Table 6. DRUG-RESISTANT STRAINS OF *Staph. aureus* ISOLATED FROM THE SKIN AND NOSE OF PIGS AND FOWLS (MODIFIED FROM SMITH AND CRABB[19])

Animals	Drug fed	No. strains examined	Percentage of strains resistant to: Tetracyclines only	Penicillin only	Both tetracyclines and penicillin
Pigs	Tetracyclines	453 (160)	92·6	0	0
	Penicillin	109 (40)	0	30·3	0
	Neither	380 (160)	4·5	0	0
Fowls	Tetracyclines and penicillin	492 (100)	9·1	41·3	19·5
	Neither	246 (100)	2·8	2·8	1·2

The figures in brackets were the numbers of animals examined, ten from each herd or flock.

Table 7. DRUG-SENSITIVITY OF *Staph. aureus* STRAINS ISOLATED FROM THE NOSE OR SKIN OF THE ATTENDANTS OF ANIMALS FED DIETS CONTAINING LOW LEVELS OF ANTI-MICROBIAL DRUGS (MODIFIED FROM SMITH AND CRABB[19])

Type of strains	Percentage of carriers among attendants of: Tetracycline-fed pigs (35*)	Pigs not fed drugs (50*)	Tetracycline- and penicillin-fed fowls (37*)
Tetracycline-resistant only	34·2	0	14
Tetracycline- and penicillin-resistant	2·9	0	4
Penicillin-resistant only	11·3	5·4	30
Sensitive to both drugs	25·7	32·4	26
No *Staph. aureus* isolated	42·8	64·8	52

Where possible, twelve strains from the nose and twelve from the skin were examined.
* Number of attendants examined.

farms on which these mixtures were not fed was only 3·6 per cent.

The impact of the common policy in Britain of feeding fowls continuously on diets containing "nutritional" levels of penicillin and/or tetracyclines on the incidence of outbreaks of infection in poultry caused by drug-resistant strains of *Staph. aureus* is shown in Table 8. Penicillin and the tetracyclines now have little application in the treatment of this disease, a situation quite different from that which existed at the commencement of the antibiotic era.

Table 8. DRUG SENSITIVITY OF *Staph. aureus* STRAINS CAUSING STAPHYLOCOCCOSIS IN FOWLS

Fowls	No. of strains examined	Percentage of strains that were resistant to: Penicillin only	Tetracyclines only	Penicillin and tetracyclines	Streptomycin
Not fed drugs	30	0	0	0	0
Fed drugs*	40	35	0	60	2·5

*At "nutritional" levels only, penicillin and/or tetracyclines.

Conclusions

The widespread use of anti-microbial drugs in animals has led to the emergence of drug-resistant strains of pathogenic bacteria and these resistant strains are now causing a considerable proportion of the disease hitherto caused by sensitive strains. This complicates the satisfactory treatment of animal disease and the position is worsening. It also has implications for human health. There is no evidence that the resistant strains are any more, or any less, virulent than their sensitive counterparts. Neither is the character of animal disease altering in any observable way—other than in its chemotherapy—that can be attributed to the increased incidence of resistant strains.

There is little doubt that the continuous feeding of animals on drug-containing diets for "nutritional" purposes has contributed significantly to the present position. The more a drug is used in diets the less its value in the treatment of clinical disease. Moreover, as the variety of drugs used for "nutritional" purposes increases, so the variety of drug-resistant strains that are incriminated in outbreaks of disease increases and the number of drugs that can be used with confidence in the treatment of these outbreaks decreases. A strong case therefore exists for limiting the number of different kinds of drugs that can be used for "nutritional" purposes. Ideally, only drugs that are unsuitable or not usually used for the treatment of disease in animals and man, and that do not produce cross-resistance with ones that are, should be used in animal feeds. Such antibiotics are now available. Finally, the information now available calls into question the rationale of the so-called preventive use of drugs, whether as food additives or in any other form, against diseases caused by bacterial species in which drug resistance of the infective type can occur. The use of drugs in this manner may well give rise to the very situations they are intended to prevent.

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Rotating Neutron Stars as the Origin of the Pulsating Radio Sources

by

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The constancy of frequency in the recently discovered pulsed radio sources can be accounted for by the rotation of a neutron star. Because of the strong magnetic fields and high rotation speeds, relativistic velocities will be set up in any plasma in the surrounding magnetosphere, leading to radiation in the pattern of a rotating beacon.

THE case that neutron stars are responsible for the recently discovered pulsating radio sources[1–6] appears to be a strong one. No other theoretically known astronomical object would possess such short and accurate periodicities as those observed, ranging from 1·33 to 0·25 s. Higher harmonics of a lower fundamental frequency that may be possessed by a white dwarf have been mentioned; but the detailed fine structure of several short pulses repeating in each repetition cycle makes any such explanation very unlikely. Since the distances are known approximately from interstellar dispersion of the different radio frequencies, it is clear that the emission per unit emitting volume must be very high; the size of the region emitting any one pulse can, after all, not be much larger than the distance light travels in the few milliseconds that represent the lengths of the individual pulses. No such concentrations of energy can be visualized except in the presence of an intense gravitational field.

