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NATURAL SCIENCES & FOREIGN LANGUAGES

NO. 4

1971



FU JEN UNIVERSITY

TAIPEI, TAIWAN, REPUBLIC OF CHINA

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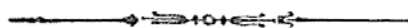


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FU JEN UNIVERSITY

TAIPEI, TAIWAN, REPUBLIC OF CHINA

ELECTRONIC SEGMENTATION OF RECORDED SPEECH

FREDRIC F. WEINGARTNER, SJ.

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1.0 SEGMENTATION

Human activities from birth to death are mostly continuous. There may be highlights in the life of individuals to be always remembered as a graduation ceremony or a marriage. Some events as the signing of a contract may result in a new direction for the individual. Gayety or excitement at such occasions may intensify the action of the vital organs just as grief and horror may slow them down. But one heart beat will generally be followed by another one and it would be difficult to tell whether a certain moment between beats should be ascribed to pulse one or to pulse two. Nevertheless the physician who reads a cardiogram will easily detect in it recurring peaks and troughs and thus be able to indicate how many cycles the machine registered in a given time. Such cycles are discrete units arrived at by use of a registering device whose output is interpreted by the doctor. The trace itself represents a continuum and intermissions in the trace would have to be read as danger signals.

There are events in nature that seem to be discontinuous. They happen rarely and then often with great force so that they are able to disrupt severily the continuity found in life. Such is the case when an avalanche comes down down a mountain slope leaving destruction and death in its path, and only coming to a standstill after it has reached the bottom of the valley. Even such discon-

tinuous events can be considered continuous, always under the influence of gravity which steadily loosens the ties binding the mass of snow to its surface and, upon a rapid change of temperature, brings the entire mass down at once instead of melting it slowly. In the same way the sudden jump of a beast of prey can be interpreted not as a discontinuous movement but as one built up slowly, not to say deliberately, until the moment of the chance to kill. Is it idle for the linguist to ponder over a saying like that of Heraclitus: reality is in constant flux? Or will it rather do him good, if he is ready to acknowledge that the problem of the continuum and its segmentation "covers areas much more general than that of linguistics"⁽¹⁾ namely metaphysics as well as epistemology and, for the linguist, physics as well as psychology? Only that will give the right perspective to the man who is out to segment speech either with a pair of scissors in his hand or with the finger on a gating device.

1.1 SEGMENT

With his machines the researcher can split an event of only a second into five hundred or even a thousand segments. But the question is: can segments of that size have any possible bearing on speech production and perception? Further: is there a one-to-one correspondence between segments so obtained and segments perceived? Here speculation must be supplemented by observation and experiment. A report concerning these will first have to give a working definition of a segment. Segments as studied in this paper are obtained from recorded speech and their minimum extension is such that they remain significant, because their presence or absence will be noticed by the native speaker. A threefold aspect of these segments is possible: the physiological, the acoustic and the auditory. The physiological aspect asks, what actions of what articulatory organs were necessary to produce the sound material that a segment contains? Since the study of such segments reveals that two moments of them are never identical, this implies a continuous change in the positions of the articulatory organs. The rate

of speed of this change is however not always the same. In other words, some potential segments are more uniform than others, a criterion employed by those whose aim is to classify speech events. The distinction between steadier and faster changing portions of speech has e. g. led to the time-honoured division into vowels and consonants and further division along the same line is apt to produce a full scale 'alphabet'. But the high resolution of our equipment, allows us to be more ambitious and to study sound features. Having thus entered the acoustic domain we may still, if occasion warrants, draw inferences back to the physiological one.

More than one sound feature is usually present at a time and they are not coextensive. That is, some terminate sooner, while others last longer. A segment is not a single feature but a 'bundle' of them and segmenting may mutilate one feature and leave another intact. The place of a cut is then determined by the third aspect: the auditory one. Here a remark on terminology is in order: the division common in physics and electronics between acoustic and auditory is not generally in use with linguists.

Some relate with Marouzeau,⁽²⁾ Vachek,⁽³⁾ and Springhetti⁽⁴⁾ acoustic to the the ear, while others, as Pei-Gaynor,⁽⁵⁾ relate it both to sound and sound perception. With Pay-Gaynor and Vachek there is no entry for auditory while Marouzeau⁽⁶⁾ and Springhetti⁽⁷⁾ consider it equivalent to auditive, which for them is in opposition to visual. Only Hamp distinguishes clearly between acoustic⁽⁸⁾ as pertaining to air molecules and auditory⁽⁹⁾ as pertaining to the ear. We shall follow him as well as physics and electronics, and define acoustic as designed to carry sound and capable of doing so⁽¹⁰⁾, and auditory as pertaining to hearing⁽¹¹⁾ with the proviso: perceptual under normal field conditions⁽¹²⁾. But is segmentation by the ear possible? Hardly twenty years ago M. Joos expressed the opinion "We can only guess that speech may possibly be analyzed into segments in the perceptual [our auditory] aspect also."⁽¹³⁾ And his reviewer states: "Perception of speech is inaccessible to exact investigation. Whatever can be said about it is mere speculation."⁽¹⁴⁾ The situation has changed since the gradual rise of psycholinguistics.

Moreover, results obtained from synthetic speech, when checked against life-speech, led e.g. to the sweeping statement: "It is by no means true, that the acoustic cues for manner, place and voicing are located in separate segments of...the utterances."⁽¹⁵⁾ A paper on segmentation written today must therefore combine all three aspects: the articulatory, the acoustic and the auditory. We hope to prove that this can be done even though the main source of information, as coming from taped speech, is acoustic. To indicate how this was done calls for a brief account on instruments to be used and on methods employed.

1.20 INSTRUMENTS

Following the principle that instruments should be selected on the basis of the job they are expected to do, and be at the same time economical both in terms of time and funds, a variety of instruments seems preferable to the exclusive use of one which is rather complicated, provided a variety of hardware is at hand. For segmentation the following instruments are available at the Tien Speech Research Laboratory (TSL): oscillomink with accessories, oscillograph with photographic registering equipment, electronic segmentator, and a spectrograph.

1.210 OSCILLOMINK SIEMENS

The oscillomink is basically an oscillographic voltmeter⁽¹⁶⁾ designed to reinforce the fundamental frequency and to display the harmonics present within frequencies up to the first thousand cycles. This makes the oscillomink fit for certain applications in speech research though it was neither exclusively nor primarily designed for that. As for segmentation, the restriction to the first kilocycle certainly does not interfere with the faithful display of the duration of processes investigated. Moreover, checks with a full scale oscilloscope show that this restriction does not suppress any information that is significant for the auditory domain. The decisive advantage of the oscillomink is that it works in 'real time'⁽¹⁷⁾ that is as fast as one speaks. It is also quite economical, especially if one in full-scale investigations uses paper that is available on the local market.

The usefulness of the oscillograph can be increased through accessories.

1.211 ACCESSORIES

For segmentation the High Speed Attachment comes in most handy. It increases the paper transport from 20 cm/sec to 2 m/sec, that is ten times. Since a speed of 2 m/sec adds practically nothing to traces written with half that speed, our work was mostly done at 1 m/sec. Each mm of the trace then corresponds to a millisecond of time in the speech event, a resolution that can conveniently be studied with the naked eye. For the study of intonation the Pitch Meter was used, an accessory to the oscillograph furnished by Fa. Frøkjær Jensen of Copenhagen. Though it works on a principle disparate from that of the ear⁽¹⁸⁾ its results are conform to it. Jensen's Intensity Meter displays intensity changes.

1.22 SEGMENTATOR HS 31

The HS 31⁽¹⁹⁾ was constructed in 1964 at the Phonetic Laboratory of the University of Hamburg. It is an electronic gating device of the kind described by Hart—Cohen,⁽²⁰⁾ able to select events of 5 ms duration. This is a time span which is below the threshold of hearing if both perception and identification of a speech event is called for. The segmentator is fed from a tape loop from which it either selects successive portions—a process that may conveniently be called scanning—or from which it exhibits in stationary operation the same portion of the loop for an indefinite length of time. Made visible on an oscilloscope it can conveniently be photographed. For that purpose the TSL has constructed its own Microsecond Timer as an accessory to the HS 31, thus making it possible to photograph shortest events with unfailing precision.

1.23 OSCILLOSCOPE PHILIPS PM 3206

The PM 3206 is good for a range of 300 kilocycles. Primarily intended as a servicing instrument it also can supply information not obtainable from instruments with a more limited capacity. Its accessory, Philip's Photographic Registering Equipment PM 9300

contains a Rolleicord camera which takes both ordinary and Polaroid films. It thus becomes possible to take oscillograms of events that last only one millisecond but are extended over a stretch of 8 cm.

1.24 THE SONAGRAPH

The 1965 Kay Electric Sonagraph Model-Recorder is in principle a spectrograph. That is to say it exhibits in a band the information that is contained in the linear representation provided by an oscillograph. What difference that makes is described in a wealth of literature. It may suffice to name three contributions⁽²¹⁾ about evenly spread over the twenty years of the history of spectrographic research in speech. The sonagraph at the TSL has a range of twelve kilocycles. It makes broad and narrow band analyses, 'normal' and inverted sections, magnifications of these four analyses, and amplitude displays. Developed and most widely in use in the United States of America the spectrograph has made it possible to produce true synthetic speech. In recent years it has also provided an opportunity for psycholinguistic experiments in the auditory domain. In this paper the sonagraph will be mainly used to illustrate clues found by other methods of segmentation.

1.30 METHODS

The methods used in this paper consist in finding segments, in rearranging them, and in the preparation and use of listening tapes.

1.31 FINDING SEGMENTS

Recorded speech is written with the oscillomink. It is then first necessary to establish the relation between the length of tape and that of the trace written by the oscillomink in a unit of time. When the speed of the oscillomink is twenty cm/s and that of the tape 19 cm/s, 0.95 units of tape length will correspond to one unit of trace length. Since the registration on the tape is invisible, a point must be marked from which measurements can be made backwards and forwards. This is easiest achieved by inserting a few bursts in a blank space of the tape by means of a frequency beat oscillator. At the place of this additional recording a first cut is

made in the tape using a pair of nonmagnetic scissors, and a stretch of white non-magnetic band is inserted between the two ends so cut. When the tape is written again on the oscillograph it contains a blank section, the first part of the additional recording, another blank stretch, the second part of the additional, and then the original recording. The time relation between these items is now fixed, and what can be measured on the trace, can with almost the same ease be measured on the tape. At speeds of 19 or 20 cm/s respectively 0.95 mm of tape will correspond to 5 ms of real time. Should higher resolution be desired, the fast speed attachment to the oscillograph will bring an 'enlargement' of, say five times, on the trace. To obtain a similar effect for the tape a professional tape recorder is required. The fastest presently available runs at 1.524 m a second. That will provide 1.524 mm of tape for a ms of speech. The oscillograph writing is now scanned for points of significant changes. Tentative cuts at corresponding places in the tape are most likely to coincide with borders of linguistic units. But in the majority of cases slow transitions take the place of abrupt changes and between these there appear neutral stretches. Cuts made in these areas must always be verified by the ear playing the spliced tape back time and again in order to ascertain the real boundary. In doing that, cuts must not be made too close to each other, lest the original signal will practically be destroyed. Each copy is therefore best cut only once, and a supply of up to twenty copies is made from each loop at the outset. Some consonants leave no obvious marks on the oscillograph trace. They are best processed for further study either with the oscilloscope or the spectrograph or both.

1.32 REARRANGEMENTS OF SEGMENTS

To combine the segments from various copies and to play them back without the listener even suspecting that the tape has been tampered with, is the most simple instance of synthetic work. It is at the same time a valid test for the success of segmentation. It is evident from what has been said that synthetic here does not

mean: produced artificially in its entirety, as e.g. this is done with electronic music. In a second step one combines 'samples' taken from various contexts in order to ascertain which portions make up the substance of speech and which ones are mere results of acoustic conditioning through context. By so linking the acoustic and the auditory aspects the reality of emic⁽²²⁾ units can be proven for the first time.

1.33 LISTENING TAPES

Single psycholinguistic experiments depend to a great extent on their purpose of investigation. Here phonetically similar segments are inserted at random in sequences that are not only fully conform to the syntax and semantics of the language investigated but also matched as to pitch and intensity. Tapes played back to native speakers exhibit in random sequence the original recording and the portions that have been more or less tampered with. The listeners who have been informed about the content are now asked to grade the 'naturalness' of each item. From their answers conclusions can be drawn as to the nature and extension of emic units. This is admittedly quite different from the minute auditory studies reported so far in the literature.⁽²³⁾

1.4 SEQUENCE OF INVESTIGATIONS

There follows a report on a number of investigations of which the first one—on voiced segments—offers a minimum of practical problems. But the study of voiceless segments will require additional instrumentation. The study of juncture, built on the two preceding chapters has proved especially rewarding. Stress and intonation are complicated by the problem which parameters do have the greatest influence on listeners. That segmentation of a language which is unknown to the investigator is possible, is now proven. Limitations appear to be due to the phonetics of the language with which the investigator is most familiar.

2.0 VOICED SEGMENTS

Voiced segments were obtained from recordings of Mandarin Chinese, the mother tongue of our technician. Recordings were made by Mrs. Wang, an instructor of the then Chabanel Language Institute, Hsinchu which is now affiliated with Fujen University. After describing procedures, results will be indicated.

2.1 VOWELS

The recording consists of the word /mae/ in its four tones. We shall call the four items in short conventional terms as (having) the even, the rising, the falling-rising and the falling (tone) respectively. The informant had been asked to do all four, even though she did not remember any word that had the even tone. As segmentation has long been considered an efficient means of studying polyphthongs,⁽²⁴⁾ the vowels were segmented first. Nobody however, to my knowledge, has studied the complication that tones might bring into play. First results came as a surprise to the linguistically rather unsophisticated technician who had just passed a binaural hearing test. In the even and falling tones he could only hear two vowel qualities which he marked as [a+e]. The rising tone gave three [a+e+i], and the falling-rising four [a+ei+e+i]. But with additional use of the segmentator a final [i] was heard in the even and falling tones as well and the [ei] turned out to be an [e]. All these observations fit very well into the general picture of Chinese tones if one is aware that for vowel recognition a relatively high degree of intensity and a certain duration are required. Various investigations of the time that is needed for perception of distinct events are extant⁽²⁵⁾ among whom only Gemelli-Pastori deal with a real speech situation. But even there it is not so clear what the conditions of the experiments were. Was it the experimenter himself who recognized a quality previously known to him? What were the pitch—and intensity conditions? How much time is needed to recognize changes in pitch and intensity? How much masking is done by strong neighboring events that follow? And finally how much is required, should a listener be able not only to discriminate but

also to identify qualitatively different sounds? To answer all these questions would need an extra study. For unaided discernment we are inclined to postulate a time similar to that required for optimal pitch discrimination, namely up to 500 ms,⁽²⁶⁾ the findings of other investigators notwithstanding, namely Janota-Romportl⁽²⁷⁾ with 100 ms for steady-state sounds, or Cramer⁽²⁸⁾ with 20-30 ms. For the discernment of loudness a difference of 3 db is not sufficient according to Hegedus.⁽²⁹⁾ That and other investigations⁽²⁵⁾ do not throw much light on our problem which appears to be one of masking. Masking according to its definition is only at work when two sounds are found contiguously. Segmenting removes that condition whereafter the single sounds can be recognized as the [ɪ] in the even tone and, less readily because of its short duration, the [ɪ] in the falling tone. It should also be taken into account that intensity curves of the items in question show a relative sharp decline.

