SUMMARY

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The Symposium opened with a morning devoted to the accomplishments and character of Henry Norris Russell, as one of the two originators of the Hertzsprung-Russell diagram, on the hundredth anniversary of his birth. The papers presented at this session, together with some shorter remarks made at other times during the Symposium, are to appear in a separate volume as Dudley Observatory Report. No. 13. Suffice it to say here that the picture which emerged was that of a fine man of enormous energy, prodigious memory, committed to his scientific work but with many interests, always polite and pleasant to those around him but somewhat remote.

1. FUNDAMENTAL ASEPCTS OF THE HR DIAGRAM

At the first scientific session of the Symposium, W.W. Morgan described his extension of the original MK system. Between O9 and GO there are 100 to 150 cells in a two-dimensional array of luminosity class against spectral type, each cell being defined by the lists of standard stars given by Morgan and his co-workers from time to time. A classification defined in this way has the great advantage of being free of theoretical constructs. It may also be extended by the insertion in the existing cells of one or more vectors to represent other properties of normal and peculiar spectra --both those we already know and those which may be discovered. The vectors are themselves to be defined by standard stars, but are regarded as secondary aspects or perturbations of the spectrum-luminosity class array. Three questions illustrate problems of current interest: 1.) Does the HR diagram have any strong line, normal--that is, Hyades-like--stars in the cell GO III? 2.) The

A. G. Davis Philip and D. S. Hayes (eds.), The HR Diagram, 391-403.

cell A0 V contains A0 Va and A0 Vb stars with narrow and broad H lines respectively; the latter occur in clusters. Are there any A0 Vb stars not in clusters? 3.) The cells B7 III to B9 III contain giants with relatively narrow, stellar K lines and broad HeI lines with rotational velocities less than 100 km/sec. Are there any stars in these cells for which the K and HeI lines are different?

Since the present work is based on the spectral range 3500-4700 Å, Morgan emphasized the desirability of constructing classification systems independently of the MK system but based on similar principles in the far UV, green-red, and infrared, as well as for weak-lined stars in the photographic region. When these systems are sufficiently complete, a comparison of the four systems with each other and with the MK system could be most instructive.

N.R. Walborn described an empirical luminosity classification for early O stars to serve as an extension of the MK system, which does not include types earlier than O9. This extension is based on the suggestion that the negative luminosity effect of the weakening of the absorption lines of HeII 4686 Å and NIII 4634-4640-4642 Å in the O9 to B0 stars is in fact a filling in by emission, which with greater luminosity leads to these same lines appearing in emission in the Of stars. Application of this idea to the earlier O's leads to luminosity classes in agreement with those found from other, less sensitive, spectroscopic criteria. The Of stars no longer appear peculiar but simply as early supergiants. From known distances, $M_V = -7^{m}.0$ for the Of's versus $-5^{m}.5$ for the hottest main sequence O's.

With normal O stars defined as above, several groups show peculiarities related to the presence of extended envelopes. The Onfp stars have broad absorption lines and HeII 4686 Å as a centrally reversed emission line. The Of?p stars have strong CIII 4647-4650-4651 Å in emission. The emission features are sharp relative to the absorption lines, suggesting a shell source. The OIafpe stars are very luminous supergiants with a P Cygni spectrum. The WN stars are characterized by broad emission bands. Other early type stars show chemical anomalies, which in some cases appear to be related to binary character. Possibly all OBN stars and no OBC stars are members of short-period binaries. The OBN's may result from nitrogen enrichment and the OBC's from nitrogen deficiency but the relative importance of mass transfer, mixing, and mass loss in these phenomena is unclear. There is also the group of helium rich stars near spectrum-luminosity class B2V which show enhanced and, in many cases, periodically variable HeI. Finally, Walborn described the deficiency in the strength of the metal lines in the OB stars of the SMC.

