The developmental sequence deduced from proembryonal and embryonal stages in the cultures was strikingly like that of fertilized egg cells. [The *SCI*® indicates that this paper has been cited in over 105 publications since 1959.]

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"In 1953, Philipp R. White at Bar Harbor, Maine, invited me to develop chemically defined nutrient media for 'tissue,' i.e., callus cultures, of tumorous and normal conifers. This project was finished after two years. During the work with the conifers, it occurred to me that *in vitro* cultures might be excellently suited for investigations on differentiation and development, provided they could be induced to regenerate organs or even complete plantlets. The environment of such material (nutrient medium, light, temperature, etc.) could be strictly controlled and their system for differentiation presumably would be less complex because they were separated from correlations and interactions with intact plants.

"On this theoretical basis, in 1955 I began a study with carrot cultures growing for years on a medium with a chemically undefined component, namely, coconut milk (KOM). These carrot cells had lost the ability to form shoots and rather irregularly regenerated roots only. It was my intention to induce and to control shoot regeneration with this material on a chemically defined medium.

"Soon it turned out that KOM could be replaced by various nitrogenous compounds and the use of a plant hormone which was rather stable *in vivo*. The second step, the transfer to hormone-free medium, even resulted in the formation of obviously normal plantlets. But to my surprise, these plantlets derived from normal, bipolar embryos, formed in a developmental sequence with proembryonal, globular, and other stages almost like embryo development occurring after the fertilization of egg cells.

"This was confirmed repeatedly at my laboratory without difficulty. However, it took several years before the same events—'embryogenesis *in vitro*' as I had termed it—could be induced by other workers[1] in cells of wild carrot.

"This marked the beginning of a series of publications proving that the capacity for embryogenesis *in vitro* by somatic cells, by cells regenerated from protoplasts, and even by haploid pollen cells is distributed in widely differing plant families. It has to be mentioned that the observations on the embryogenesis by somatic carrot cells had been published partly already in 1958,[2] but it was the paper in *Planta* which became better known.

"There are several reasons that the paper was cited. It proved clearly for the first time the occurrence of embryogenesis *in vitro* and its control in long-term cultures. This was not only of interest for a restricted sector of the work on 'tissue' cultures but also in connection with the idea of totipotency, i.e., the postulated ability of single cells of higher plants to develop into a pluricellular organism. We later proved that directly by photography.[3] In addition, somatic embryos became a valuable tool in genetics, plant breeding, and the propagation of economic plants. This, to my feeling, constitutes a fine demonstration of the interdependence of basic and applied research."

1. **Halperin W & Wetherell D F.** Adventive embryony in tissue cultures of the wild carrot, Daucus carota. *Amer. J. Bot.* 51:274-83, 1964. (Cited 120 times.)
2. **Reinert J.** Untersuchungen über die Morphogenese an Gewebekulturen. *Ber. Deut. Bot. Ges.* 71:15, 1958. (Cited 25 times since 1958.)
3. **Reinert J, Backs-Hüsemann D & Zerban H.** Determination of embryo and root formation in tissue cultures from Daucus carota. *Les cultures de tissus de plantes*. Paris: CNRS, 1971. p. 261-8.

 