2.2 CONSONANTS

The role of the initial sound in Chinese morphs in reference to their tone is a disputed question. According to Y. R. Chao, Chinese tones are spread "over the voiced part of the syllable."⁽³⁰⁾ This implies the statement that, while the voiced initial is part of the tone, the voiceless initial does not contribute anything to it. Another recent publication considers all initials as not pertaining to the tone.⁽³⁾ Dealing with the same problem some years ago I asserted⁽³²⁾ that both the voiceless and the voiced initial are under the influence of Chinese tones which amounts at least to a tonetic diversity of the same initial in various tones. This is all that can be said after a simple inspection of acoustically obtained traces. The question of whether or not initials are tonemic can only be decided after synthetic work and its auditory evaluation. It may be pointed out that in the study referred to above all samples were studied in the same context namely in isolation. This time the study was restricted to one voiced initial and its behaviour in the four tones. Segmentation yielded the following data for the initial [m-]:

tone	length	pitch	intensity in db
even	220	even at 220	rising: 25-47
rising	150	rising-falling: 200 to 226 to 200	rising-falling: 35-45-35
mid-low	100	falling: 300 to 250	rising: 25-47
falling	300	rising: 160 to 200	rising: 25-40

2.3 LISTENING TAPE

With the above facts in mind a random listening tape was made in order to ascertain the roles of the following entities in Chinese tones:

- a) the phonetic nucleus
- b) the phonemic nucleus
- c) the initial versus the rest of a morph (yün).

Synthesized and non-synthesized items were connected in random sequence and the listeners were first asked how an item would rate on a scale of four in naturalness. The second question was: what tone is represented by the item? As each item consists of two or more segments which are taken from the four Chinese tones, this gives the following table for the phonetic nucleus:

item	[m]	[a]	[ei]	grades	tones
2	2	1	2	3	φ
3	1	4	1	4	φ
5	4	1	4	3	4
8	3	2	3	3	2
9	3	4	3	3	φ
10	1	3	1	3	φ
12	3	1	3	2	2
19	2	3	2	3	3
21	2	4	2	3	φ
31	4	2	4	2	φ
35	1	2	1	3	1
37	4	3	4	2	φ
12				36:12	8:12

This shows that the average degree of naturalness was 3 (strange) and that 66% (8 of 12) were given no tone class or a wrong one. It follows that exchanging the phonetic nucleus destroys both naturalness and tone class. For the phonemic nucleus the following table was obtained:

item	[m]	/a/	[ei]	grades	tone
4	2	4	2	1	2
7	1	3	1	2	ϕ
14	3	2	3	1	3
15	3	4	3	2	3
17	1	4	1	3	1
25	1	2	1	3	2
27	3	1	3	1	3
29	4	1	4	1	4
30	2	3	2	1	2
32	2	1	2	2	2
33	4	2	4	1	4
34	4	3	4	2	4
12				20/12	

The average degree of naturalness was 1.6, which is a deflection just notable. With two exceptions tones were correctly identified according to the phonetic surrounding of the nucleus. It follows that the /a/ is a phoneme, and that the selection of another allophone is barely noticed and does not alter the meaning consistently. For the initial see the following table:

item	[m]	[aei]	grades	tone
1	4	1	2	1
11	3	4	1	4
18	1	3	2	3
20	2	1	4	1
22	3	1	3	1
24	1	4	1	4
24	2	4	2	4
26	4	2	1	2
28	2	3	2	3
38	3	2	1	2
39	1	2	2	2
40	4	3	1	3
12			22:12	100%

The average degree of naturalness was 1.83 that is less than when exchanging the phonemic nucleus. The identification of tones was 100% correct. This is a clear proof that the voiced initial in Chinese tones is a phoneme and that its alternants are unable to change the meaning of a morph.

Our segmentation of polyphtongs has thus brought about the identification of their elements together with their prosodic properties (duration, pitch, intensity). It has also proven the acoustic basis for setting up vowel phonemes for their nucleus. Moreover initials of various tones are only phonetic variants.

3.0 VOICELESS SOUNDS

With permission of Fa. Cornelsen a copy was made of unit 11, number 24 of a recording done under the direction of Prof. G. Scherer⁸⁸, Berlin which is designed to illustrate secondary stress in English. Diverting the attention of the speaker to something else makes recordings often more valuable.

3.1 SOUNDS STUDIED

Twelve word-pairs that contain voiceless consonants in all positions both stressed and unstressed were therefore selected from this tape on stress. The recording exhibits a male voice and is that of either Mr. Armour or Mr. Taylor. Tape loops were made of each word pair and of these again some 20 identical copies. A list was prepared which exhibited the voiceless sounds contained in this corpus and their position:

word	initial	medial	final
character	<i>k</i>	<i>k+t</i>	
characteristic	k	k+t; s+t	
pronounce	p		<i>t+s</i>
pronunciation	p	t+s; š	
qualify	k		
qualification	k	k; š	
peculiar	p	k	

word	initial	medial	final
peculiarity	<i>p</i>	<i>k; t</i>	
temperament	<i>t</i>	<i>p</i>	<i>t</i>
temperamental	<i>t</i>	<i>p; t</i>	
examine		<i>k+s</i>	
examination		<i>k+s; š</i>	
central	<i>s</i>	<i>t</i>	
centralization	<i>s</i>	<i>t; š</i>	
particular	<i>p</i>	<i>t; k</i>	
particularity	<i>p</i>	<i>t; k; t</i>	
instrument		<i>s+t</i>	<i>t</i>
instrumentation		<i>s+t; t; š</i>	
interpret		<i>t; p</i>	<i>t</i>
interpretation		<i>t; p; t; š</i>	
material		<i>t</i>	
materialistic		<i>t</i>	<i>k</i>
superior	<i>s</i>	<i>p</i>	
superiority	<i>s</i>	<i>p; t</i>	

The 22 sounds of this list that are represented by italics were selected for segmentation and closer inspection. As expected the segmentation of voiceless clusters needed considerable time, although the oscillomink trace provided enough clues as to indicate where the nucleus of each sound was. The length of these sounds was now measured in ms, and the following (average) values were obtained:

sound	initial	medial (in clusters)	final
<i>p</i>	29.20	119.56	
<i>t</i>	93.00	98.64 (45)	
<i>k</i>	53.50	149.00 (113)	152.85
<i>s</i>	100.55	(112)	
<i>š</i>		105.25	

Our next interest centered on the question as to how voiceless sounds appeared in the oscilloscope. As expected, the high-frequency portions became now visible and were photographed.

3.2 LISTENING TAPE

From a listening tape with a random distribution of the segments that had been studied listeners were asked to identify the following voiceless sounds:

no.	sound	word
1	k—	<i>character</i>
2	—k—	character
3	—t—	character
4	k—	<i>characteristic</i>
5	—k—	characteristic
6	—t—	characteristic
7	—s—	characteristic
8	—t—	characteristic
9	k—	characteristic
10	p—	<i>peculiarity</i>
11	—k—	peculiarity
12	—t—	peculiarity
13	t—	<i>temperamental</i>
14	—p—	temperamental
15	—t—	temperamental
16	—s—	instrumentation
17	—t—	instrumentation
18	—t—	instrumentation
19	—t—	materialistic
20	—s—	materialistic
21	—t—	materialistic
22	—k—	materialistic
23	s—	superiority
24	—p—	superiority
25	—t—	superiority

The first impression of the listeners was that they were asked to do something impossible. There is no smooth onset or cauda for any sound. Besides, sounds differ very much as to intensity. A phonetically trained listener got four answers right on one run but when listening on another occasion his answers were not consistent.

The answers of others were close to mere guesswork. This seems to justify the conclusion that voiceless stops segmented from life speech cannot be identified even though their length exceeds 100 ms. The failure is not only due to acoustic-auditory factors, as stops ad hoc produced in isolation can generally be identified especially by trained linguists. Statements about the threshold for speech recognition should therefore indicate in great detail what is to be recognized and under what conditions.

4.0 JUNCTURE

That linguistic units can be joined in various ways was always known and gave rise to various puns: e.g. the French:

	il est tout vert	'it is all green'
and	il est ouvert	'it's open'

The problem is whether such pairs are completely homophonous or whether they differ in some sounds or at least sound features. From the year 1931 we have a lengthy list⁽⁴⁹⁾ of such pairs, without mentioning juncture or any attempt of systematization. From less than a decade later we have N. Trubetzkoy's⁽⁵⁰⁾ teaching on boundary signals from which it becomes evident that the phenomenon, as found in a great many languages, is of interest to general linguistics.

Trubetzkoy already deals with the emic status of boundary signals, and distinguishes positive and negative signals in cases where the second is not a zero element. He further makes clear that such signals are used in various languages to mark morph- or word boundaries or both. One might add that boundary signals are not restricted to phonology or morphology. They are very important in syntax as well and a great help there for analyzing unknown texts. The term used by Trubetzkoy shows a slightly different way of looking at the phenomenon than does the other term now commonly in use: juncture. It seems to have been introduced by Trager and Bloch together with a limited amount of systematization.

The authors believe combination, not separation to be the basic function of juncture. They distinguish external open juncture which

is next to a pause, internal open juncture, marked by similar signals, but not joined to a pause, and close juncture marked by signals at that time not yet clearly defined, but expected to be found by 'experimentalists.'⁽⁵¹⁾ The challenge was accepted by I. Lehiste⁽⁵²⁾ who through a combination of spectrographic analysis and listener response was able to prove the existence of junctures for American English. According to her, junctures are phonological and not internally related to morphologic or syntactic entities. Lehiste's later studies include Estonian which, according to the author marks syllable boundaries, and has a set of juncture phenomena which is quite different from English. The aim of the present paper is not primarily to check or to modify previous results. On the contrary it wishes to point out, that by a different method of investigation similar results may be obtained faster and more economically.

4.1 ENGLISH JUNCTURE

The following twenty sentences were recorded by a native speaker of General American English:

There is no training today.
It's not raining today.
He is a nice man.
I would welcome an iceman.
One's two lips.
They sold all their tulips.
It sprays easily.
It's praise unlimited.
The night-rate is cheaper.
The nitrate is an acid.
It's just a name.
One ought to have an aim.
An ocean of pleasure.
His notion of pleasure.
The attack was imminent.
Let me have a tack.
It was just a tease.

Always at ease.

Why choose her?

She polished her white shoes.

From these sentences the following pairs were obtained through segmentation:

no training	not raining
a nice man	an iceman
two lips	tulips
it sprays	it's praise
the night-rate	the nitrate
a name	an aim
an ocean	his notion
a tack	attack
a tease	at ease
white shoes	why choose

Of these minimal pairs oscillographs were written and the length of the sounds that are contiguous to junctures were measured. Here are the results in ms:

no training:	[n]	80	not raining:	[n]	64
	[c]	100		[o]	90
	pause	60		[t]	40
	[t]	70		pause	20
	[r]	30		[r]	62
a nice man:	[ə]	62	an iceman:	[ə]	60
	pause	ϕ		[n]	56
	[n]	68		pause	ϕ
	[ae]	130		[ae]	140
two lips:	[t]	70	tulips:	[t]	50
	[u]	120		[u]	82
	pause	ϕ		[l]	20
	[l]	30		[r]	66
	[i]	70			
it sprays:	[r]	56	it's praise:	[r]	56
	[t]	40		[t]	45
	pause	50		[s]	45

	[s]	60		pause	80
	[p]	38		[p]	40
	[r]	28		[r]	28
night rate:	[n]	64	nitrate:	[n]	58
	[æ]	108		[æ]	90
	[t]	52		[t]	64
	pause	φ		[r]	66
	[r]	76		[ei]	100
	[ei]	130			
a name:	[ə]	52	an aim:	[a]	56
	pause	φ		[n]	58
	[n]	76		pause	φ
	[ei]	172		[ei]	225
	[m]	160		[m]	210
(a)n ocean:	[n]	50	notion:	[n]	40
	pause	φ		[o]	128
	[o]	130		[š]	92
	[š]	108		[n]	76
	[n]	86			
a tack:	[ə]	72	attaack:	[ə]	40
	pause	φ		[t]	90
	[t]	98		[æ]	124
	[æ]	166			
a tease:	[a]	58	at ease:	[a]	68
	pause	60		[t]	38
	[t]	72		pause	φ
	[i]	260		[i]	340
white shoes:	[wh]	60	why choose:	[wh]	60
	[æ]	92		[æ]	140
	[t]	90		pause	φ
	pause	φ		[t+š]	140
	[š]	130		[u]	120
	[u]	200			

These data do contain a clue for juncture: the sound that follows it is always longer. However, as the difference sometimes amounts

to barely a centisecond this can only be considered a secondary clue. After that pitch- and intensity curves were written from our minimal pairs. As for pitch-curves only the following items show differences:

item	context	tune
white	white shoes	rising
why	why choose	even
tack	a tack	falling
-tack	attack	rising-falling

This is easy to explain. In contrast to all the other sentences these items fill different slots in different syntactic constructions. Tune being a matter of intonation in English, the pitch curves contain no clues concerning junctures. The case is different with the intensity curves:

no training	prolonged return to base line on tr-.
not raining	instantaneous return to base line between -t and r-.
a nice	fast rise, then fall on [ə]+[n].
an ice-	slow rise, then even on an.
two lips	words separated by valley, peak on lips, fast descent after it.
tulips	no valley, peak on tu-, slow descent after it.
it sprays	higher rise, shorter valley (156 ms), late second peak.
it's praise	lower rise, longer valley (170 ms) early second peak.
the night-rate	longer valley (86 ms) between night and rate.
the nitrate	shorter valley between [ae] and [ei].
a name	only slight valley after [ə].
an aim	marked valley after [n].
an ocean	late peak at [o] with marked fall after it.
a notion	peak in middle of [o] with slow fall after it.
a tack	longer valley (62 ms); second elevation has less intensity (49 db).
attack	shorter valley (44 ms); second elevation has higher intensity (51 db).
a tease	first elevation (80 ms) to 45 db, return to base line for 110 ms,

at ease	first elevation (110 ms) to 49 db, no return to base line.
white shoes	early peak on white, long return to base line (200 ms), first peak 55 db.
why choose	late peak on why, shorter return to base line (116 ms) first peak 52 db.

Differences in intensity are thus found in each pair. To detect a general behaviour it will be helpful to study the items that contain no juncture:

tulips	nitrate
notion	attack

Considering them as basic we find that junctures are marked in their contrasts by reduction of intensity. This is manifested in various ways e.g. through a delay of the peak in the item *ocean*. The same reduction, manifested for each item in its own way, is found in our other twelve instances. Acoustically there are thus two prosodic cues for English juncture: reduced intensity at the place of juncture and lengthening of the sound after it.