P.C. Keenan presented an HR diagram for G, K and M stars designed to bring out the fine structure in the luminosity-spectrum plane by

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plotting only those stars with the best established positions. The luminosity of the GB is known to 0.2 mag. and the dispersion is 0.4 mag. The ridge of the GB is defined by luminosity class IIIab, stars on the upper side are called IIIa and those on the lower IIIb. The three classes yield separate bands in his HR diagram. There is a scarcity of the most luminous K supergiants, which is not an artifact of the classification scheme; from G7 to K1, class II bright giants are extremely rare.

P.C. Boeshaar reported that the coolest halo subdwarfs are not subluminous and that very cool M subdwarfs can be conveniently identified by the enhanced CaOH 5530 Å band and NaI D-lines.

One might be excused for approaching the next three papers of this session with some skepticism but the quality of the results in each case were impressive. I. Appenzeller and H. Zekl described a completely automated procedure designed to yield spectroscopic parallaxes in which spectra at 115 Å/mm are scanned, approximate spectral type derived, and line widths, depths, and ratios are compared to those in standard stars. Preliminary results yield parallaxes as accurate as conventional visual classification. Th. Schmidt-Kaler reported on a completely computerized process for deriving two-dimensional classifications from objective prism spectra. Since the resolution of such spectra depends on the seeing, he employs equivalent widths, which are little affected. Plate calibration is obtained from the numerous stellar spectra themselves. Classification of B0 to F2 stars at 570 Å/mm to the accuracy of the MK system can be obtained in 30 seconds. Finally M. Parthasarathy showed slides which demonstrated convincingly that spectra taken at the ultra-low dispersion of 10,000 Å/mm can be used effectively for reconnaisance, for example on objects such as the LMC. The resulting microspectra are about 250 microns in length along the spectrum, and spectral types can be assigned to an accuracy within half a spectral class.

V.M. Blanco, A.A. Hoag and M.F. McCarthy have found that the ratio of the number of carbon to late-type M stars per unit area is a useful indicator of stellar populations at various points both in the nucleus of the Galaxy, where it is low, and the central regions of the LMC and SMC, where it is high.

From BVRI photoelectric photometry and Van Vleck Observatory parallaxes, A.R. Upgren has constructed enriched main sequences for K and M spectral types for the Hyades and field stars in the solar neighborhood. The dispersion of the latter group about the main sequence is about ±0.4 mags. after removal of the dispersion from parallax errors.

A. Heck reported on absolute magnitudes for various ranges of spectral types as determined by statistical parallaxes. S.V.M. Clube and J.A. Dawe used statistical parallax procedures to investigate the motions and luminosities of RR Lyrae variables in the solar neighborhood as a function of the period and Preston's ΔS = 10 (spectral type from H - spectral type from Ca). They found a low and a high velocity group and identified the latter with the RR Lyrae's in the Galactic center and halo and in the SMC and LMC. This led to corrections to the distances to these objects. R.E. Stencel pointed out that weak emission lines of iron-peak elements in the wings of H and K in late giants and supergiants can be used to determine M_V as well as the run of the temperature and non-thermal line broadening as a function of atmospheric height. The latter information can be used to study mass loss.

W.J. Luyten presented a set of informative plots of reduced proper motion, H, against color. The former, first used by Hertz-sprung for stars with unknown parallaxes, is found from an expression identical with that for M using m and the parallax, p, except that to find H, p is replaced by μ. On average, H therefore tends to increase when M does. Plots based on proper motion surveys to some limit are more representative of the stars in a given volume than those based on some limiting magnitude. The four plots presented were for 5000 degenerate dwarfs, 5000 doubles with common proper motion, stars of very low luminosity and more than 10^5 stars of all types together.

D.S. Hayes discussed very clearly the transformation, freed as far as possible from theoretical constructs, from the observed magnitudes and spectral types or color indices to M_{bol} and log T_{eff} by way of absolute energy distributions and angular diameters.