The great precision of the constancy of the intrinsic period also suggests that we are dealing with a massive object, rather than merely with some plasma physical configuration. Accuracies of one part in 10^8 belong to the realm of celestial mechanics of massive objects, rather than to that of plasma physics.

It is a consequence of the virial theorem that the lowest mode of oscillation of a star must always have a period which is of the same order of magnitude as the period of the fastest rotation it may possess without rupture. The range of 1·5 s to 0·25 s represents periods that are all longer than the periods of the lowest modes of neutron stars. They would all be periods in which a neutron star could rotate without excessive flattening. It is doubtful that the fundamental frequency of pulsation of a neutron star could ever be so long (ref. 7 and unpublished work of A. G. W. Cameron). If the rotation period dictates the repetition rate, the fine structure of the observed pulses would represent directional beams rotating like a lighthouse beacon. The different types of fine structure observed in the different sources would then have to be attributed to the particular asymmetries of each star (the "sunspots", perhaps). In such a model, time variations in the intensity of emission will have no effect on the precise phase in the repetition period where each pulse appears; and this is indeed a striking observational fact. A fine structure of pulses could be generated within the repetition period, depending only on the distribution of emission regions around the circumference of the star. Similarly, a fine structure in polarization may be generated, for each region may produce a different polarization or be overlaid by a different Faraday-rotating medium. A single pulsating region, on the other hand, could scarcely generate a repetitive fine structure in polarization as seems to have been observed now[8].

There are as yet not really enough clues to identify the mechanism of radio emission. It could be a process deriving its energy from some source of internal energy of the star, and thus as difficult to analyse as solar activity. But there is another possibility, namely, that the emission derives its energy from the rotational energy of the star (very likely the principal remaining energy source), and is a result of relativistic effects in a co-rotating magnetosphere.

In the vicinity of a rotating star possessing a magnetic field there would normally be a co-rotating magnetosphere. Beyond some distance, external influences would dominate, and co-rotation would cease. In the case of a fast rotating neutron star with strong surface fields, the distance out to which co-rotation would be enforced may well be close to that at which co-rotation would imply motion at the speed of light. The mechanism by which the plasma will be restrained from reaching the velocity of light will be that of radiation of the relativistically moving plasma, creating a radiation reaction adequate to overcome the magnetic force. The properties of such a relativistic magnetosphere have not yet been explored, and indeed our understanding of relativistic magnetohydrodynamics is very limited. In the present case the coupling to the electromagnetic radiation field would assume a major role in the bulk dynamical behaviour of the magnetosphere.

The evidence so far shows that pulses occupy about 1/30 of the time of each repetition period. This limits the region responsible to dimensions of the order of 1/30 of the circumference of the "velocity of light circle". In the radial direction equally, dimensions must be small; one would suspect small enough to make the pulse rise-times comparable with or larger than the flight time of light across the region that is responsible. This would imply that the radiation emanates from the plasma that is moving within 1 per cent of the velocity of light. That is the region of velocity where radiation effects would in any case be expected to become important.

The axial asymmetry that is implied needs further comment. A magnetic field of a neutron star may well have a strength of 10^{12} gauss at the surface of the 10 km object. At the "velocity of light circle", the circumference of which for the observed periods would range from 4×10^{10} to $0{\cdot}75\times10^{10}$ cm, such a field will be down to values of the order of 10^3–10^4 gauss (decreasing with distance slower than the inverse cube law of an undisturbed dipole field. A field pulled out radially by the stress of the centrifugal force of a whirling plasma would decay as an inverse square law with radius). Asymmetries in the radiation could arise either through the field or the plasma content being non-axially symmetric. A skew and non-dipole field may well result from the explosive event that gave rise to the neutron star; and the access to plasma of certain tubes of force may be dependent on surface inhomogeneities of the star where sufficiently hot or energetic plasma can be produced to lift itself away from the intense gravitational field (10–100 MeV for protons; much less for space charge neutralized electron-positron beams).

The observed distribution of amplitudes of pulses makes it very unlikely that a modulation mechanism can be responsible for the variability (unpublished results of P. A. G. Scheuer and observations made at Cornell's Arecibo Ionospheric Observatory) but rather the effect has to be understood in a variability of the emission mechanism. In that case the observed very sharp dependence of the instantaneous intensity on frequency (1 MHz change in the observation band gives a substantially different pulse amplitude) represents a very narrow-band emission mechanism, much narrower than synchrotron emission, for example. A coherent mechanism is then indicated, as is also necessary to account for the intensity of the emission per unit area that can be estimated from the lengths of the sub-pulses. Such a coherent mechanism would represent non-uniform static configurations of charges in the relativistically rotating region. Non-uniform distributions at rest in a magnetic field are more readily set up and maintained than in the case of high individual speeds of charges, and thus the configuration discussed here may be particularly favourable for the generation of a coherent radiation mechanism.

If this basic picture is the correct one it may be possible to find a slight, but steady, slowing down of the observed repetition frequencies. Also, one would then suspect that more sources exist with higher rather than lower repetition frequency, because the rotation rates of neutron stars are capable of going up to more than 100/s, and the observed periods would seem to represent the slow end of the distribution.

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