4.3 LISTENING TAPE

To check the auditory correlates of these cues a listening tape of 40 items was prepared. In 20 of them junctures were linked with their contrastive surroundings as in the following pair:

why choose	white shoes
------------	-------------

The other 20 items are untouched originals. The listeners were asked to classify items with the juncture to the right—as in no+training—under A, the others—as in not+raining—under class B. Here are the results. Seventeen items were falsely classified, among them 5 originals. The following reasons can be given for that failure.

Synthesis for ten items results in homophony:

no.	4	two	lips	no.	26	why	shoose
	9	it	sprays		29	an	aim
	10	it	's praise		35	no	training
	17	not	raining		37	attack	
	20	an	iceman		38	notion	

A second group contains juncture signals below the threshold of hearing (5 items):

In nos. 13 and 22 a tack for attack and viceversa postjunctural [t] is only 8 ms longer and the junctural valley though 18 ms longer than its contrast lies below the threshold of hearing.

In no. 14 an ice for a nice
postjunctural [ae] is only 10 ms and postjunctural [m] only 12 ms longer. There is only 1 db difference in the junctural valley.

In no. 25 notion for (a)n ocean
postjunctural [o] is only 2 ms longer. Since no investigation on the effects of displacement of peaks as a sole⁽⁵³⁾ variable exists, it is difficult to indicate what the consequences of an absolute displacement of 28 ms might mean.

As for the last pair, namely a name (no. 19) and an aim (no. 31) we first could find no plausible reason for their poor recognition. That was not due to the length of sounds that follow the juncture. When measured on the original recording, postjunctural n is 40 ms and postjunctural [ei] 53 ms longer than the same sounds in the paired item. As for the junctural valley, it is true that the one between a and name is almost non-existing (49-47-50 db). But it is very clear in an aim (47-25-46 db). A comparison with an oscillomink writing of the listening tape solved the problem. The cut in the item *a name* had by mistake been made well inside the [n]. As a result postjunctural n became only 18 ms longer and the junctural valleys became the same. Thus the two items could no longer be distinguished. We felt there was no need to institute another listening test after the wrong cut was corrected.

5.0 STRESS

An attempt to deal with stress generally, would first have to include a study of the various kinds of stress that are employed in the known languages of the world.⁽³⁵⁾ Too heavy reliance on literature could here be deceptive, as various terms may mean the same thing or same terms may mean different things. Unfortunately the study of stress requires a good knowledge of the languages in question which makes the plan just outlined impractical. But to study the

stress system of a single language is no mean task either, especially its definition as an articulatory, acoustic or auditory phenomenon with length, pitch or intensity prevailing.⁽³⁶⁾ It is for the lack of agreement on such general matters that investigations even of restricted areas⁽³⁷⁾ can not find the approval of others.⁽³⁸⁾

5.1 ENGLISH ADVANCED STRESS

Advanced stress is the shifting of stress as against the stress pattern of the unsuffixed basis by which the main stress of the radical becomes a secondary stress in the derivative.⁽³⁹⁾ G. Scherer has incorporated into his Language Laboratory Drills⁽³⁴⁾ twelve pairs of words designed to illustrate the phenomenon just described. The booklet does not contain any theory, nor do we intend to establish one here.

But the material presented provides a basis for the illustration of an additional application of segmentation by which the validity of an implicit statement as the one above can be ascertained. We made a master copy and prepared 24 tape loops. Each suffixed item was then segmented into basis and suffix. Each word-pair consisted now of three items: the unsuffixed basis, the suffixed basis and the suffix. E. g. from the pair central-centralization we obtained:

the unsuffixed basis: central
the suffixed basis : central-
the suffix : -ization

5.2 LISTENING TAPE

A random listening tape could now be prepared in which the original items were matched by an equal number of synthetic items. In the following list of segments obtained, column III stems from column II.

no.	I	II	III	IV
1	character	characteristic	eharacter-	-istic
2	pronounce	pronunciation	pronunc-	-iation
3	qualify	qualification	qualif-	-ication

no.	I	II	III	IV
4	peculiar	peculiarity	peculiar-	-ity
5	temperament	temperamental	temperament-	-al
6	examine	examination	examin-	-ation
7	central	centralization	central-	-ization
8	particular	particularity	particular-	-ity
9	instrument	instrumentation	instrument-	-ation
10	interpret	interpretation	interpret-	-ation
11	material	materialistic	material-	-istic
12	superior	superiority	superior-	-ity

There follow the items on the listening tape and their composition:

no.	item	no. (list above)	composition
1	characteristic	1	II
2	examination	6	I + II
3	temperament	5	III
4	pronunciation	2	I + IV
5	superiority	12	II
6	examine	6	III
7	characteristic	1	I + IV
8	interpretation	10	II
9	peculiar	8	III
10	temperament	5	I
11	interpret	10	III
12	temperamental	5	II
13	superiority	12	I + IV
14	centralization	7	II
15	interpretation	10	I + IV
16	particularity	8	II
17	temperamental	5	I + IV
18	peculiarity	4	II
19	pronounce	2	I
20	centralization	7	I + IV
21	qualif(y)	3	III
22	instrumentation	9	I + IV

no.	item	no. (list above)	composition
23	central	7	I
24	superior	12	I
25	material	11	I
26	character	1	I
27	pronunciation	2	II
28	materialistic	11	I + IV
29	qualification	3	I + IV
30	pronounce	2	III
31	peculiar	4	I
32	material	11	III
33	particular	8	I
34	examination	6	II
35	character	1	III
36	peculiarity	4	I + IV
37	qualify	3	I
38	superior	12	III
39	particularity	8	I + IV
40	instrument	9	I
41	examine	6	I
42	materialistic	11	II
43	instrumentation	9	II
44	particular	8	III
45	qualification	3	II
46	instrument	9	III
47	interpret	10	I
48	central	7	III

5.3 AUDITORY RESULTS

All untouched items were correctly graded as perfectly natural. So was item 21 *qualify* for which segment I had been inserted into the listening tape instead of segment III, because in contrast with all the other items *qualif-* is not a full word. Five more items obtained grade one. Their intensity curves, when compared with their contrasts, do give indications of advanced or basic stress contrary to expectation. Peak values in db.

no.	item	peak 1	peak 2	stress
9	peculiar-	52	50.5	advanced
17	temperament	52	49	basic
36	peculiar	51	47.5	basic
39	particular	51	48	basic
44	particular-	50	51	advanced

But the ear did not perceive these indications, either because they were not clear enough (items 9, 44) or they were too weak (items 17, 36, 39).

The following items obtained grade two:

no.	item	peak 1	peak 2	stress
4	pronuntiation	54	52.5	basic
13	superiority	54	45	basic
22	instrumentation	55	46	basic
29	qualification	53	49	basic
46	instrument-	47	50	advanced

Of these only item 46 is expected to have basic stress. In reality it clearly has advanced stress. It was therefore classified as acceptable but manipulated. All the other items should have advanced stress because of their suffix. They do not. Lengthening of the second peak up to 200 ms (item 29) can not make up for that.

Eleven items were given grade three:

no.	item	peak 1	peak 2	stress
2	examination	54	45	basic
3	temperament	51	50	advanced
7	characteristic	54	50	basic
11	interpret-	52	52.5	advanced
15	interpretation	55	51	basic
20	centralization	53	47	basic
28	materialistic	54	46	basic
30	pronunci-	54	49	advanced
32	material-	52.5	52	advanced
35	character-	51	53	advanced
38	superior-	51	53	advanced

Again all the items with basic stress were expected to have advanced stress. This is not the case with any of the items labelled as basic. On the other hand the items with advanced stress should have basic stress. Three of them (3, 30, 32) in fact do, but the signals are at the most 3 db apart and thus create the impression of hesitancy. The items 11, 35 and 38 on the contrary have advanced stress the last with its flat second elevation of 105 ms length showing that all too clearly. But once again the effect is strangeness.

Two items were found to be very strange:

no.	item	peak 1	peak 2	peak 3	stress
6	examin-	53	47	49	advanced
48	central-	55	50	48	advanced

One could add to them the item 35 qualifi-, if it had been segmented. These items contain more than two peaks, while their untouched contrasts have only one really marked peak. It is this feature which earned them grade 4.

Finally, in order to find out what is meant acoustically by basic or advanced stress we have to list the items that were left unsegmented. There are two groups of them: unchanged items with basic stress and unchanged items said to have advanced stress. The first peaks of items with basic stress pattern are on the average nearly 6 db higher.

no.	item	peak 1	peak 2
10	temperament	52	47
19	pronounce	54	52.5
23	central	53	47
24	superior	54	45
25	maternal	54	46
26	character	54	50
31	peculiar	51.5	47.5
33	particular	51	48
37	qualify	53	49
40	instrument	55	46
41	examine	54	45
47	interpret	55	51

Items with advanced stress are far less neatly patterned:

no.	item	peak 1	peak 2	peak 3
1	characteristic	51	53	
5	superiority	51.5	50.5	
8	interpretation	52	52.5	
12	temperamental	51	50	
14	centralization	55	50	48
16	particularity	50	51	
18	peculiarity	52	50.5	
23	examination	53	47	49
27	pronunciation	52	49	
42	materialistic	52.5	52	
43	instrumentation	47	50	
45	qualification	52	46	47

We observe either small (less than 3 db) differences in peaks (items 1, 5, 8, 12, 18, 27, 42, 43) or an added peak (items 14, 49, 47). Levelling of peaks rather than transposition of them is thus the acoustic signal for 'advanced' stress.

6.0 INTONATION

A recent monograph on intonation⁽⁴⁰⁾ and the well founded reservations of its reviewer⁽⁴¹⁾ show that intonation is a topic which is possibly even more difficult to deal with than stress. As for its definition accumulating information on tone languages has made the opinion obsolete that intonation is a matter of tone. Linguists may agree that it is a matter of tune. Alas, unison does not go much further. A problem which appears to be fundamental for some⁽⁴²⁾ is not given the same attention by many others: that is the question of the minimum linguistic unit over which intonation extends. Is it the syntagm, the phrase, the clause or the sentence? Whatever the decision of an author will be, he will have to define his unit within a larger framework of syntax. In spite of vigorous advances by generative-transformational syntax it would be too optimistic to

credit this direction in linguistics with the merit of having provided such a system for general linguistics. The larger portion of research on intonation was therefore done in specific languages especially in English. General attention was focused on the intonation of American English after K. L. Pike's pioneering⁽⁴³⁾ work and paralleled by the work of R. Kingdon that culminated in the book: the Groundwork of English Intonation.⁽⁴⁴⁾ A special problem in English is its rising intonation.⁽⁴⁵⁾

6.1 ENGLISH RISING INTONATION

Here again G. Scherer⁽⁴⁶⁾ has provided recordings which exhibit pairs of sentences that differ by one feature only. In addition to that fact, there is the additional feature that these sentences can be segmented in many places and remain meaningful. This may provide hints on the number of elements an intonation contains and free the few samples from the narrow field of meaning which the 12 original sentences circumscribe. A copy of the recording of the following sentences was made, each being given twice, once with what Scherer calls Low Rise, once with what he calls Fall-Rise:

1. Is there anybody?
2. Was it an error?
3. Is he a foreigner?
4. Can you understand it?
5. Have you seen him?
6. Would she help him?

Pitch- and intensity curves were now written from the six pairs of sentences. Then a tape loop was manufactured for each of the twelve sentences and a supply of identical copies was made. The sentences were now analyzed as to words. To no surprise many of the gaps between written symbols are absent on the tape and in the trace. Thus four days were needed for the analyzing. Here are the results:

Sentence 1: Is there anybody?

a) low rise:

words	ms	pitch in c/s		intensity in db	
is	130	high even at	160	peak	40
there	155	falling to	80	peak	47
any	214	high even at	200	falling to	30
bo-	159	falling to	100	peak	51
dy?	230	rising	80-180		

b) fall-rise:

words	ms	pitch in c/s		intensity in db	
is	94	high even at	180	peak	45
there	122	rising to	250	peak, level	51
any	245	falling to	90	falling	58-25
bo-	167	falling to	60	falling	45-35
dy?	214	rising to	200	peak	49

Sentence 2: Was it an error?

a) low rise:

words	ms	pitch in c/s		intensity in db	
was	142	falling	140-100	peak	47
pause	21	rising	60-200	peak	32
it	129	rising	60-180	rising	25-45
an	130	rising	60-180	rising	25-45
er-		falling	180-100		
ror?	424	rising	100-200	final fall	45-25

b) fall-rise:

words	ms	pitch in c/s		intensity in db	
was	135	rising	120-160	peak	49
it	90	rising	120-200	peak	47
pause	18	valley	60	peak	47
an	105	high	225	slow fall	45-40
er-		falling	160- 60	slow rise	40-49
ror?	450	rising	60-300	slow fall	49-25

Sentence 3: Is he a foreigner?

a) low rise:

words	ms	pitch in c/s		intensity in db	
is	89	level at	180	peak	40
	57	level at	60	peak	40
he	91	rising	60-200	elevation at	43
		falling	200- 60		
a	70	level	60	elevation at	43
foreign-		rising	60-300	falling to	25
ner?	670				

b) fall-rise:

words	ms	pitch in c/s		intensity in db	
is	120	rising	225-275	peak	49
he	80	rising	60-300	peak	51
a	105	falling	300- 60	peak	49
for-		rising	60-180	peak	51
eig-		falling	180- 60	falling	51-28
ner?	575	falling	275-200	final fall	40-25

Sentence 4: Can you understand it?

a) low rise:

words	ms	pitch in c/s		intensity in db	
can	133	falling	225-180	level	37
you	115	falling	250-150	level	37
under-	424	rising	160-300	level	37
		falling	300-200		
stand	465	falling	180- 60	peak	46
		rising	60-300	level at	30
it?	123	rising	160-200	peak	47
		falling	200-160		

b) fall-rise:

words	ms	pitch in c/s		intensity in db	
can	170	level at	250	level at	47
you	62	level at	60	rising	47-49
under	180	falling	150-120	falling	49-37
		rising	120-250	rising	37-48
stand	471	falling	250- 60	falling to	25
				peak	50
				slow fall	50-27
it?	145	rising	60-200	final fall	43-25

Sentence 5: Have you seen him?

a) low rise:

words	ms	pitch in c/s		intensity in db	
have	172	slow rise	120-140	peak	37
you	116	rising	60-160	peak	36
		falling	160- 60	falling below	25
seen	317	level at	225	peak	37
him?	320	rising	60-225	peak	37
		falling	225-100	falling below	25
		rising	100-180		

b) fall-rise:

words	ms	pitch in c/s		intensity in db	
have	174	falling	225- 60	peak	32
you	104	rising	60-250	peak	47
		falling	250- 60		
seen	296	rising	200-250	peak	47+40
him?	335	rising	225-300	elevation at	45
		falling	300-140		
		rising	140-180	final fall	45-25

Sentence 6: Would she help him?

a) low rise:

words	ms	pitch in c/s		intensity in db	
would	101	level	200	peak	46
she	187	falling	180- 60	peak	44
help	300	rising	100-225	peak	46
pause	34	level at	60	peak	42
him?	342	rising	120-225	peak	40
		rising	160-200		

b) fall-rise:

words	ms	pitch in c/s		intensity in db	
would	105	rising	140-200	peak	49
		falling	200- 60		
she	119	falling	300- 60	peak	42
help	228	rising	180-250	peak	50
		falling	250- 60		
pause	17			falling below	25
him?	330	falling	200-120	falling	30-26
		rising	120-250	rising	26-30
		falling	250-160	falling below	25
		rising	160-180		

Synthetic work proceeded in various stages. For step one the two first words of each sentence were considered a unit (phrase). That gave four elements for each sentence pair that could be combined, as illustrated here on the first sentence:

Is there/anybody?	Is there/anybody?
1 a A 1 a B	1 a A 1 b B

Where 1 is the number of the original sentence, a represents the low-rise type, b the fall-rise type, while A means the first part, and B the second part of the sentence. This gave the additional items:

1 b A + 1 b B	1 b A + 1 a B
---------------	---------------

Elements were further exchanged where meaning would permit it as: Is there an error? Is there a foreigner? and Can you help him? Would she understand it? The last item for example provided the combinations:

6 a A + 4 b B	4 b A + 6 a B
---------------	---------------

Another series of combinations was done on the word level, taking care that meaningful relations were not upset. Sentences as the following were now obtained:

Have you seen+anybody?
 Is+it an error?
 Would she help+anybody?
 Can+she+understand it?
 Have you+seen+a foreigner?
 Would+you+help him?