2. HR DIAGRAMS: SOLAR NEIGHBORHOOD

W. Gliese gave some interesting statistics on our knowledge of stars nearer than 22 parsecs. 1500 stars in this volume have trigonometric parallaxes and of these about 1000 have M_V known to 0.5 mags. Only 600 have MK spectral types, but (B-V) photometry has been done on 1300. There are 53 degenerate dwarfs in the (B-V, M_V) diagram. The percentage of dMe stars increases in the later spectral types, many are flare stars. D.C. Barry reported that although the solar spectrum defines type G2 V, its color and line strengths are close to G3 and G4 stars. N. Houk and R. Fesen showed an interesting HR diagram based on the quality 1 and 2 normal stars of Volume 1 of the Michigan Catalogue of Two-Dimensional Spectral Types for the Henry Draper Stars. The use of appropriate symbols made immediately clear the approximate number of stars assigned to a given spectral type and luminosity type.

3. HR DIAGRAM, SUBLUMINOUS STARS

A number of interesting but somewhat separate points were made

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in this session. J. Greenstein reporting on his large, significant program had found the halo G and K dwarfs to be as much as 1.0 mag. brighter than those of the old disk population, but with no difference between the M's. Composition differences in the M's affect their spectra little, but Pop. II sdM stars are recognizable by the strength of MgH and CaH compared to TiO. Halo stars fainter than visual absolute magnitude $15^{m}_{\cdot}5$ and old disk stars fainter than $18^{m}_{\cdot}5$ are uncommon. Dwarf Me's were found above but in the scatter of the main sequence.

Large composition variations are found among the degenerates. Very few red degenerate dwarfs have been found, very possibly as the result of envelope convection which leads to rapid cooling and short lifetimes. The lowest temperatures found are 4500 to 5000 K. Bolometric luminosities run from 10^{-4} $L_{\odot}$ to 10 $L_{\odot}$. P.R. Wesselius reported that hot subdwarf O's can be 5 mags. brighter at 1550 Å than in the V band.

H.L. Shipman pointed out that for degenerates, colors derived from different model atmosphere calculations are in relatively good agreement. These fluxes together with known parallaxes yield average radii of 0.013 $R_{\odot}$ for 95 hydrogen-rich, and 0.011 $R_{\odot}$ for 13 helium-rich, white dwarfs. These values are not significantly different and, when corrected for estimated observational selection, yield 0.011 $R_{\odot}$. This radius corresponds to a mass of 0.7 $M_{\odot}$. V. Weidemann emphasized the constant average radius, log $R/R_{\odot}$ = -1.90 ± 0.10, from hot to cool DA's. The corresponding range of masses is (0.55 ± 0.2) $M_{\odot}$. Using surface gravities, the mass range is 0.40 to 0.65 $M_{\odot}$. Mass loss in the red giant stage is therefore substantial. There was disagreement in regard to the existence of more than one cooling sequence. S. Tapia found evidence for two sequences among the DA's but Weidemann did not. On the basis of an astrometry and photometry program at the Naval Observatory, C.C. Dahn and R.S. Harrington also found no support for more than one sequence. They also did not find convincing evidence for subluminous stars between the subdwarfs and the degenerates.

4. HR DIAGRAMS: CLUSTERS

A. Gutiérrez-Moreno and H. Moreno employed a photometric quantity, ΔD, which measures emission or absorption in the Balmer continuum, to confirm emission in circumstellar envelopes in pre-main sequence stars in the Orion and Upper Scorpius associations. W. Herbst and R.J. Havlen reported that there are gaps in the color magnitude diagram for the Ara OB1 association, just on the red side of the turn-up points. These gaps measure 0.07 mag. in (B-V) and 0.25 mag. in (U-B).

D.L. Crawford gave a systematic review of the wide variety of

"HR diagrams" which are employed for intercomparison of magnitudes, spectra, temperatures, and numerous color indices. R.F. Garrison discussed the overlaping of the main sequence of 6 clusters, the Hyades, Alpha Persei, II Sco., NGC 6231, NGC 2244 and NGC 2264, to obtain a composite main sequence extending from O4 V to K4. This overlapped sequence can be used for absolute magnitude calibration.

