treated wild-strain trout were enhanced 2.7-fold, whereas domestic trout displayed a much more modest increase of only 9%. Cranial abnormalities and silver body coloration were also seen in only the hormone-treated animals from the domestic strain (Fig. 1d). The fact that domestic trout respond to the exogenous growth-hormone protein but not to *OnMTGH1* transgenesis suggests that 'stronger' gene constructs could be effective, although they might be associated with a higher incidence of abnormalities.

The effect of introducing a growth-hormone gene construct into fish to increase growth rates appears to be dependent on the degree to which earlier enhancement has been achieved by traditional genetic selection. Such effects are likely to be specific for different species, strains and transgenes — in selected mice or in domesticated, rapidly growing farm animals, for example, growth-hormone transgenesis can have little effect on growth or it can induce pathological effects[9,10], as we have seen in transgenic salmonids.

Depending on the genetic and physiological basis, not all gains made by selection are likely to be epistatic to the effects of growth-hormone transgenesis, and some might actually prime metabolic pathways to respond to endocrine stimulation. In partially domesticated coho salmon strains, we have observed that domestication and the *OnMTGH1* transgene can work synergistically in hybrid strains to increase overall growth (Fig. 1e). In contrast, growth-hormone constructs that work well in salmon may not work as well in species that grow rapidly[4]. The phenotypic and genetic character of the starting species or strain, as well as the strength of the gene construct, need to be considered when attempting to improve agricultural animal species.

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Cavitation science

Is there a simple theory of sonoluminescence?

An abiding issue in cavitation science is the focusing of energy by the collapse of a gas bubble in water. In particular, one would like to understand the origin of the flash of light ('sonoluminescence') that accompanies bubble collapse[1]. Hilgenfeldt *et al.*[2] have presented a simple explanation for this light emission, based on a hydrodynamic (Rayleigh–Plesset) analysis of bubble dynamics. Here we argue that their model is too simple, on the grounds that it cannot account for some well-established observations and that it involves the application of this hydrodynamic equation outside its range of validity.

Hilgenfeldt *et al.*[2] calculate the interior temperature of a collapsing gas bubble in water, T_g, from the Rayleigh–Plesset equation for the radius, $R(t)$, of a pulsating bubble:

$$R\ddot{R}+\frac{3}{2}\dot{R}^2=\frac{1}{\rho}(P_g-P_o-P_a)-\frac{4\eta\dot{R}}{\rho R}-\frac{2\sigma}{\rho R}+\frac{R}{\rho c}\frac{d}{dt}(P_g-P_a) \quad (1)$$

supplemented by adiabatic equations of state for the gas temperature T_g and pressure P_g inside a uniformly compressed bubble:

$$P_g(R)=\frac{P_0R_0^{3\gamma}}{(R^3-a^3)^\gamma};\qquad T_g(R)=\frac{T_0R_0^{3(\gamma-1)}}{(R^3-a^3)^{\gamma-1}} \quad (2)$$

where γ is the ratio of heat capacities C_p/C_V; a is the radius of the gas when compressed to its van der Waals hard core; and ρ, c, σ and η are the density, speed of sound, surface tension and viscosity of water. Equation (2) applies when the motion is sufficiently rapid, when $R \leqslant R_0$, the equilibrium radius. (For slow pulsations, $T_g \approx T_0$, the ambient temperature.) When an isolated bubble is trapped and driven by a sound field with amplitude $P_a(t)=P'_a\cos\omega_a t$, the bubble emits one flash of light with each cycle[3].

Although helium and xenon have very different physical properties, the similarity of their sonoluminescence constitutes a litmus test for theories. When dissolved in water at 3 torr partial pressure, these gases can form light-emitting bubbles with $R_0=4$ μm and a maximum radius of $R_m=30$ μm at 40 kHz driving frequency. Equations (1) and (2) yield a collapse temperature, T_c, of 17,500 K when the bubble has been compressed to a radius $R_c \approx a$. Light is emitted from this region, which is comparable in size to (or smaller than) the wavelength of the light.

According to standard formulae of plasma physics, the photon–matter interaction length is large compared to a (ref. 4). Therefore, the proposed spectrum[2,5] is not that of a black body, but bremsstrahlung from a thermally ionized plasma. At 17,500 K, the noble gases are only weakly ionized, and the radiation is approximately proportional to the square of the degree of ionization, $e^{-\chi/kT}$, where χ is the ionization potential (25 eV for helium and 12 eV for xenon). Thus, radiation from a uniform He bubble should be less than that from a Xe bubble by more than four orders of magnitude for electron–ion bremsstrahlung, and by two orders of magnitude for electron–neutral bremsstrahlung. But in fact, the observed emission from He is less than that from Xe by only about a factor of 3 (refs 1, 6) — a discrepancy between theory[2] and experiment of one to three orders of magnitude[7].

Another problem with Hilgenfeldt *et al.*'s model is that the theory encapsulated in equations (1) and (2) is applied in a limit where it is not valid[8]. For Rayleigh's equation to apply, the speed of the collapsing bubble wall, $\dot{R}$, must be small compared to the speed of sound in the gas, c_g (that is, the Mach number, $\epsilon \equiv \dot{R}/c_g$, must be much less than 1). But experiments show[1] that $\epsilon_g > 1$, undermining the assumption that the bubble's contents are uniformly compressed[2].

Although sonoluminescence is arguably nature's most nonlinear oscillator[9], equation (1) is derived using the linear wave equation to describe the motion of the water. Photographs of high-Mach-number shocks emanating from a bubble[10] show that the physics of sonoluminescence contradicts the simplifications of equations (1) and (2). Löfstedt *et al.*[8] have also pointed out the inconsistencies involved in applying these equations to a sonoluminescence bubble near R_c.