The last sentence gave the following combinations:

Would	you	help him?
6 a	4 a	6 a
6 a	4 b	6 a
6 b	4 a	6 b
6 b	4 b	6 b

6.2 LISTENING TAPE

From these synthesized sentences a random listening tape was prepared which contains 64 items. A slanted line means a cut at

phrase level, + indicates one at word level. The parentheses tell what elements have been combined. Take e. g. sentence three:

"can" is the first word of sentence 4, low rise

"she" is the second word of sentence 6, low rise

the remainder is from sentence 4, low rise

1. Would she help/anybody? (6b, 1a)
2. Is there/anybody? (1a, 1b)
3. Can+she/understand it? (4a, 6a, 4a)
4. Is+it/an error? (3a, 2b)
5. Would she help/anybody? (6a, 1b)
6. Can+she help him? (4b, 6b)
7. Was+he a foreigner? (2a, 3b)
8. Would she help/anybody? (6b, 1b)
9. Is there/an error? (1a, 2b)
10. Can+she/understand it? (4a, 6a, 4a)
11. Can+she help him? (4a, 6a)
12. Have you/seen a foreigner? (5b, 3a)
13. Can you/help him? (4a, 6b)
14. Can+she help him? (4a, 6b)
15. Have you seen/a foreigner? (5b, 3b)
16. Would she/understand it? (6b, 4a)
17. Have you seen/a foreigner? (5a, 3b)
18. Would+you/help him? (6b, 4a, 6b)
19. Would she/understand it? (6a, 4b)
20. Is+it an error? (3a, 2a)
21. Can+she/understand it? (4b, 6a, 4b)
22. Can you/help him? (4b, 6a)
23. Was+he a foreigner? (2b, 3b)
24. Can+she help him? (4b, 6a)
25. Have you seen/anybody? (5a, 1b)
26. Would+you understand it? (6b, 4a)
27. Can you/help him? (4a, 6a)
28. Would she/understand it? (6b, 4b)
29. Would+you understand it? (6b, 4b)
30. Can you/understand it? (4a, 4b)

31. Was+he a foreigner? (2a, 3a)
32. Is he/a foreigner? (3b, 3a)
33. Have you/seen him? (5a, 5b)
34. Would+you understand it? (6a, 4b)
35. Can you/understand it? (4b, 4a)
36. Would+you understand it? (6a, 4a)
37. Is+it an error? (3b, 2a)
38. Would+you/help him? (6b, 4b, 6b)
39. Is there/anybody? (1b, 1a)
40. Is+it an error? (3b, 2b)
41. Would she/understand it? (6a, 4a)
42. Have you seen/anybody? (5b, 1b)
43. Would+you/help him? (6a, 4a, 6a)
44. Have you seen/an error? (5a, 2b)
45. Is he/a foreigner? (3a, 3b)
46. Have you seen/anybody? (5a, 1a)
47. Have you seen/a foreigner? (5a, 3a)
48. Can you/help him? (4b, 6b)
49. Would she/help him? (6b, 6a)
50. Have you seen/an error? (3b, 2a)
51. Would she/help him? (6a, 6b)
52. Would+you/help him? (6a, 4b, 6a)
53. Can+she/understand it? (4b, 6b, 4b)
54. Is there/an error? (1b, 2a)
55. Have you seen/an error? (5b, 2b)
56. Was it/an error? (2a, 2b)
57. Would she help/anybody? (6a, 1a)
58. Have you seen/an error? (5a, 2a)
59. Was it/an error? (2b, 2a)
60. Was+he a foreigner? (2b, 3a)
61. Have you/seen him? (5b, 5a)
62. Is there/an error? (1b, 2b)
63. Have you seen/anybody? (5b, 1a)
64. Is there/an error? (1a, 2b)

As gathered from pages 29-32 the acoustic differences of the two types of English rising intonation are the following:

a) pitch (average values in cycles per second)

word 1	word 2	peak	valley	end
174	125	179	113	203
215	227	205	90	222

The type with a higher valley is the low rise, the other the fall-rise tune.

b) intensity (average values in db)

word 1	word 2	peak 1	peak 2	peak 3
40.16	39.33	38.00	43.66	
40.16	47.66	42.33	41.50	41.00

The fall-rise tune has one extra peak and all of them are—in contrast to the low rise tune—clearly separated by valleys.

When listeners were asked to classify the items as to low rise (a) and fall-rise (b) tunes, 33 items were heard as tune *a* of whom 60% began with an *a* element. While 31 were heard as tune *b* of whom 60% began with a *b* element. How can that be explained? Intonation is best studied with minimal pairs, of which our collection fortunately contains a good number.

With the segmentals 'is it an error?' we have for example the items 4, 20, 37 and 40 that have the following composition:

$$\begin{array}{ll}
 4 : 3 a + 2 b & 37 : 3 b + 2 a \\
 20 : 3 a + 2 a & 50 : 3 b + 2 b
 \end{array}$$

It soon became clear that only those items that are minimal pairs and have the same first element were judged to be of the same tune.

The following items do not conform to that rule:

item	composition	classified	first element (c/s)
6	4 b + 6 b	b	170
11	4 a + 6 a	b	225
26	6 b + 4 a	b	200
29	6 b + 4 b	a	200
34	6 a + 4 b	a	200
36	6 a + 4 a	b	200

It can be seen that the first element of all these items deviates sharply from the average values in terms of cycles per second: 4 a is 48 c/s higher, 4 b is 45 c/s lower. On the contrary 6 a and 6 b have the same height though they should differ by 40 c/s.

Minimal pairs that had more than the first element exchanged do not conform to the above rule. This makes it safe to say that the auditory classification of low rise and fall-rise tunes in English depends on the first element only which therefore is the distinctive signal.

7.0 SPEECH UNKNOWN TO THE INVESTIGATOR

C. F. Hockett⁽⁴⁷⁾ mentions a dispute of the late 1930's on the problem: Can one analyze a language one does not know? He recalls that Boas and Sapir had sent their students out for a summer of 'field work' and accepted their report as an academic paper. He also mentions that note books and file boxes could possibly serve as a substitute for a living memory. Our problem was very much unlike that of Hockett and Sapir: can one segment a recorded sentence into sounds and words, given the assurance that it represents a natural language? Can this be done by a person not linguistically trained? People who can appreciate a good phonetic training might be inclined to say no. So might these answer who believe that the acoustic side represents only a fraction of the linguistic reality. Others that have more confidence in and experience with acoustic records might rather be inclined to answer positively. But the best thing seems to be: simply try. That is what we did.

7.1 A SENTENCE FROM PUEL.

Puel is a North-West African language spoken by the Fouta-Djallon in what used to be French Guinea. The recording was made by a Mr. M. O. Diallo at the Institut Géographique National in Paris and published by Haudricourt-Thomas together with the record.⁽⁴⁸⁾ The material is divided into single words and sentences. Our technician was asked to pick a single sentence from the recordings, to make a tape loop from it and to analyse that loop as to sounds and

words. The sentence selected reads in IPA notation: [ʔardu e ɕeiŋu ma ʃǎpo] 'come tomorrow with your wife'. In it the vowels are reasonably close to the cardinal values and the diacritic ~ means a nasalized vowel. The sentence contains five less common consonants.

- ʔ glottal plosive
- ɓ glottalized voiced bilabial plosive (injective)
- ŋ velar nasal
- ɟ voiced palatal plosive
- ɶ palatal nasal

A preliminary notation entirely relying on the auditory effect contained symbols for fifteen sounds. But their identification was in most cases incorrect. It reflects to a great extent the sound system of Mandarin Chinese, the language with which the investigator is familiar.

His sentence reads: [a:ru:ɕ deu mae ɣaŋɔ:]. There are no consonant clusters in Mandarin, [-ŋg] is the attempt to render a very unfamiliar sound stretch. Mandarin has no glottals nor glottals nor glottalized plosives. The former was completely ignored, the latter heard as [d]. The velar nasal which occurs in Mandarin in final position only, was also missed. One feature of the palatal plosive—also transcribed [dj]—was recognized and by metathesis linked to the preceding element: ma+i. Nasalization was missed, as there are no nasalized vowels in Mandarin Chinese. Nor is there a palatal nasal or a close [o] in Mandarin. So the [ɔ] was selected instead, as the nearest substitute available. Monophthongs in stressed positions are long in Chinese. Vowels that created this impression were marked long. Segmentation corrected a number of these misconceptions and introduced another one instead: exchanging the [r] for the [l], a switch made very frequently by speakers of Mandarin which does not have a rolled alveolar nor a tongue tip [r]. The special writing exhibited in the trace between the [r] and the [u] was isolated and promptly recognized as a [d]. Suspicion arose that the item [deu] contained more than had been heard so far. The feature of velarity was recognized and incorporated as [degu]. Nasality in the last item [ɣaŋɔ] was interpreted as length: [ɣa:ŋɔ:].

In an additional step the initial glottal plosive found its reflex, again by metathesis, in a question mark after the first vowel [a:ʔl du:].

The analysis of sounds completed, the investigator also tried to give the number of words contained in the message. Admittedly a difficult task. Here are his results:

a:ɪl du e
d e gu:
m a e
ya: ŋ g ɔ:

Needless to say the auditory and acoustic information told nothing about the meaning of that message. The solution thus fails to recognize that [e] is a word by itself and would affirm the transition of phonic material from one lexeme to another. For some of these shortcomings the lack of linguistic training in the investigator can be made responsible, and one might expect that a linguist would do better. But even what an untrained person can do shows that an analysis of an unknown language from acoustic data is possible.

8.0 CONCLUSION

The preceding pages might call for a few clarifications, one of a more general nature, the others concerning auditory procedures.

8.1 EMPHASIS ON METHODS

The reader who tries to list our results obtained so far will recall the following: the tonetic nature of the initial in Mandarin Chinese words, the findings concerning the threshold of hearing, the new description of the juncture signal for English, the nature of English advanced stress, a new way of obtaining minimal pairs from a limited corpus in order to classify intonations, and means to overcome one's native prejudices about language.

Whether or not these results are spectacular is beside the point of this paper on a certain method in linguistic research.

8.2 AUDITORY PROCEDURES

Exactness in segmentation and synthesis is essential for the auditory procedures that follow. The listening tape, when completed

should therefore be run through the oscillograph in order to make sure that changes were not made inadvertently. Persons who device listening tapes should only introduce as many distinctions as there are warranted by the material. For only very intelligent listeners might help themselves by adding e. g. a third category to a dichotomy: neither A nor B, or they might assign only two grades out of a scale of four. Further, one might not expect grade one if—as in our material on intonation—the listening tape does not contain unsegmented items.

The number of persons doing the listening tape can ideally never be too large. But substantial agreement of a few unpreoccupied listeners of various background will make even a sharply limited number of judgements usable. Lack of time forced us to employ the latter method for this report. The investigation of remaining differences, in the judgment of listeners is, while very instructive, rather time-consuming.

The above describes only some of the more interesting applications of electronic segmentation.

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使用電子儀器析解語料

FREDRIC F. WEINGARTNER, SJ.

摘 要

藉電子儀器對於語音、韻律和句法用六種析解研究，特別得到關於下列四點的結果：國語音韻學的音不變音調，聽覺所需最小限度的刺激，從有限的語料如何獲得其他語對，而學外語的時候如何克服從小所學語言的影響。

THE NUMERALS OF THE PUYUMA LANGUAGE (KATIPOL DIALECT)

ARNOLD SPRENGER, SVD.

INTRODUCTION

The Puyuma Language spoken by some 6000 aborigines in Eastern Taiwan belongs to the family of Austronesian languages.⁽¹⁾ Almost 2000 people of the Puyuma tribe live in Katipol (Chihpen) village.⁽²⁾ Their language differs considerably from that of Nanwang, the other major Puyuma village. Slight differences have been observed also between the Katipol dialect and the language as spoken in the remaining Puyuma villages. While rather extensive ethnological fieldwork has been done in Katipol village, linguistic analysis of the Katipol dialect is still wanting save for phonetic remarks introducing phonetic transcriptions or some grammatical explanations accompanying written texts.⁽³⁾ Since my own phonemic analysis of the Katipol dialect has not been completed yet, the writing system used in this paper should not be considered fully phonemic. Note that [ɬ] stands for a voiceless, alveolar, retroflex stop, [ʐ] for a voiced alveo-palatal, retroflex fricative, [l] for a voiced (finally voiceless) lateral fricative, [ɭ] for a voiced, alveolar, retroflex (lateral) flap; [q] denotes a forced glottal stop, in final position exploding into [h].

The numeral system of Katipol seems to be a rather complicated one. This probably is due to the fact that the numerals above ten have rarely been used and thus not undergone simplification. The informants had sometimes a hard time figuring out the correct expressions. Abstract mathematical terms denoting addition, subtraction, division etc. do probably not exist in this language. Any attempt to elicit expressions of that type met with failure. Where mathematics has to be dealt with (e. g. in school, in business) Chinese, Taiwanese, or Japanese terms are used nowadays.

Readers not well acquainted with Austronesian languages will be introduced to processes in the formation of words with resulting

morphophonemic changes that can hardly or only to a limited extent be observed in western languages.