The recent suggested change in the distance to the Hyades from 40 to 46 pc. implies an increase in absolute magnitude of the ZAMS, which could formally be obtained by taking Z in the range from 0.06 to 0.10. Rather than accept such high metallicities, P.J. Flower has discussed the influence on the comparison of the color-magnitude diagram with the theoretical ZAMS of reasonable changes in the parameters of the latter due to uncertainties in the opacity, Z-value, stellar rotation, and mixing length, and changes in the color-magnitude diagram due to evolution. He concluded that a distance of 43 pc. is more nearly correct.

H.A. Abt and H. Levato from a study of 455 stars in 12 open clusters found that Ap stars first appear after about 10^6 yrs and increase thereafter to the frequency among field stars in about 10^8 yrs. The percentage of Am stars does not depend on cluster age. The rotational velocities of Ap and Am stars decrease inversely as the square and fourth root of their age respectively. Half of the stars in the Orion Nebula cluster (age $10^{5.7}$ yrs) have very broad H line wings, but only 2 percent in the Orion association ($10^{6.7}$ yrs). C.A. Pilachowski and W.K. Bonsack have made a survey of clump giants in open clusters, looking for peculiar stars and evolutionary effects. Indices have been developed which, when quantified, will yield overall cluster abundances of CH, CN, and Fe group elements. The "barium index" can be used to estimate the mean mass of a clump giant. A Ba star in the clump of NGC 2420 has been tentatively identified.

R.C. Henry and J.E. Hesser reported on their K-line photometry of A stars in Coma and NGC 6475. In the latter cluster, 2/3 of the 31 stars studied are Am stars.

From a study of several intermediate to old galactic clusters, R.D. McClure finds He and/or CNO abundances are independent of Fe abundance, with the differences possibly related to position with respect to the galactic plane and to age. In the open clusters, one finds much the same abundance ratios in all cluster members. Norris suggested that the difference between globular and open clusters is that the globulars are massive enough to hold whatever is made but is lost or blown out of open clusters.

R.P. Kraft opened his excellent discussion of non-homogeneity of the metals in globular clusters with a qualitative explanation due to A. Renzini of the effects of Z_{CNO} and Z_{Fe} on model calculations. Near the turn-off point from the main sequence for stars between 0.6 and 1.0 $M_\odot$, the CNO cycle becomes dominant over the pp-chain with the result that the rate of energy generation increases linearly with Z_{CNO}, H exhaustion occurs earlier, and turn-off occurs sooner and at a lower luminosity. In two temperature ranges, the opacity depends heavily on Z. At 4000 K or below, the principal contributor is H^-, with the electrons determined primarily by Z_{Fe}. Near 10^6 K, the opacity depends on the b-f transitions of C, N, and O, that is on Z_{CNO}. Thus near turn-off, for surface temperatures greater than 4000 K, evolution depends on Z_{CNO} whereas for surface temperatures of 4000 K or less subgiant, giant branch, and red giant top move to the right with increasing Z_{CNO} and Z_{Fe}, but much more rapidly with Z_{Fe}.

ω Cen and M22 have been found to contain stars with enhanced Ba, and possibly Sr, along the red edge of the giant branch. This result implies a slow neutron flux but the mechanism is unclear. From a study of 23 giants in M22 and two other clusters with $<[Fe/H]>=-1.7$ to -2.0, Mallia finds $[Ba/Fe]=0.0$, in contrast to the aging effect found by Peterson for field halo giants.

Since Fe-peak and α-process elements are not produced in low mass stars, the great width of the giant branch of ω Cen indicates primordial variations in abundance but Norris and Bessell found a correlation of CaII (K) and CN bands suggesting that mixing also plays some role, possibly by way of effects of CN on the atmospheric opacity, with resulting influences on the intensity of strong resonance lines.

