



**Figure 1 | Engineering cytoplasmic male sterility with  $\beta$ -ketothiolase<sup>1</sup>.** **a**, In chloroplasts, acetyl-CoA, the substrate for the synthesis of fatty acids, is normally converted by acetyl-CoA carboxylase to yield malonyl-CoA. This pathway results in the correct development of anthers, pollen grains and seeds. **b**, In the transgenic chloroplasts,  $\beta$ -ketothiolase out-competes acetyl-CoA carboxylase for acetyl-CoA, with acetoacetyl-CoA being produced instead. The upshot is distorted anthers and failure of pollen development. Fertility in plants grown from the resulting hybrid seeds is restored under continuous illumination, with reversion to the normal pathway.

sterility. But the transgenic plants were otherwise unaffected.

So much for producing male sterility. How about restoring it? The hybrid seed itself is valuable for growing certain ornamental species, for example, or for producing vegetables. But in cases such as oilseed rape, sunflower or maize, where the crop germinates from the second-generation seed of the hybrid plants, fertility has to be restored.

In some plants, the nuclear genome overrides cytoplasmic male sterility to restore male function, but this process often works inefficiently and has deleterious effects on plant growth because it interferes with general metabolism and development<sup>4,5</sup>. In the case investigated by Ruiz and Daniell<sup>1</sup>, no nuclear-encoded restoring factor is involved. This is where the *psbA* promoter and associated regulatory elements come in, because they confer light-sensitivity on the gene they control<sup>6</sup>.

The authors hypothesized that, even though both acetyl-CoA carboxylase and  $\beta$ -ketothiolase are controlled by light-inducible promoters, under continuous illumination the carboxylase would gain the upper hand, so restoring normal fatty-acid synthesis and male fertility. That turned out to be the case, at least to some extent. When grown under continuous illumination for 10 days, a sample of transgenic plants produced four flowers with viable pollen, and in due course viable seed.

Genetic transformation of chloroplasts in the cytoplasm has several advantages over nuclear transgenic technologies<sup>7</sup>. Apart from transgene containment<sup>8-11</sup>, those advantages

include a comparatively high level of transgene expression, yielding proteins that are properly folded and fully functional; lack of side effects, such as stunting or other abnormalities<sup>12</sup>; and elimination of the laborious back-crossing that is needed with nuclear transformation to introduce cytoplasmic male sterility into elite plant lines. The new method is likely to be especially advantageous when applied to crop plants with longer generation times, such as cotton, maize and rice.

As to future research, it is not clear from Ruiz and Daniell's study how sterility was reversed by continuous illumination because the two competing enzymes are both light-regulated. That, then, is one aspect that calls for further investigation.

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## 50 YEARS AGO

"A caesium resonator" — A frequency standard based on the natural resonant frequency of the caesium atom has been constructed at the National Physical Laboratory and used for calibrating the quartz clock standards with an accuracy of  $\pm 1$  part in  $10^9$  (0.0001 sec. per day)... The resonance observed is that due to transitions between the hyperfine structure energy-levels caused by the interaction between the nuclear and electron spins... all the allowed transitions have been observed, and from measurements made under a variety of conditions the frequency of the central line and zero field was found to be  $9\,192\,631\,830 \pm 10$  c./s... The results reported here appear to be the first examples of the use of an atomic frequency standard with an accuracy greater than that obtained by using a unit of astronomical time. They also represent the highest accuracy ever achieved in the measurement of any physical quantity in terms of a definitive standard. L. Essen & J. V. L. Parry  
From *Nature* 13 August 1955.

## 100 YEARS AGO

"A Modern Utopia." By H. G. Wells. — It is instructive to watch the growth, both in power and in hopefulness, of Mr. Wells's criticism of life. In the "Time Machine" his forecast of the future of humanity was frankly appalling; in "When the Sleeper Wakes," more lurid (albeit far more probable) than the worst imaginings of "reforming" socialists... "Mankind in the Making" contained much vigorous criticism and many sensible and practical suggestions. In the present book Mr. Wells has become still more moderate and practicable and hopeful, without in the least derogating from his ingenuity and originality. We sincerely hope, therefore, he will not, as he threatens, stick henceforth to his "art or trade of imaginative writing," but will continue from time to time to regale and stimulate us with sociological speculations.  
From *Nature* 10 August 1905.

50 & 100 YEARS AGO