1. CARDINALS

1.1 Counting

1.11 The cardinal numbers from 'one' to 'ten'

isa	'one'
zu'a	'two'
ʔəlu (ʔəlo)	'three'
pat	'four'
lima	'five'
ənəm (nəm, unəm)	'six'
pito	'seven'
walu (wało)	'eight'
iwa	'nine'
puləqh	'ten'

1.12 The cardinal numbers from 'eleven' to 'nineteen'

mukʔəp misamaqh la saya	'eleven'
mukʔəp misamaqh la zu'aya	'twelve'
mukʔəp misamaqh la ʔəlu'a	'thirteen'
mukʔəp misamaqh la (pa)pata	'fourteen'
mukʔəp misamaqh la lo'aʔa	'fifteen'
mukʔəp misamaqh la nanəma	'sixteen'
mukʔəp misamaqh la pito'a	'seventeen'
mukʔəp misamaqh la waluwaluwa	'eighteen'
mukʔəp misamaqh la iwa'iwaya	'nineteen'

The numeral mukʔəp misamaqh la saya 'eleven' may be translated: ten have left (part.) one

Note that in the above two sets the two forms meaning 'ten' seem to have nothing in common. The units 'one' to 'nine' differ mainly in that the affix [-a(-ya, -wa)] occurs in the second set suffixed to the forms of the first set. The semivowels [-y-] and [-w-]

preceding [-a] are optional. In addition to the suffix [-a] the feature of reduplication distinguishes digits 'four', 'six', 'eight', and 'nine' of the second set from the corresponding numbers of the first set. Full reduplication is observed e.g. in [iwa'iwa] from [iwa] and [waɭu-waɭuwa] from [waɭu]. Partial reduplication occurs in [papata] from [pat] where the final consonant of the root syllable does not appear in the reduplicated form. In [nanəma] from [ənəm] partial reduplication is accompanied by the vowel change [ə] to [a] the latter vowel being assimilated to the suffix [-a]. The form [saya] from [isa] is marked by the loss of the the initial vowel. An explanation for the change from [ɭima] to [lo'ata] is still wanting.

1.13 The cardinal numbers from 'twenty' to 'ninety-nine'

makav(ə)ʈaqan	'twenty'
makav(ə)ʈaqan misamaqh la saya	'twenty-one'
makav(ə)ʈaqan misamaqh la zu'aya	'twenty-two'
makaʈəlun	'thirty'
makap(ə)təl	'forty'
makalo'aʈ	'fifty'
makənəmən	'sixty'
makapitun	'seventy'
makawałun	'eighty'
maka'iwa	'ninety'

The teens consist of four-syllable words. They are formed by prefixing [maka-] to the units. The unit denoting 'two' does not in any way resemble the one occurring in the previous sets. Most of the other units have undergone various morpho-phonemic changes in the process of the formation of the teens, see e.g. metathesis in [makanəmən] from [ənəm] or the change of vowel plus addition of [-n] in [makapitun] from [pito]. The numbers between the tens may also be formed in the following way:

makav(ə)ʔaqaŋ mimakaʔəlun la zu'aya 'twenty-one' which
 twenty have thirty (part.) one

may be translated with 'twenty plus one of the thirtees.'

1.14 The cardinal numbers 'one hundred' and above

saɭ(ə)man	'one hundred'
saɭ(ə)man misamaqh la saya	'one hundred and one'
saɭ(ə)man misamaqh la ʒu'aya	'one hundred and two'
saɭ(ə)man ʒimukʈəp	'one hundred and ten'
saɭ(ə)man ʒimakav(ə)ʈaqan	'one hundred and
misamaqh la saya	twenty-one'
saɭ(ə)man ʒimakav(ə)ʈaqan	'one hundred and
mimakaʈəlun la saya	twenty-one'
saɭ(ə)man ʒimakaʈəlun	'one hundred and thirty'
saɭ(ə)man ʒimakap(ə)təl	'one hundred and forty'
ʒu'al(ə)man	'two hundred'
ʈəlul(ə)man	'three hundred'
patəl(ə)man	'four hundred'
lo'aʈəl(ə)man	'five hundred'
nəmɭ(ə)man	'six hundred'
pitul(ə)man	'seven hundred'
waɭul(ə)man	'eight hundred'
iwal(ə)man	'nine hundred'
waɭul(ə)man ʒimaka'iwa	'eight hundred and
misamaqh la papata	ninety-five'
sakoʒul	'one thousand'
ʒu'akoʒul	'two thousand'
sakuʒau	'ten thousand'
ʒu'akuʒau	'twenty thousand'
saɭ(ə)man kuʒau	'one hundred thousand'
sakuʒulkuʒau	'one million'
pitokoʒul ʈəluləman	'seven thousand three hundred
ʒimakanəməən mimakapitun	and sixty-five'
la lo'aʈa	

The hundreds and thousands are formed by prefixing the units to [ɭ(ə)man] and [-koʒul] respectively. Note again the loss of [i-] with the unit 'one'. The tens between the hundreds are marked by the prefix [ʒi-].

1.2 Enumerating

1.21 The cardinal numbers for enumerating inanimate and animate objects (except human beings)

sa (sayə) kisi/vuyo	'one bowl/one chicken'
zuzu'aya (zu'aya)	'two'
taʔəluwa (ʔəlu'a)	'three'
papata (pata)	'four'
lalo'aʔa (lo'aʔa)	'five'
nanəma	'six'
pitopitowa (pito'a, papito'a)	'seven'
waluwaluwa (waluwa)	'eight'
iwa'iwaya	'nine'
mukʔəp	'ten'

In some cases the shorter forms, in some cases the longer ones are the same as those employed in the formation of the teens. Younger people prefer [zazu'aya] 'two' to the forms given above or even [ðaðu'aya] 'two' following the general shift from [z] to [ð] that is taking place in the sound system of the young generation. As pointed out before, the main features of word-formation are suffixation [-a] and reduplication with their corresponding morpho-phonemic changes. According to the informants, Puyuma speakers hardly ever go beyond the numeral 'ten' when enumerating objects. If they do, refuge is made to the numerals that have been treated under 1.12-1.14.

1.22 The cardinal numbers for enumerating persons

sasa ʔao	'one man'	a'anəm	'six'
zazu'a	'two'	papito	'seven'
taʔəlu	'three'	wawaʔu	'eight'
a'apat	'four'	a'iwa	'nine'
lalowəʔ	'five'	mukʔəp (papuʔəqh)	'ten'

In most cases [mukʔəp] is used for 'ten' as in [ula mukʔəp (n)a ʔao] 'There are ten people'

Important to note here are again morpho-phonemic changes that occur as a result of the prefixation of [a-] to the forms of 1.11. No

such change is observed with [a'iwa] from [iwa] 'nine'. Forms of 1.11 that begin with a consonant are not only prefixed by [a-] in the process of forming the numbers for enumerating persons, in addition to that the initial consonant of the original form is added to the prefix [a-] functioning as the initial consonant of the new word, e. g. [zazu'a] from [zu'a] 'two', [papito] from [pito] 'seven'. The semi-vowel [w-] in [wawaļu] from [waļu] 'eight' functions like the initial consonants. All the above forms except [sasa] 'one' are three-syllable words. The word [a'apat] from [pat] 'four' fits into this scheme since the two syllables [a'a-] have been prefixed to the one-syllable form [pat]. In [a'anəm] from [ənəm(nəm)] 'six' we observe in the one case a vowel change from [ə] to [a] and in the other another three-syllable formation: [a'anəm] from [nəm].

1.3 The interrogative 'how many?'

The interrogative [papiða] 'how many?' is used with human beings as e. g. in [papiða ʔao] 'how many people?' The interrogative [piðaya] 'how many?' is used with objects other than human being: [piðaya vuyo] 'how many chickens?' A third interrogative [manəman] 'how many, how much?' may be employed at all occasions. The latter word is a reduplicated form of [qman] 'what?'

2. ORDINALS

2.1

For the formation of Ordinals except the first, [puka-] is prefixed to the numerals of either 1.11 or 1.22. But these forms alone suffice only in certain situations which will be described below (2.3) When the people of Katipol make use of the ordinals they often conjoin them with either the adverbial [pukaŋawai] 'in front, before' or the adverbial [puļi'akuʒan (likuʒan, li'akuʒan)] 'behind, after'.

pukaŋawai kaniŋko pukalalo'aʔ	'the fifth before me'
puļi'akuʒan kaniŋko pukalalo'aʔ	'the fifth after me'

To express the idea 'the very first' either of the two following words may be employed: rakaz or ʔaŋorəqh

In the set below the prefix [puka-] plus numerals are given:

puka(za)zu'a	'the second'	puka(pa)pito	'the seventh'
puka(ta)ʔəlu	'the third'	puka(wa)walu	'the eighth'
puka(a)'apat	'the fourth'	puka(a)'iwa	'the ninth'
puka(la)lo'aʔ	'the fifth'	puka(pa)mukʔəp	'the tenth'
puka(a)'anəm	'the sixth'	or puka(pa)puləqh	'the tenth'

2.2

When a certain set with a definite number of things or elements is referred to, the individual members may be pointed out by placing the word [pinaka] 'divide, separate' before the cardinal numbers of 1.11. The Ten Commandments are handled this way.

pinaka isa	'the first'
pinaka zu'a	'the second'
pinaka puləqh	'the tenth'

2.3

If Puyuma people ask for the position or the rank of someone within a group, e. g. what his position or rank in class is, they place [puka-] before [papiða] 'how many?' The answer will simply be [puka'a'apat] 'the fourth' etc.

2.4

When used as adjectives, the ordinals except the first are placed before the nouns, themselves preceded by the particle [ka] 'the, that'. The forms employed are those of 1.11. The 'first' is expressed through [limivak] 'the very beginning'. To illustrate the use of the ordinals the noun [wari] 'day' is introduced here.

limivak kana wari	'the first day'
kazu'a wari'an	'the second day'
kaʔəlu wari'an	'the third day'
kamukʔəp misamaqh la saya wari'an	'the eleventh day'
kamakav(ə)ʔaqan wari'an	'the twentieth day'

The suffix [-an (as in wari'an)] when used with expressions of time generally denotes 'a longer stretch of time, a time where there are many (days, months etc)'.

3. FRACTIONS

The fractions are formed by suffixing the verb-forming affixes [-au] or [-o(Imperative)] to the cardinals of 1.11 and by having these cardinals preceded by the prefix [parka-] 'separate, divide'. In some instances the informants were not quite sure about the correct versions of the numerals.

parakazu'ayau	na	paiso	'divide (in) two that money'
parktəluwau	na	paiso	'divide (in) three that money'
parkapatau	na	paiso	'divide (in) four that money'
parkapato	na	paiso	'divide (in) four that money!' (Imp.)
parkamukʔəpo	na	paiso	'divide (in) ten that money!' (Imp.)

4. DISTRIBUTIVES

A series of distributive numerals signifying 'so many at a time' is formed by the following process: [ka-] is prefixed to the reduplicated cardinals of 1.11 and preceded by the verb-forming prefix [moto-] 'line up...' or by [(k)oto-] 'line up...! (Imp.)'. The first numeral is again set apart in its formation from the rest of the series.

motokasakasa	'(line up) one by one, one after another'
motokazu'azu'a	'(line up) two by two, two at a time'
motokaʔəluʔəlu	'(line up) three by three, three at a time'
motoka'apa'apat	'(line up) four by four, four at a time'
motokalo'alo'aʔ	'(line up) five by five, five at a time'
motokamukʔəpkəʔəp	'(line up) ten by ten, ten at a time'
motokamukʔəp misamaqh la sasasasa	'eleven by eleven, 11 at a time'
motokamukʔəp misamaqh la kazu'azu'a	'twelve, by twelve, 12 at a time'
motokamav(ə)ʔav(ə)ʔaqan	'twenty by twenty, twenty at a time'

5. NUMERAL ADVERBS

The numeral adverbs denoting 'so many times' are made by prefixing [par- (para-, parə-)] to the cardinals of 1.11. Final [-n(-ən)]

is added to cardinal numbers ending in a vowel ('nine' being the only exception). The second numeral adverb is irregular. The prefix [urə-] is employed when the numeral adverb refers to the future, the particle [la] 'past tense, (action) completed' follows the numeral adverb when it refers to something completed.

parasan	'once'	parnəmən	'six times'
parpo'an	'twice'	parpitun	'seven times'
parṭəlun	'three times'	parwaḷun	'eight times'
parpatən	'four times'	par'iwa	'nine times'
parlo'aṭ	'five times'	parmukṭəp	'ten times'
parmukṭəp misamaqh la parasan	'eleven times'		

The Puyuma equivalent for 'how many times?' is [parpiðan].

6. VARIOUS TERMS OF TIME

The Puyuma language does not provide a word for 'week' nor are there any special terms for the days of the week in use. Possibly under the influence of the Japanese a system of counting the days of the week was adopted which to a certain extent is still being used by the older generation while young people use Japanese or/and Chinese terms.

kaliwak wari'an	'Monday'	ka'apat wari'an	'Thursday'
kaṣu'a wari'an	'Tuesday'	kalo'aṭ wari'an	'Friday'
kaṭəḷu wari'an	'Wednesday'	ka'anəm wari'an	'Saturday'
		kapito wari'an	'Sunday'
ka'anəm wari'an harəm	'today is Saturday'		
kapito wari'an noqmanan	'tomorrow is Sunday'		

No term exists for 'one minute'; the word [toki] 'clock, hour' has been adopted from the Japanese. The Puyuma word [qilas] 'moon' may also denote 'month', the word meaning 'year' is [qami].

The time of the day is described in terms of the constellation of the sun and the moon; cock-crowing plays also an important role in determining the time of the day.

Below some more expressions of time are given.

piða(ya) wari'an	'how many days?'
piða(ya) qilas	'how many months?'
no(a)ðaman kana saya qilas	'next month'
no(a)ðaman kana pukazu'a qilas	'two months from now'
no(a)ðaman kana pukaʔəlu qilas	'three months from now'
aðaman kana qilas	'last month'
aðaman	'yesterday, in the past'
aða:man	'day before yesterday, a long time ago'
noqmanan	'tomorrow'
no saya wari qmanan	'day after tomorrow'
	(qmanan 'morning dawn')

The following observed feature is worth noting: the word [aða:man] with a high pitch on [a: (long vowel)] denotes 'in the past, a long time ago'; with a low pitch on [a:] the meaning of the word is 'in the future, a long time from now'.