The overabundance of C in the CH stars of ω Cen and M22 can be accounted for as a result of the mixing of triple-α products to the surface at He-core flash or He-shell flashes. The N overabundance in M92 and the C^{12}/C^{13} ratio close to the equilibrium value follow from CNO-processing and mixing. The fact that metal-rich globular clusters show wide variations in the strength of CN while metal-poor clusters for the most part do not can also be accounted for by CNO-processing and mixing. Exceptions among the metal-poor clusters can be explained by assuming a second ascent of the giant branch following He shell-flashs for ω Cen and M22 or primordial N overabundance for M10 and NGC 7006, with their CN-strong stars. Again CNO-processing and mixing can account for the weakness of the g-band of CH on the asymptotic giant branch as compared with the subgiant branch. If future observations can reach stars fainter than those for which, according to theory, mixing first occurs, we can separate the effects of primordial abundance from those resulting from mixing.

M. and F. Spite reported on Ba differences in halo dwarfs and giants. G. Wallerstein and C. Pilachowski measured CO and OI in globular clusters with different horizontal-branch morphologies and found C and O enhanced relative to Fe in clusters with red horizontal branches. From a study of halo globular clusters, R. Canterna and

R.A. Schommer found no [Fe/H] gradient beyond 20 kpc but enhanced CN appears in some cases. They suggested that age and/or primordial He abundance are responsible for horizontal-branch morphologies. D. Butler, R.A. Bell, R.J. Dickens and E. Epps reported that the range of values of [Fe/H] for the RR Lyrae variables in ω Cen is sufficient to explain the great width of the giant branch. Both metal-rich ([Fe/H] > -1.0) and metal-poor ([Fe/H] < - 1.0) groups appear, with average periods of 0.57 and 0.66 days respectively. Superposition of evolutionary tracks supports composition-dependent mass loss, with the metal-rich group becoming 0.1 $M_{\odot}$ less massive than the metal-poor one but not more than 0.1 mag. fainter. J. Norris described his work done with M.S. Bessell and K.C. Freeman on ω Cen and 47 Tuc. The latter cluster shows the same anomalous bimodal distribution of CN in the giant, asymptotic, and horizontal branches. 47 Tuc appears to have no CH or Ba stars and no RR Lyrae's, but TiO is normal. DDO photometry shows that the M stars of ω Cen and 47 Tuc are not alike. The giant branches of ω Cen and 47 Tuc are clearly not similar. They find that at $M_V \approx -1^m$ stars on the red side of the giant branch of ω Cen have much stronger CN than those on the blue. T.Lloyd Evans finds the giant branch of ω Cen much narrower in the (I, V-I) diagram than in (V, B-V) with a number of members on the red side of the giant branch. These stars show strong BaII and, where the temperature allows, strong CN. A high primoridal metal content and mixing are suggested. Dr. R.J. Tayler argued that the peculiarities of ω Cen must originate in unusual primordial abundances--possibly its great mass enabled it to retain more gas--rather than in mixing because otherwise the stars would have to know they were in ω Cen and required to give a broad giant branch.

6. HR DIAGRAMS: HORIZONTAL-BRANCH STARS

A.G. Davis Philip finds from a review of Strömgren four-color photometry of HB stars that A-F spectral types and luminosity classes III-V can be transformed to theoretical HR diagrams, which for both Pop I and II agree with the theoretical predictions. Future studies of blue HB stars offer the possibility of comparing the dispersion in the giant and horizontal branches and of investigating the role of primordial abundances and mixing. V. Castellani finds that the position of the hot HB stars in the HR diagram is largely independent of the original chemical composition but raises the question of the Draco dwarf galaxy which has a red HB cluster but $Z=3\times10^{-5}$, a value so low that theoretically it would not be possible for the HB to evolve to the red side of the instability strip for $Y \gtrsim 0.20$. F. Fusi-Pecci and A. Renzini in a very clear paper on HB morphologies and dispersions investigated the effects of mass loss and initial rotation, and the identity of the "second parameter" beyond the abundance of the elements of low ionization potential. They find that if the cores of evolving Pop II stars keep most of their original angular momentum, the spread in the