If the asymptotic expansion leading to equation (1) were applied within its range of validity ($\epsilon_g \ll 1$; $\epsilon \equiv \dot{R}/c \ll 1$), then terms that appear at higher order in ϵ should have a small effect. But this is not the case: adding a typical ϵ^2 term $[\epsilon^2(R^2/\rho)d^2P_g/dR^2]$ to the right side of equation (1) now yields a collapse temperature of 9,000 K, and an even greater discrepancy between theory and experiment.

Another problem with Hilgenfeldt *et al.*'s theory[2] is that it neglects the important role of water vapour[11,12]. For all noble gases, strongly different sonoluminescence intensities can be observed as the ambient temperature is varied[1]. As this effect can occur at fixed bubble size, one concludes that water vapour is a key feature of sonoluminescence[11,12].

Attempts to close out research on cavitation luminescence by using equation (1) are not new. In 1966 it was discovered that light emitted by bubbles formed in flow through a Venturi tube[13] came out in flashes of duration too short to be measured. At the time these were the shortest man-made flashes of light, but this line of research was abandoned when the cavitation 'establishment' declared it uninteresting because all of the results could be parametrized by equation (1) (ref. 14).

If sonoluminescence originates in a transparent plasma[15], and if this plasma is formed from molecules of dissolved gas, such as He or Xe, then the similarity of sonoluminescence from He and Xe suggests the existence of an additional energy-focusing mechanism within the bubble[5,11] — a mechanism that could create a strongly ionized (nano)plasma.

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Hilgenfeldt et al. *reply* — The comment by Putterman *et al.* in essence addresses two questions: the role of water vapour inside bubbles that undergo single-bubble sonoluminescence, and the use of Rayleigh–Plesset dynamics to describe collapsing bubbles.

Regarding the first point, water vapour is indeed present in sonoluminescing bubbles[1–7]: it invades the bubble during its expansion, and at bubble collapse the remaining water vapour and its reaction products (O,H, …) contribute to the light emission. We have discussed in detail[8,9] how the discrepancy between our model and the results for helium bubbles can be explained by including this effect: as the ionization energy of oxygen and hydrogen is similar to that of argon and higher than that of xenon, the light-emission intensities with additional oxygen and hydrogen atoms in the bubble are hardly different from those for the pure inert gases. In contrast, in the case of helium with its very large ionization energy, the light-emission process is dominated by water and its reaction products. Meanwhile, we have quantitatively included water vapour in our model[7].

Regarding the second point, it has long been known that the assumptions used to derive the Rayleigh–Plesset equation indeed break down at bubble collapse, and that there are many ways to extend equation (1) of Putterman *et al.* to higher orders in $\dot{R}/c$ (ref. 10). Although the quantitative details depend on which extension is chosen, the trends in the parameter dependences and the orders of magnitude of the energies involved are robust. Equations of types (1) and (2) have provided useful results when applied over the whole oscillation cycle of the bubble, as evidenced in the pioneering work of Gaitan[11,12] and the later studies of the Putterman group[13], in which the criticized Rayleigh–Plesset equation was used to fit various parameters to experimental data on $R(t)$.

FinalIy, we would like to stress that, contrary to what Putterman *et al.* state, equation (2) was never used in our model. Rather, we change γ dynamically, following Prosperetti[14,15], which allows for a more realistic heating of the bubble interior.

Our model reproduces the salient features of sonoluminescence light emission with comparatively little computational effort, allowing for direct comparison with experiment over a wide range of control parameters. Far from "closing out" sonoluminescence research, it has promoted quantitative extensions and refinements by others and by ourselves.

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Genetic imprinting

Urinary odour preferences in mice

Odour cues influence a variety of social activities in mammals, including kin recognition, mate selection, inbreeding avoidance and juvenile dispersal from the natal area[1–3]. Inbreeding avoidance is particularly evident across the mammalian phyla because inbreeding can cause a reduction in fitness[4]. Here we show that the attraction of mice to the urinary odours of other mice is subject to a 'parent-of-origin' effect[5] which causes both males and females to prefer the odour of urine from mice of an unrelated strain to that of urine from mice of the same strain as their mothers.

As the genes of inbred strains of mice are homozygous at nearly all loci, reciprocal crosses between two independent strains will produce first-generation (F_1) offspring with the same complement of genes. However, each cross will differ in their expression of those genes that are subject to a parent-of-origin effect and, if these are polymorphic, the offspring may exhibit different phenotypes. To exclude the possibility that odour preference might be influenced by familial imprinting[6], we used mice derived by embryo transfer to genetically unrelated foster mothers.

We tested F_1 mice to see whether they had any preference for urine from either maternal- or paternal-strain females compared with urine from non-related female controls (BALB/c mice). The animals were given a choice of two urine samples with different odours, placed in the end chambers of a three-chambered arena. We measured the time each mouse spent in each end chamber over a two-minute test period. Male and female (CBA/Ca × C57Bl/6)F_1 mice (maternal strain is written first) showed a significant preference for the control urine ($P < 0.05$) over urine from the maternal strain (CBA/Ca) (Fig. 1a). This cross did not show any preference between the control and the paternal-strain (C57Bl/6) urine.

The reciprocal cross (C57Bl/6 × CBA/Ca) showed the same pattern of preference with respect to parental origin, but the opposite pattern of preference with respect to genotype (Fig. 1b). Males and females of this cross preferred the control odour to that of