7. PUYUMA NUMERALS IN SENTENCES

- (1) Ula a'apat na təmak(ə)si kimakavaŋ i
 There is four (Article) student go (locative)
 ðaðaran
 road
 'There are four students going'
- (2) mənəqo ko la mukʔəp misamaqh la lo'aʔa la
 see I (Art.) ten left (Art.) five (Art.)
 vavu'i i ʒənan
 pig (loc.) mountain
 'I see fifteen pigs on the mountains'
- (3) noqmanan ula makav(ə)ʔaqaŋ na nanko lalaŋ
 tomorrow there is twenty (Art.) my same group
 na təmak(ə)si ʒu'a ki'avaŋ
 (Art.) student come play
 'Tomorrow twenty classmates will come and visit me'
- (4) ini'am lalowaʔ mo avəruk mi noqmanan
 we five (Part.) return we tomorrow
 'We five people come back tomorrow'

- (5) mənəqo mi la ʔəlu'a ayam vavi'i
 see we (Art.) three bird fly
 'We see three birds flying'
- (6) nanko vau saya wari parʔəluŋ pas(ə)ki zənan
 my older brother one day three times climb mountain
 'My brother goes three times a day to the mountain'
- (7) na hikoki ito kaʔu'aʔu'a vavi'i kaʔi itas
 (Art.) airplane (Jap.) two by two fly (loc.) high, up
 'The airplanes fly two by two'
- (8) papiða na ʔao kanmo i savak/
 how many (Art.) people you (loc.) inside?/
 wawaļu kani ni'am i savak
 eight (Art.) our (loc.) inside
 'How many people are you at home? We are eight people at home'

8. THE NUMERALS OF PUYUMA AND THE NUMERALS OF OTHER AUSTRONESIAN LANGUAGES

	Puyuma (Katipol)	Tagalog ⁽⁴⁾	Bisayan ⁽⁵⁾	Bahasa Indonesia ⁽⁶⁾
'one'	isa	isa	usa	satu, se-
'two'	ʔu'a	dalawa	duha, duruha	dua
'three'	ʔəlu (təlo)	tatlo	tolo	tiga
'four'	pat	apat	upat	empat (empat)
'five'	lima	lima	lima	lima
'six'	ənəm (nəm)	anim	unom	anam (enam)
'seven'	pito	pito	pito	tudjuh
'eight'	walu (walo)	walo	walo	delapan
'nine'	iwa	siyam	siyam	sembilan
'ten'	puļəqh	sangpoqo	napolo	sepuluh

NOTES

- (1) For more information on this language see Michio Suenari, "A preliminary Report on Puyuma Language (Rikavong Dialect)", in *The Bulletin of the Institute of Ethnology*, Taipei, Academia Sinica, No. 27, Spring 1969, 141-164.
- (2) My sincere thanks to the S.M.B. missionary at Chihpen, Father Patrik Veil, who himself has a working command of the Katipol dialect and

is extremely interested in the linguistic analysis of the language. He invited me to his place and did everything to secure a fast start.

- (3) Ethnological research based on a great amount of tape-recorded texts has been carried out by Dominik Schröder SVD. Up to now the following articles (with notes introducing the phonetic symbols used in the written texts) have appeared: "Die Puyuma von Katipol (Taiwan) und ihre Religion. Ein Kurzbericht aus dem Felde". *Anthropos*, 61 (1966), 267-293.—"Zum Hochgottglauben der Puyuma von Katipol (Taiwan)", *Anthropica*, Gedenkschrift zum 100. Geburtstag von P.W. Schmidt. *Studia Instituti Anthropos*, Vol. 21, St. Augustin, 1968, 323-361. In this latter report D. Schröder introduces his informants (p. 324 f.) who were also extremely helpful to me during my work in Katipol in July 1970 and Jan./Febr. 1971.

In Ogawa, N. and E. Asai.: *Takasagozoku Densetsushu* (Myths and Traditions of the Formosan Aboriginal Tribes), Taipei, 1935, the Nanwang dialect has been dealt with rather extensively (pp. 299-323); the ethnological texts are preceded by a short outline of the grammar (pp. 299-307), but only one Katipol story has been recorded with some grammatical notes accompanying the text (pp. 324-327).

- (4) Blake, F. R.: *A Grammar of the Tagalog Language*. Published by the American Oriental Society, 1925. Reprinted: New York, 1967, p. 22. Tagalog is the chief native idiom of the Philippines, widely spoken in Manila and in the middle region of Luzon.
- (5) Odijik Van. A.: *Elementary Grammar of the Bisayan Language*. Convento Opon, Cebu, 1959, p. 19. Bisayan is the principal language of Cebu and the other Bisayan islands (Philippines).
- (6) Poetzelberger, H. A.: *Einführung in das Indonesische*. Wiesbaden. 1965, p. 35. Bahasa Indonesia is the modern national idiom of Indonesia.

知本村山地語言之研究

ARNOLD SPRENCER, SVD.

提 要

本文有下列目的：(1)喚起語言學家對山地語言的注意。這些語言不久即將消失。(2)顯示山地語言與中南太平洋列島 (Austronesian) 語言的密切關係。(3)簡介某些文字的形成過程。此或未為讀者所知曉。

本文作者現正從事知本村山地語言之研究。此方言到目前還未獲得語言學家的注意。

MARSHALL McLUHAN

OR

THE RETURN OF THE NONLITERATE

PIERRE E. DEMERS, SJ.

Since 1964, the mention of means of communication—or media, as they are now designated—in America or in Europe, unfailingly brings up to mind the name of Marshall McLuhan. 1964 is the year McLuhan's major work *Understanding Media*⁽¹⁾ appeared. As one of the editors noted in dismay, seventy-five per cent of the material was new and "a successful book cannot venture to be more than ten per cent new."

The material was not only new, it was highly controversial. One university professor commented on the author: "He's swinging, switched on, with it, and Now. And Wrong." A book reviewer found him "virtually unreadable," his syntax "soporific," and his metaphors "mastodonian." For a Columbia University coed reading McLuhan is like taking LSD: "it can turn you on. LSD doesn't mean anything until you consume it—likewise McLuhan." For a *Time* book reviewer the book is "fuzzy-minded, lacking in perspective, low in definition and data, redundant, and contemptuous of logical sequence." For another, McLuhan "can only be considered a stimulating thinker on a scale quite similar to Freud and Einstein."

Like Freud, Einstein, and Darwin in their beginnings, McLuhan's new insight into the media has gained him fascinated disciples and exasperated critics. Few are indifferent. His name has now crossed language boundaries. It is indicative of the size of the controversy that the French use *mcluhanisme* to mean the world of mixed-media pop art, while the English use McLuhanism to refer to an irritable handling of concepts and some Americans as a synonym of obscurity.

What seems to excite the most passionate opposition to McLuhan is his analysis and own handling of the medium of the written and printed word. His widely recognized contribution, however, is to

have shifted the attention of students of the media from the effects the *contents* of media have on culture to the effects the media *themselves*, independently of their contents, have on the individual and society, and consequently, on culture.

In one of his illuminating illustrations of what he means, McLuhan tells the story of the contemporary primitive tribe in the Pacific which still used the stone ax as its main tool. The stone ax was hard to make and rare, and exclusively used by male adults. It had become the symbol of male superiority and prerogative. The tribe's way of life was based on this assumption. Civilized men came along and thought the best thing they could do to improve the standard of living of this stone age tribe was to make them a gift of metal axes. They brought such a quantity that everyone in the tribe, men, women, and children could get hold of one. The adult male no longer had his symbol of superiority and prerogative, he suffered in his dignity. The whole life of the tribe underwent radical change.

The point of the story is, of course, that it is not the content of the new medium or the new tool, nor the increased productivity it allows that really affect a culture but the psychical effects the new medium has on the individuals and society. It is the medium that reshapes society, not its content. This insight is rendered more complex by the fact that the contents of media are themselves media; but the contents affect culture as media and not as contents.

The first chapter of *Understanding Media* is entitled "The Medium is the Message." The phrase has become McLuhan's label. It expresses McLuhan's basic insight that all media are extensions of some human faculty, psychic or physical. The wheel is an extension of the foot, the book is an extension of the eye, electric circuitry—telegraph, telephone, television—is an extension of the central nervous system. Such extensions result in changes of balance among the five senses of man, giving dominance to one sense and altering the way man feels, thinks and acts in the new environment he perceives. All media, in other words, work us over completely. This is the point of the title *The Medium is the Massage*⁽²⁾ which McLuhan gave to a

paperback rehashing of the main ideas of *Understanding Media*. He claims the media

are so pervasive in their personal, political, economic, aesthetic, psychological, moral, ethical, and social consequences that they leave no part of us untouched, unaffected, unaltered....Any understanding of social and cultural change is impossible without a knowledge of the way media work as environments.⁽³⁾

The railway, for instance, did not introduce movement or transportation or wheel or road into human society, but it accelerated and enlarged the scale of previous human functions, creating totally new kinds of cities and new kinds of work and leisure. This is quite independent of what the railway medium carries, its content. The airplane, on the other hand, is undoing the form of city, politics, and association that the railway created, simply by accelerating the rate of transportation, quite independently of what the airplane is used for.

The media massage men and society and reshape them into something quite new. McLuhan quotes A. N. Whitehead: "The major advances in civilization are processes that all but wreck the societies in which they occur." This was true of the stone ax tribe; it was also true of the Western world at the advent of the phonetic alphabet.

Before the advent of the phonetic alphabet, the social life of man was basically tribal. He received information by word of mouth, his culture was oral, the dominant organ of sensory and social orientation was the ear—"hearing was believing." The ear favors no particular point of view, there is no point of hearing. Sounds envelop, music fills the air, not a particular segment of the air. "We hear sounds from everywhere, without ever having to focus. Sounds come from above, from below, from in front of us, from behind us, from our right and from our left. We can't shut out sound automatically. We are simply not equipped with earlids. Where the visual space is an organized continuum of a uniformed connected kind, the ear world is a world of simultaneous relationship."⁽⁴⁾ We hear from all directions and distances at the same time—the distant roar of a

jet plane, the nearby baby's cry, a bird's melody, an upstairs radio's jazz quartet, and the shouts of children at play.

Tribal culture, based on the ear, is total and produces an immediate reaction to an action. Man reacts immediately at what he hears. Tribal man lives in a closely knit society, he is personally involved in all the happenings of the village, he is committed, he has not a job to do but a role to fulfill.

The introduction of the phonetic alphabet wrecked the tribal culture and shaped three thousand years of Western history. The phonetic alphabet gave an eye for an ear. It is a construct of fragmented bits and parts which have no semantic meaning in themselves, and which must be strung together in a line bead-like, and in a prescribed order. Through its use Western man acquired the habit of perceiving all environment in visual and spatial terms "particularly in terms of a space and of a time that are uniform, continuous, and connected. The line, the continuum—this sentence is a prime example—became the organising principle of life."⁽⁵⁾ Connected and sequential facts or concepts came to mean rationality and logic. "For many people rationality has the connotation of uniformity and connectedness. 'I don't follow you' means 'I don't think what you're saying is rational....The fact that the most conscious experience has little 'visuality' in it is lost on Western man.'"⁽⁶⁾

The new literate men could read in privacy and in isolation from others. The private, fixed point of view became possible. Literacy conferred the power of detachment, non-involvement. The phonetic alphabet brought about individualism.

Gutenberg's movable types just helped propagate this individualism to the masses and transform the masses into a public. In McLuhan's terminology the public consists of separate individuals walking around with separate, fixed points of view.

In addition printing provided the first uniformly repeatable commodity, the first assembly line—mass production. It is the beginning of the machine which is also linear, produces something at the end of a series of processes. It brought about the industrial world, where everyone has a specialty that is his own and separates him

from the others with different specialties. Each one has a job which is a stage in the vast mechanical process. We are far from the tribal community and its total involvement in each event of the village, where he is an organ in a living whole.

The farthest-reaching psychological effects of the environment created by printing, what McLuhan calls the Gutenberg galaxy, are felt today in existentialism and the theater of the absurd where man is an isolated prisoner of his own consciousness, a self-analysing nut, over-conscious of his unconscious.

The very excess of the visual, uniform, fragmentary, and mechanical world we have known is bringing about a reversal process. The latest major technical development that tends to wreck present society and shape another, in as deep a way as the phonetic alphabet and the Gutenberg galaxy achieved through centuries, is electric circuitry—telegraph, telephone, radio, television, computer, automation.

The first effect of the electric circuitry is to substitute instant awareness for the sequence type of information we have been used to receive through the written and printed word. The new media give man the ability to see, hear, feel, what is happening in the whole world at the moment it happens. Man becomes open to the whole world and consequently feels himself personally involved in what is happening in the whole world.

This total knowledge and the emotional involvement it incurs affect the whole being of man and consequently the society in which he lives. Being open to the "others," man is thus liberated from himself and involved with the others in a community of feeling that includes the whole world. J.F. Kennedy's funeral witnessed by the whole American nation on television at the moment it took place created a nation-wide involvement in depth to the point of causing a community feeling of guilt.

Such community feeling was an attribute of primitive villages, of pre-literate man. The tribe reacted in a block to the happenings of the village, and the guilt of one man was felt to be the guilt of the whole village. Modern electric media are in the process of

making the whole world a village, a global-village, and thus of retribalizing man.

This involvement-in-depth effect of modern media is caused not only by the fact that people witness an event but also, and mainly, by the way the media themselves affect our senses. This is McLuhan's basic insight. Television, for instance, affects us in a way that requires a participation of all our senses. His analysis is worthwhile quoting in full:

The mode of the TV image has nothing in common with film or photo, except that it offers also a non-verbal gestalt or posture of forms. With TV, the viewer is the screen. He is bombarded with light impulses that James Joyce called the "Charge of the Light Brigade" that imbues his "soulskin with subconscious inklings." The TV image is visually low in data. The TV image is not a still shot. It is not photo in any sense, but a ceaselessly forming contour of things limned by the scanning-finger. The resulting plastic contour appears by light *through*, not light *on*, and the image so formed has the quality of sculpture and icon, rather than of picture. The TV image offers some three million dots per second to the receiver. From these he accepts only a few dozen each instant, from which to make an image.

The film image offers many more millions of data per second, and the viewer does not have to make the same drastic reduction of items to form his impression. He tends instead to accept the full image as a package deal. In contrast, the viewer of the TV mosaic, with technical control of the image, unconsciously reconfigures the dots into an abstract work of art on the pattern of a Seurat or Rouault....The TV image....is a mosaic mesh of light and dark spots which a movie never is, even when the quality of the movie image is very poor....The TV image requires each instant that we "close" the spaces in the mesh of light and dark spots by a convulsive sensuous participation that is profoundly kinetic and tactile, because tactility is the interplay of the senses, rather than the isolated contact of skin and object.⁽⁷⁾

This definition of tactile, as of visual, is an instance of McLuhan's use of words that occasioned a field day for his critics. But it helps us understand what he means when he says that the psychic effect of electric media is to alter the balance among the five senses which used to be dominated by the eye in the literate age. The electric age is introducing a culture dominated by the ear, and other senses, by simultaneous perceptions of all senses, which entails a total

involvement of the perceiver, that is, creates an environment favorable to wholeness of being. Electric circuitry is in the process of creating a new environment; "the extension of one sense" he says, "alters the way we think and act—the way we perceive the world."⁽⁸⁾ The tribal man of the electric age, the non-literate, is a man who has developed the ability to perceive simultaneously with all his senses and so to live in depth, in wholeness of being, in sanity. The medium is really the *massage*. Literate man lives on one plane of being only, he has only one "point of view."

McLuhan's view of the psychic effects of the media distinguishes "hot" media from "cool" media. A "hot" medium extends one single sense in "high definition," that is to say, fills it with data, information. Radio, photography, cinematography are "hot" media, because they do not leave much to be filled in or completed by the listener or viewer. They are low in participation.