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latter can explain the HB dispersion. From 30,000 VBLUW measurements on 170 Cepheids and 100 RR Lyrae Stars, J.W. Pel and J. Lub find that: a) the short period, Pop I Cepheids have very similar compositions; b) the Cepheid strip is wider in the HR diagram at higher luminosities; c) the blue Cepheids of small amplitude are probably pulsating in the first harmonic; d) the double-mode Cepheids have compositions of Pop I and are probably related to fundamental-overtone transitions; e) the RR Lyrae stars have a wide range of Z; f) members of group ab typically have radial amplitudes of 14 percent and those of group c about 5 percent; g) among the field stars one finds groups with properties, such as average periods of $0\overset{d}{.}55$ and $0\overset{d}{.}65$, like those identified by Oosterhoff in his globular clusters of type I and II; h) for group ab, Y=0.28 $\pm$0.02. On the assumption of Y=0.75 in Cepheid convection zones, involving 10^{-4} or less of the star's mass, and possibly originating in a stellar wind much richer in H than He, A.N. Cox and S.W. Hodson have computed ratios of the periods of the second overtone and fundamental, positions of bumps in the light and velocity curves, and periods at various points in the instability strip, all in agreement with observations. L.A. Balona reported a study of a small sample of RR Lyrae stars which yielded an absolute visual magnitude of -0.5 and supported the idea that group c variables pulsate in the first harmonic.

7. GALAXIES AND OTHER SUBJECTS

Beatrice M. Tinsley gave a superb talk on HR diagrams of galaxies. Her paper must be read to appreciate the many interesting and significant points she makes. Extreme types of stellar population are those rich in young stars, Pop I, and those deficient in young stars, similar to Baade's Pop II, but metal rich. Differing mixtures of the extreme and intermediate populations account for the properties of the sequence of galaxies. Low mass stars radiate most of their energy as late red giants. Bright stars are the principal source of the integrated light. The star formation rate, SFR, is indicated by the relative number of upper main sequence and turn-off stars. In the integrated light, the contribution of the young component from the upper main sequence stars and their descendent supergiants indicate the SFR; and the contribution of the turn-off stars and their descendent red giants indicate the total number of stars formed. Color corrected normal galaxies define a narrow band in the UBV plane, of which the lower part contains the central bulges of spirals, ellipticals, and S0's. Using the local initial mass function, solar composition, and declining SFR, Larson and Tinsley found for all models a narrow locus for normal giant galaxies with ages from 5 to 20×10^{9} yrs. Galaxy formation from primordial gas clouds may account for the observed morphology, mass, and population. Ellipticals and the nuclear bulges of spirals formed in a few free fall times. Disks form slowly, and the lower the SFR the flatter they are. The SFR also

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depends on the rate of accretion of ambient gas, sudden brief increases in accretion rate can yield bursts of star formation. Intracluster gas creates van den Bergh's anemic spirals and S0's by sweeping out the interstellar matter.

D. Crampton pointed out the similarity of the spectra and luminosities of OB stars in the LMC to those in the Galaxy.

R.M. Humphreys reported that the supergiants in the Galaxy and the LMC are very similar with M_{bol} between -10^m and -12^m for O stars but an upper limit of $-9^m.5$ for other spectral types. S. van den Bergh presented arguments which suggest that Fe/CNO is lower in disk than in halo stars. R.A. Schommer, E.W. Olszewski and W.E. Kunkel described the color-magnitude diagram for the Ursa Minor dwarf galaxy, which indicates [Fe/H] = -2.1 and exhibits a HB which is heavily populated on the blue side of the RR Lyrae gap in contrast to other halo objects and dwarf galaxies. B. Hauck described the use of the Geneva photometric system to detect Am and Ap stars and to obtain an estimate of their chemical composition.

M. Golay reported photometric parallaxes for several galactic clusters. D.S. Evans described a remarkably close relationship between a stellar visual surface brightness parameter and Johnson (V-R) color, which is largely independent of interstellar extinction and luminosity class but lacks a clear physical foundation. It has been used to calculate angular diameters, and changes therein, from photometric observations. If linear diameters, or variations thereof, are known as for Cepheids, white dwarfs, or eclipsing binaries, distances can be found. At the least, this relationship appears to be very useful for reconnaisance. E.E. Mendoza V described the use of narrow, intermediate, and broad band photoelectric photometry to place A stars precisely in the HR diagram.

V. Straižys described the effective, seven-color, intermediate band, photometric system of the Vilnius Observatory. After appropriate calibrations, the intersection of five lines based on the seven-color measurements yields the reddening-free location of a normal star in the log T_{eff}-log g or the M_V-spectral type diagrams, and deviations from a close intersection can be immediately interpreted by a trained investigator as indicating subdwarf, metal-deficient giant, Am or Ap star, white dwarf, or double star. Discussions are underway in regard to some unifying of the Geneva and Vilnius systems, and D.S. Evans suggested that any resulting system be referred to as the "Genius System".

8. THEORETICAL PAPERS

H. Kähler in an interesting paper pointed out that the mathematical arguments which have been used to "prove" the Vogt-Russell theorem--that a unique solution of the equations of stellar structure exists for given mass and chemical composition--apply to systems of linear differential equations with appropriate boundary conditions, whereas the equations of stellar structure are highly non-linear. Indeed, counter examples to the theorem are familiar. A "local" formulation--small changes in the parameters lead uniquely to small changes in the model--can be established for the neighborhood, in the mathematical sense, of a stable model, and some statements can be made about the number and stability of equilibrium models in general.

M.N. Perrin and G. Cayrel de Strobel find that stars in the same six-dimensional box, 0.01 mag. on a side in each of the 6 measures or combinations of the Geneva photometry, can differ substantially in M_{bol}. In a separate paper, these two authors report that the interpretation of an observational log T_{eff}-M_{bol} diagram derived for nearby F, G, and K stars using the theoretical diagrams of Hejlesen and those of Ciardullo and Demarque yields similar ages and compositions.

P.G. Gross discussed the possible contribution of magnetic mixing to surface chemical composition. Magnetic fields arising from flux conservation or the dynamo action of turbulence and rotation could create magnetic bubbles, buoyant because of the magnetic pressure forces. Detachment could result from the buoyancy or the aerodynamic drag of differential rotation. The bubbles would be expected to rise 1 or 2 pressure scale heights, which under appropriate conditions could carry processed nuclear matter from the He flash region to the bottom of the outer convective envelope, with the concomitant downward motion of the H leading to the possibility of s-process element formation.

A.V. Sweigart reviewed certain results of his large computational program covering about 100,000 stellar models using uniform numerical procedures and similar input physics. In a number of cases, his conclusions confirm in a particularly clear way already known or suspected results. For higher mass, central H exhaustion occurs in a larger volume and is followed by sudden contraction and evolution to the left. Near turn-off, log T_{eff} and log L increase for increasing Y and decreasing Z, primarily Z_{CNO}. The RGB moves to the left with decreasing Z or increasing mass, Y, or ratio of mixing length to pressure scale height. The luminosity at the RGB tip and the maximum stellar mass for a He-core flash decrease with increasing Y or decreasing Z. The maximum extent of the temperature inversion from neutrino losses occurs shortly before He-core flash and increases with core mass. On the SGB, when the H-burning shell moves up from the region partly H exhausted during the MS stage to the region mixed by the envelope convection, it encounters a higher H concentration and pauses in its evolution, yielding a larger concentration of stars at that point and therefore a peak in the luminosity function. The duration of this pause and the luminosity at which it occurs decrease with smaller Y and larger Z. Semi convection can increase HB life-times by a factor of almost two.

R.B. Ciardullo and P. Demarque have computed CM diagrams, luminosity functions, integrated colors, etc. based on extensive stellar models as a function of time for several chemical compositions, converted to observables using model stellar atmospheres, and analyzed the effects of such parameters as initial mass function and mass loss.