"Cool" media are the opposite. They extend one single sense in "low definition," their data do not fill the sense but require participation from it and all other senses. A cartoon is a "cool" medium because it provides little visual information that has to be completed by the senses and so requires participation. A photograph is hot, a cartoon cool. Radio is very hot, it requires so little participation that it can be used as background. The telephone is cool, the whole being answers it; even its buzz can hardly be left unanswered; on the stage, the ringing of the telephone creates a dramatic tension. McLuhan illustrates the power of the telephone with an item from the *New York Times* for September 7, 1949:

On September 6, 1949, a psychotic veteran, Howard B. Unruh, in a mad rampage on the streets of Camden, New Jersey, killed thirteen people, and then returned home. Emergency crews, bringing up machine guns, shotguns, and tear gas bombs, opened fire. At this point an editor on the Camden Evening Courier looked up Unruh's name in the telephone directory and called him. Unruh stopped firing and answered, "Hello."

"This Howard?"

"Yes...."

"Why are you killing people?"

"I don't know. I can't answer that yet. I'll have to talk to you later. I'm too busy now."

This classification of media into "hot" and "cool" has become a sort of party game among McLuhan enthusiasts. Some of the more imaginative findings—backward, unmechanized countries are cool, industrialized countries are hot; rustic man is cool, the city slicker is hot; the Charleston with its aspect of a mechanical doll agitated by strings is hot while the Twist, involved in form and improvised, is cool. Nylon stockings are hot, mesh silk stockings requiring participation in filling up the spaces are cool. McLuhan's hint to girls—men don't make passes at girls with glasses because glasses give too much data about the eyes of the wearer; dark glasses, though, invite participation.

TV is cool and combined with the telephone forms the coolest medium at our disposal. It requires the highest unconscious participation, it makes the user live on all planes of existence at the same time; it puts him in instant contact with the global village. It is the opposite extreme of the printed word. The television-telephone generation is a quite different generation from the literate one. The former lives on all planes of existence; the latter on one. The generation gap is psychic.

To the literate man the retribalized TV generation can only appear as retrograde, primitive. In fact it lives totally, in depth, and cares little for the shrunk existence of the literate. Countries making use to the full of electronic media are looked upon as degenerate by countries in the process of industrial development, the ideal social form of the literate. McLuhan quotes *Life* magazine for Sept. 13, 1963, reporting that in Russian restaurants and night-clubs, though the Charleston is tolerated, the Twist is taboo, and explains this attitude by the fact that the Charleston is mechanical and hot, an image of Russian stressing industrialization, while the Twist is a cool and involved form requiring the spontaneity of life and full participation typical of post-mechanical, post-literate countries. Far advanced countries find the *avant-garde* in the cool and primitive, with its promise of depth involvement and integral expression. The TV age is turning the American culture into a cool one that is quite unacquainted with itself.

The danger for this kind of culture in the process of cooling down is a lack of understanding of itself, not knowing what is happening and being driven unawares. Awareness means control and direction: "When IBM discovered that it was not in the business of making office equipment or business machines, but that it was in the business of processing information, then it began to navigate with clear vision."⁽⁹⁾ Without this awareness of the effects of the media, man will try to deal with the problems of the electric age with the tools and modes of thought of the literate age. McLuhan offers Poe's mariner in "The Descent into the Maelstrom" as a model for students of mores. The mariner staved off disaster by understanding the action of the whirlpool in which he had fallen: "I must have been delirious, for I even sought amusement in speculating upon the relative velocities of their several descents toward the foam below." The mariner's insight offers a possible stratagem for understanding our predicament, our electrically-configured whirl.

McLuhan is very harsh on students of the media who focus their attention on the contents of the media and think that improving these will have a great effect on culture, remaining blind to what is really going on in the world—that is—a radical change in the ratio of sense perceptions. He compares these professional and parlor social philosophers to the General Electric Company that makes light bulbs and lighting systems and has not yet discovered that it is in the business of moving information. Such people are rushing into the future looking at their environment in a rear-view mirror instead of around and ahead of them.

The cultural change brought about by the electric media is unconscious and inevitable. McLuhan flays Arnold Toynbee for failing to understand how media have shaped history. Toynbee observed that although Oriental societies have accepted industrial technology and its political consequences, yet on the cultural plane, there is no tendency to abandon the traditional culture and admit a new one. For McLuhan, "this is like the voice of a literate man floundering in a milieu of ads who boasts, 'Personally, I pay no attention to ads.'"⁽¹⁰⁾ The spiritual and cultural reservations that the Orient

may have toward industrial technology will not avail them because the effects of technology do not occur at the level of opinions and concepts, but alter sense ratios or patterns of perception steadily and without any resistance. "The serious artist is the only person able to encounter technology with impunity, just because he is an expert aware of the changes in sense perceptions."⁽¹¹⁾ For instance, the operation of the money medium in seventeenth century Japan had effects not unlike the operation of typography in the West. According to G. B. Sansom in *Japan*:

The penetration of the money economy caused a slow but irresistible revolution, culminating in the breakdown of feudal government and the resumption of intercourse with foreign countries after more than two hundred years of seclusion.⁽¹²⁾

As McLuhan notes after this quotation: "Money has reorganised the sense life of peoples just because it is an extension of our sense lives. This change does not depend upon approval or disapproval of those living in the society."

The psychic and social changes worked by the media are inevitable; the function of the social thinker is to discover what is happening and learn how to ride the newly created maelstrom, in the manner of Poe's mariner.

In McLuhan's view, the educational implications of the new environment are no less than revolutionary. The lack of awareness of what is going on has created a clash between educator and student that may lead to catastrophe unless the Gutenberg trained educators begin to understand the electric trained students. McLuhan's notion of today's youth's predicament is clear:

There is a world of difference between the modern home environment of integrated electric information and the classroom. Today's television child is attuned to up-to-the-minute "adult" news—inflation, rioting, war, taxes, crime, bathing beauties—and is bewildered when he enters the nineteenth-century environment that still characterizes the educational establishment where information is scarce but ordered and structured by fragmented, classified patterns, subjects, and schedules. It is naturally an environment much like any factory set-up with its inventories and assembly lines.

The "child" was an invention of the seventeenth century; he did

not exist in, say, Shakespeare's day. He had, up until that time, been merged in the adult world and there was nothing that could be called childhood in our sense.

Today's child is growing up absurd, because he lives in two worlds, and neither of them inclines him to grow up. Growing up—that is our new work, and it is *total*. Mere instruction will not suffice.⁽¹³⁾

Youth's awareness and capacity for mass protest is well illustrated by a UPI news item from Paris, February 20, 1971:

French high school students bolstered by a unity not seen since the near-revolution of 1968, vowed today to continue their fight against a government already shaken by infighting and labor unrest.... The crowd began to shout the 1968 war cry, "this is only the beginning, continue the fight." They ran through the streets, handing out leaflets calling for continued demonstrations.

The normal reaction of the Gutenberg generation is one of bafflement. What do they want? Why don't they go to class and learn before they commit themselves? McLuhan sees the TV generation as a grim bunch, more earnest and dedicated than the children of any other period. But the youth of today are not permitted to approach the traditional heritage of mankind through the door of technological awareness. This only possible door for them is slammed in their faces by a rear-view-mirror society. They live mythically and in depth. But they encounter instruction in situations organized by means of classified information—subjects are unrelated, they are *visually* conceived in terms of a blueprint. The classroom is now in vital struggle for survival "with the immensely persuasive 'outside' world created by new informational media. Education must shift from instruction, from imposing of stencils, to discovery—to probing and exploration and to the recognition of the language of forms. The young today reject goals. They want roles, that is, total involvement. They do not want fragmented, specialized goals or jobs."⁽¹⁴⁾

In Toronto, a few years back, four randomized groups of university students were given the same information at the same time about the structure of preliterate languages. One group received the information by radio, one from TV, one through lecture, and one in print. All the media, except print, used the same speaker; each

group had half an hour of exposure to the material. Each was asked to fill in the same quiz afterwards. The TV group stood well above the other groups.

In his most recent book, *Mutations 1990*,⁽¹⁵⁾ McLuhan foresees a world-wide use of television for education. It will produce feedback, he says, that is, an awareness of the real effect on the "other," and cause communication to become a dialogue rather than monologue. It will bring down the wall separating the school from daily life, and reach people wherever they are. Then will we realize that the true place of studies is the world itself, the whole planet. The present day insulating school is in the process of becoming the open school, the global-school.

As artists are professionally the most aware of the change taking place in the ratio of sense perceptions today, arts and literature are evolving towards a new form, incomprehensible and irksome to those who ignore the nascent culture of simultaneous perceptions. Renaissance three-dimensional art, with its illusory perspective, is the result of the "point of view" culture created by the phonetic alphabet. The viewer of a perspective by Canaletto stands outside the frame of the picture.

The cubists, ahead of their time, foreshadow the present mass culture of simultaneous perceptions and involvement by suppressing the "point of view" and presenting the object from multiple sides at the same time on a two-dimensional surface, forcing the participation of the viewer. Cubism leads naturally to "happenings" where the mixed media affect the participants at the same time.

McLuhan defines myth as the mode of simultaneous awareness of a complex group of causes and effects. Myth reduces to a moment and a story the long process of development and the complexities of the various planes of existence of humanity. In this sense, electric circuitry confers mythic dimension on our individual and group actions. Student demonstrations, minority violence, protesting marches, are basically "happenings" where everyone does his thing, satisfying the participation mystique of the TV generation. In *The Medium is the Massage* McLuhan shows a photograph of the "the biggest and

best woman in the world," an 82-foot-long 20-foot-high sculpture in Moderna Museet, Stockholm, "you can walk around in her."⁽¹⁶⁾

The best of the cinematographic art is not so much the rival of T. V. as its imitator. McLuhan sees TV commercials as having the deepest influence on the movies. He blames the critics of television for failing to realize that the motion pictures they most praise—such as "The Knack," "Hard Day's Night," "What's New Pussycat?"—would prove unacceptable as mass audience films if TV commercials had not first preconditioned viewers to abrupt zooms, elliptical editing, no story line, flash cuts.

Among artists of the written word, James Joyce ranks highest in McLuhan's mind. He listened to the simultaneous messages of Dublin and released "the greatest flood of oral linguistic music that was ever manipulated into art."⁽¹⁷⁾ Above all the Joyce of *Finnegans Wake* who saw that the wake of human progress can return to "the night of sacral and auditory man." And the Finn cycle of tribal institutions can return again in the electric age, but in full awareness. "Joyce could see no advantage in our remaining locked up in each cultural cycle as in a trance or dream. He discovered the means of living simultaneously in all cultural modes while quite conscious."⁽¹⁸⁾ It is this consciousness that McLuhan tries to awake in his readers.

McLuhan's own way of writing has nothing in common with Joyce's counterpoint technique. *Understanding Media* avowedly tries to imitate Hebrew and Eastern styles as McLuhan sees them:

The Hebrew and Eastern mode of thought tackles problem and resolution, at the outset of a discussion, in a way typical of oral societies in general. The entire message is then traced and retraced, again and again, on the rounds of a concentric spiral with seeming redundancy. One can stop anywhere after the first few sentences and have the full message, if one is prepared to "dig" it. This kind of plan seems to have inspired Frank Lloyd Wright in designing the Guggenheim Art Gallery on a spiral, concentric basis. It is a redundant form inevitable to the electric age, in which the concentric pattern is imposed by the instant quality, and overlay in depth, of electric speed. But the concentric with endless intersection of planes is necessary for insight. In fact, it is the technique of insight, and as such is necessary for media study, since no medium

has its meaning or existence alone, but only in constant interplay with other media.⁽¹⁹⁾

This style, seemingly full of confusion and repetition, produces nevertheless a striking effect of simultaneity which reminds one of Joyce and mirrors the effects of mass media themselves.

The *Medium is the Massage* drops the Hebrew and Eastern mode for the ad mode. It is an exercise in non-Gutenberg style of book writing, imitating the shock technique of ads, mixing picture and word, reminding one more of Blake than of Joyce. "Unless a statement is startling," he says, "no one will pay any attention; they will put it down as a point of view."

The non-Gutenberg mode, however, by avoiding sequence and consequence, finally eliminates order and finality from both art and nature. McLuhan enthusiastically endorses John Cage's statement:

One must be disinterested, accept that a sound is a sound and a man, give up illusions about ideas of order, expressions of sentiment, and all the rest of our inherited claptrap. The highest purpose is to have no purpose at all. This puts one in accord with nature, in her manner of operation. Everyone is in the best seat. Everything we do is music. Theater takes place all the time, wherever one is. And art simply facilitates persuading one this is the case.⁽²⁰⁾

A student of the Diagrams of the Book of Changes, Cage concludes: "They told me to continue what I was doing, and to spread Joy and Revolution." This is also McLuhan's emotional attitude toward the media and the revolution they are operating. His writings are full of the joy, energy, and optimism of the discoverer of a new world, too dear to him to allow suspicion of the evil lurking in it. Forceful in blaming students of the mass media for paying attention to the content of the media and neglecting the psychic and social effects of the media as extensions of the senses, he seems unaware or unscared of the power a totalitarian or hidden persuader can wield in manipulating the media. Such thoughts chill his wary readers but leave him and his followers cool. He is quite aware that we are coming into a world automatically controlled to the point where we could say "Six hours less radio in Indonesia next

week or there will be a great falling off in literary attention," or "We can program twenty more hours of TV in South Africa next week to cool down the tribal temperature raised by radio last week."⁽²¹⁾ Whole cultures could now be programmed, but to McLuhan this power is no more threatening than the power we have now to maintain the equilibrium in the commercial economies of the world. In *The Medium is the Massage* he recognizes that environment as a processor of information is propaganda, but he joyfully argues that propaganda ends where dialogue begins. The defensive strategy is simply to talk to the media themselves. To talk to the programmer is pointless, "like complaining to a hot dog vendor at a ballpark about how badly your favorite team is playing."⁽²²⁾ With so little wariness of the danger, the world we are moving into might not be so much the world of McLuhan's *Mutations* 1990 but that of 1984's Big Brother. Characteristically, McLuhan enthusiasts are found among both economic and political revolutionaries and reactionaries. Both are interested in turning mass communication media into mass manipulation media. Those intent on preserving the liberating power of art recoil before the invasion of what Northrop Frye calls the anti-arts. Anti-arts like publicity and propaganda breed the myth of progress which, in turn, generates a feeling of alienation and anxiety in man. For Northrop Frye, the function of art is to express this anxiety, to denounce the myth, and rebel against it. For Communications Theorist McLuhan the fear, as expressed in the theater of the absurd, comes from the misguided effort of man not to adapt himself to the new technology and environment. It is the same kind of fear that the late medieval theme "The dance of death" expressed before the advent of print technology.

Much of the criticism directed against McLuhan is blind to the Communications Theorist's real reason for energetic joy and optimism, so shocking to the generation of the absurd. Critics tend to ignore McLuhan's repeated statement that the new environment created by the media is for good or bad, but here to stay. His job, he says, is to alert society to what is going on, to force eyes away from the rear-view mirror and make them look around and ahead at the real

environment we are entering into. His joy does not spring from a feeling that the environment is better, but from his understanding of our predicament, our electrically configured whirl. His joy is, again, that of Poe's mariner: "he figures out the relative velocities of currents and saves himself."