S.A. Lamb gave a particularly clear review of the evolution of massive stars beyond core He burning. Stars of more than about 10 $M_\odot$ can burn C quiescently with the iron peak elements as the eventual product. Except for the few stars of more than 80 $M_\odot$, quasistatic evolution ends in the photodissocation of the iron peak elements, primarily into α-particles. The products of nucleosynthesis are dependent on the temperature, density, and the extent of convective mixing at various depths, all of which at this stage for these massive stars are largely determined by the energy loss from neutrinos arising from pari-, plasma-, or photo-interactions. The heavier products tend to occur in the deeper layers. Products appear at the surface if convective envelopes carry them there or mass loss reveals the inner layers as for the late-and early-type supergiants respectively. Envelope convection does not penetrate the H burning shell so that the products of He and later burning stage are expected only if mass loss occurs. The products of core nucleosynthesis may appear in supernova remnants if the explosion was preceded by sufficient mass loss.

C. Chiosi gave a very complete and interesting review of the structure and evolution of massive stars, starting with the role of semiconvection, the relation of the Schwarzschild and Ledoux conditions for convective stability in regions with a gradient of molecular weight, Kato's discussion on the local basis and the need for a satisfactory treatment of non-local convection. Semi-convection is not a major consideration in the main sequence phase but is a dominant consideration in H shell, or largely He core, burning, since the chemical profile and the resulting changes in the depth of the convective envelope at the upper end of the red supergiant branch influence looping in the HR diagram. Mass loss for stars of less than 15 $M_\odot$ is moderate and their evolution is not greatly influenced. For more massive stars, mass loss can reach substantial fractions of the initial mass with resulting changes in the He abundance and increases in N^{14}, C^{13}/C^{12}, and O^{17}/O^{18}.

It became apparent in the course of discussion that the new Carson opacities, which for stars of more than 10 $M_\odot$ lead to a broadened main sequence and modified evolutionary tracks, are not yet generally accepted. The detailed calculations have not been published and some attempts to reproduce specific values have not been successful.

P.S. Conti reported mass loss rates of the order of 10^{-6}, 10^{-5} and 10^{-4} $M_\odot$/yr. for O, Of, and WR stars respectively but found no gross differences in the velocity structure of the envelopes. He suggested that if the mass is sufficient, evolution proceeds from O to Of stars and thence to WR stars.

D.S.P. Dearborn and V. Trimble evolved stars of 12 and 32 $M_\odot$ of Pop I composition and Pop II metal composition but two different Y's to early carbon burning. Assuming a Salpeter birthrate function and various mass loss rates, they find lower limits to the ratio of the enrichment of He to that of the metals in the galaxy, from the time of the first stars, which can match any value derived from the observations.

Using their own model atmospheres, R.A. Bell and B. Gustafsson have computed synthetic spectra and colors of G and K giants for different metal abundances. Included in the computations are some 50,000 atomic and molecular lines. The effects of terrestrial atmospheric and interstellar extinction and changes in the Doppler broadening velocity and the damping were studied. Agreement of the computed and observed colors was good except for the ultraviolet and for the CN indices. These differences can be traced to the omission of weak lines and failure to include N enrichment from CNO processed matter respectively.

R. Foy suggested that microturbulence could be used as a third dimension to yield the age of a G-K giant in the HR diagram. He finds that microturbulence is not a result of departures from LTE but is related to stellar atmosphere parameters and is a function of stellar evolution.

K. Kodaira has found that the effect on the transformation from the theoretical to the empirical HR diagram of considering the sphericity of the extended atmospheres of late type giants, with the accompanying decrease in g and increase in the dilution of the radiation field, cools the outer layers and enhances the TiO and H_2O, with the blanketing effects leading to changes in M_V and color.

In summary one can say that Symposium 80 was most pleasant and informative and that the participants and attenders owe substantial thanks to A.G. Davis Philip and the Scientific and Local Organizing Committees.