NOTES

- (1) McGraw-Hill, New York, 1964.
- (2) Bantam Books, 1967.
- (3) *The Medium is the Massage*, p. 26.
- (4) Ibid. p. 111.
- (5) Ibid. p. 44.
- (6) Ibid. p. 45.
- (7) *Understanding Media*, p. 313.
- (8) *The Medium is the Massage*, p. 41.
- (9) *Understanding Media*, p. 9.
- (10) Ibid. p. 18.
- (11) Ibid. p. 18.
- (12) Ibid. p. 18.
- (13) *The Medium is the Massage*, p. 18.
- (14) Ibid. p. 100.
- (15) Montreal, 1969.
- (16) p. 136.
- (17) Ibid. p. 120.
- (18) Ibid. p. 120.
- (19) *Understanding Media*, p. 26.
- (20) *The Medium is the Massage*, p. 119.
- (21) *Understanding Media*, p. 26.
- (22) *The Medium is the Massage*, p. 142.

馬歇爾·麥克路亨的理論

PIERRE E. DEMERS, SJ.

摘 要

此篇文章在介紹傳播理論學家馬歇爾·麥克路亨 (Marshall McLuhan) 的理論：電化傳播工具，如電話，無線電，電視等，擴展了人們的感官範圍，而人們對四周事物的感性也深受其影響。新的傳播工具正推動著人們。這種推動所產生的精神效果和社會效果相當的深切而廣泛。電化時代 (electric age) 正在創造新的人類及新的社會。

過去的機械時代 (mechanical age) 是由標音字母 (phonetic alphabet) 的發明而產生的最後結果，由於字母的發明，我們的行為則主要以所見，所觀察，行為與思想的離異，以及直線型的邏輯 (the linear type of logic) 為準則，這種現象自然造成了各種機械的發明及機械時代的來臨，這個時代的特徵即是全面的部門化以及行動與反應間的緩慢動作。

在標音字母發明以前，人們是部落羣居的，當任何事件發生時，他們能羣起一致的立刻有所反應。不識字人們的生活比識字人們的生活更整體化，識字的人們只過著以理性主義為水準的生活。

電化時代的人們其生活又回復到以往不識字的部落生活方式。我們的神經系統中心已被技術地擴展到與整個人類息息相關，而且也成為整個人類的一部分，這種擴展後的神經系統同時也迫使我们干與世界上每一事件的結果。我們不再可能繼承那種冷漠而與事無干的西方識字人的生活方式，電工學發展的自然結果將導致人們對事物的整體性，人與人間精神上的溝通，以及對世事警覺的更進一步的需求。我們希望無論何人何事都更能完全表現其整個本質。

麥克路亨的目的在喚起人們對電化時代的警覺。因為如果缺乏對新時代的警覺性，我們將雖已如部落時代的人們不可分離的生活在一起，但仍以舊的，直線型的，破碎的空間及時間型式去思想。至於目前這種意識的擴延是否有益，這並非我們討論的問題；但為了使各個人及各件事更能完全的表現其本質，麥克路亨深信，所有的生物終將和諧一致。

The best teacher is not life, but the crystallized and distilled experience of the most sensitive, reflective, and most observant of human beings, and this experience you will find preserved in our great books and nowhere else.

Nathan M. Pusey
President of Harvard U.

People who do not read have no advantage over people who cannot read.

Mark Twain

SAMUEL BECKETT AND THE NOVEL OF "PHILOSOPHIC MONOLOGUE"

JOHN M. MCLELLAN

Modern English Literature, as compared with that of earlier periods, is intensely "internationalized". This is the result of a process that has been going on for about a hundred years. Three aspects of this process of "internationalization" may be enumerated as follows:

1) Many of the outstanding writers have not been Englishmen. There have been Americans, such as Henry James, T.S. Eliot, Ezra Pound; Irishmen such as W.B. Yeats and James Joyce. There have even been outstanding writers for whom English was not their native language; for example, the Indian, Tagore; the Pole, Joseph Conrad and more recently the Russian, Vladimir Nabokov. For such a large number of the really outstanding writers to be non-Englishmen is a new and astonishing phenomenon.

2) The subject matter of literature has become world-wide. Instead of writing about English life, Conrad described various places all over the world. Henry James' stories are often set in Paris, Rome or Switzerland. Nabokov often writes about Russia or about Germany where he lived for many years. In short, the English novel no longer describes life in England but life all over the world.

3) The English tradition has become mixed with many foreign traditions. James imitated the French novel. Nabokov continued the Russian tradition using the English language. Eliot carried on the manner of the French Symbolists, even writing some of his poems in French. Pound based his style on Provencal, French, Italian and even Chinese models. English has inherited a fantastically varied and complex mixture of styles, conventions and genres from a number of foreign countries.

The emergence of Samuel Beckett as a major writer has added further complications to the situation outlined above. Already liter-

ary historians have had a problem with writers of American birth who have taken English citizenship—Eliot and James are the outstanding examples. There is some question as to whether they should be considered as belonging to British literature or to American literature. But Beckett, for the first time, presents the problem of a British-born author about whom there is a problem whether he should be considered as belonging to French literature or English literature. About half of his published works were first written in English and then translated (usually by himself) while the other half were written in French and later translated (again, with one exception, by himself) into English.

Of course, this is not the first time that an English writer has been bi-lingual. The medieval poet, John Gower, composed works in French and Latin as well as English. At a later period, John Milton wrote his earlies poems in Latin before deciding to use English as his medium. In our own time, T. S. Eliot has written a few poems in French and Ezra Pound has done some writing in French and some in Italian. On the other side, the medieval French poet, Charles d'Orleans (who spent many years in England as a prisoner of war) wrote a number of poems in English. But in all these cases the most important works of the writer have been in his native language and his works in a foreign language have been of secondary importance. Conrad, of course, and Nabokov set examples of foreigners producing masterpieces in English but Beckett is the first major English writer whose most important works were written in a foreign language.

Beckett's use of French is not a mere stunt or a display of his linguistic ability but is the result of a slow evolution. Born in Dublin in 1906, he graduated from Trinity College in 1927, majoring in French and Italian. He taught for about six years. Two of those years were in Paris where he taught at the Ecole Supérieure Normale and the rest were in Dublin. In 1936 he settled down in Paris to stay. His earliest writings were literary criticism; in 1929 an essay on Joyce; in 1931 a book about Proust. After this, he produced some poems and philosophic essays and finally, in 1938, his

first novel, *Murphy*. This novel, like all the books he wrote until the end of World War II, was written in English. Already, however, one language wasn't really enough for Beckett. With the help of a French friend, Alfred Perron, he immediately set to work to translate his novel into French and by the end of 1939 he had completed the job. Since this translation was not published until 1947, many critics have assumed that it was written many years after the original novel, but this is not so. Almost from the beginning, Beckett has been trying to express himself in both languages.

During World War II, Beckett remained in France. First he moved to southern France which, at that time, was under the Vichy government and not occupied by German troops. Later, when the German troops moved into southern France also, Beckett still remained there, in hiding, working as a farmhand in Vaucluze. When the allied armies invaded France Beckett was evacuated but managed to return as a red-cross worker. Thus he remained in France throughout a very difficult period, showing how closely he identifies himself with his adopted country.

It was during this period (1942-44) that he composed his final "English" novel, *Watt*. Again, there was a long delay in getting it published and it did not appear until 1953. This has led some critics to suppose that Beckett continued writing some of his novels in English even after he began to use French as his language of composition. This, however, is not true. Before 1945 he was an English writer who sometimes translated his work into French. After 1945 he was a French writer who usually translated his work into English. Nor was the English translation quickly and easily done. After *Molloy* appeared in French in 1951, Beckett persuaded his friend, Patrick Bowles, to translate it for him, he himself offering to revise and correct the translation. He thought this would save time for himself. He found, however, that it took him even longer to read and correct the translation of another man than it would have taken him to do the translation himself. The translation appeared in 1955—four years after the original. Thereafter, Beckett translated for himself but the time gap between the French and the

English version remained about four or five years. In translating, Beckett was able to revise his text freely whenever he felt this to be advisable since it was a text written by himself. For this reason there are often interesting differences between the French and English versions and a student of Beckett's work should read both.

It was in the early fifties and writing in French that Beckett produced his greatest work: *Molloy* and *Malone Dies* in 1951; a play *Waiting For Godot* (his most famous work) in 1952; *The Unnamable*, which completes the trilogy begun with *Molloy* and *Malone Dies*, in 1953. It is on these four works that I will concentrate attention here.

In 1947 Beckett became interested in the theatre. His first play, *Eleutheria* remains unpublished. His second is *Waiting for Godot* which made him famous immediately. Since then he has written several more, the most famous of which are *Endgame*, *Krapp's Last Tape*, *All That Fall*, *Act Without Words* and *Happy Days*. Two of these were written first in the English version. They form the only exception to the rule that Beckett's original writing since 1945 has been in French. The two plays, *All That Fall* and *Krapp's Last Tape* were commissioned by the BBC and so were first performed in English. Beckett, who dislikes the idea of working on commission prefers to say that they were "suggested" by the BBC.

Beckett's success in the theatre will seem amazing to the casual reader who retains conventional ideas of drama. There are few characters and no action in his plays. There is not even much talk; no clever argument, no social criticism, no expounding of profound philosophical ideas. There is no conflict and no climax. The characters are not individualized or developed. What in the world is left with which to form a play?

If there is a single phrase which could serve to describe the essence of a Beckett play it is probably this: lyrical drama without poetry. It is a form of prose drama that continues the traditions of the poetic drama of the first half of the century. If Beckett inherits something from Ibsen and O'Neill, he inherits even more from Eliot and Yeats. These two poets created a form of drama in

which action, character and conflict were less important than emotions and the verbal forms in which they were expressed. Eliot once remarked that one of his problems as a playwright was that he had difficulty remembering that in a play something is supposed to happen every once in a while. Beckett does not even attempt to remember this. If he holds an audience, it is through the force of his emotion alone and the words in which he expresses it. Yeats and Eliot began with rich emotions expressed in complicated poetic forms and displayed with a touch of pageantry. Their earlier plays were of older, exotic times: the ancient Ireland of Cuchulain; the medieval Canterbury of Thomas Beckett. Their later plays, however, became much more realistic and their style much closer to prose. In his final play, *The Elder Statesman* and, indeed, in all his later plays beginning with *The Cocktail Party*, Eliot writes a poetic drama which is almost indistinguishable from prose. Yeats comes even closer to Beckett in stark simplicity. Many years ago, when I first read Yeats' play *Purgatory*, I thought no one would ever write a more stark and simple drama. The play is only seven pages long. It has only two characters. It is written in an irregular iambic pentameter which is almost free verse. Surely—or so I once thought—nothing could be more short and simple and still retain the form and quality of drama. But Beckett has found an even more radical simplicity. In at least three of his plays there is only one character. The briefest of these is only five pages long and contains no spoken lines at all. The script consists entirely of stage directions. And yet, in this brief pantomime, Beckett is able to express his idea of the relation between God and man and his feelings on the subject. Besides this, in the play of Yeats' which I have mentioned there is some action—and rather sensational action at that. There is a murder (one of the two characters murders the other). Also there are ghosts—indications of another, supernatural world. In Beckett's plays there is no world but this one and nothing happens in it—certainly nothing as exciting as a murder. Moreover, Yeats' language, although flat and plain by the standards of Romantic poetry (including Yeats' early poetry) is not nearly so bald, colloquial and

crude as that of Beckett. Compared to Beckett's work Yeats' simplest play seems florid and melodramatic.

This is also true of *Waiting For Godot* although it is not nearly so short and simple as *Act Without Words* and actually crowds the stage with four characters. "Godot" seems to stand for God and it is possible that the title was inspired by the title of a book by Simone Weil published some years previously, *Waiting For God*. Miss Weil's book is in a mystical vein and suggests that there is no need to "seek God". God himself comes to those who wait if they wait with the right attitude. This seems to be what occupies the characters of *Waiting For Godot*. They are waiting for Mr. Godot who is to meet them at sundown. At the end of Act I Godot sends a messenger to say he will not be able to come today but he will certainly come tomorrow. They are to wait at the same time and in the same place. In Act II they wait once more. At the end of the act Godot sends a messenger to say he will not be able to come today but he will come tomorrow. They are to wait in the same place at the same time. While waiting, the characters express the boredom of everyday life. Godot's failure to appear represents the ultimate frustration. His promise that he will "come tomorrow" indicates that they will spend every day of their lives in the same way only to meet again and again the same ultimate frustration. The play is a brilliant stage representation of an emotion—and an emotion very hard to represent of the stage (without boring the audience): i.e. the boredom and frustration that every man feels every day.

Krapp's Last Tape is a radio play for one actor, written (in English) for performance on the BBC. Krapp is a writer who keeps a kind of diary recorded on tape. In the play, he is listening to passages from the past in his "diary" and making a new recording commenting on the old ones. As we listen to short passages from his life of twenty years before, ten years before, more recent episodes and his comments on all of these we realize his steady degeneration, his frustration, his despair. The purpose of this play like that of Yeats' "poetic drama" is to reveal a "state of soul".

When the revelation is complete, the play ends. The purpose is to achieve what Joyce would have called an "epiphany" and the theory and practice of Joyce as well as Yeats have probably influenced this development. The revelation is accomplished in a very brief span of time (the play lasts about fifteen minutes) and the "tape-recorder diary" is a very clever device for revealing a man's entire life to a radio audience. This play is to be heard and not seen just as *Act Without Words* was to be seen and not heard. The limitations imposed on the drama make it stark and hence more effective. Beckett, being a highly skilled craftsman, is able to adapt himself to either medium—pure sight (pantomime) or pure sound (radio).

In his novels, as in his plays, Beckett is most interested in the inner workings of the mind. He is not interested in the external relations between people nor in external action. His novels are accordingly as unconventional as his plays. The novel centers around one person (Murphy or Molloy or Malone, for example) and explains to the reader the consciousness of that character. Although other people and events are occasionally mentioned the central purpose is always to penetrate deeper into the mind of the narrator. But it is not into his personality or his character that one penetrates but into his consciousness. Character and personality are, for Beckett, externals and he is interested only in the real inner layer of the mind—the man underground as he calls it. Personality and character are different in different people but the man underground is the same in all. This idea is expressed by his making different people in different novels, or sometimes in the same novel, identical. Murphy is Watt is Molloy is Moran is Malone is the Unnamable; and all are Samuel Beckett. Each character is the same person but at a deeper level and Beckett's whole oeuvre is the constant effort to dig deeper and yet deeper into that identity. He is like an archeologist who finds one city under another under another. So the man underground develops into an infinite series until one despairs but, even despairing, must continue. In the closing words of *The Unnamable*, "I must go on. I can't go on. I'll go on."

The style in which this is presented is infinitely flexible and subtle. It owes something to Swift, something to Joyce, something to Proust. But, especially it reminds the reader of Kafka, who was also obsessed with the interior problems of the individual, including the problem of identity. Where Beckett exceeds Kafka is in his stronger emotion and greater sensual impact. Kafka describes things only as they are seen. But Beckett includes smells, feeling, textures. He does not present ideas or even dreams but what seems to be actual experience, yet what we really find are things impossible to exterior experience, things that are actually an exteriorization of interior experience.

Let us take *Molloy* as our first example of "the man underground", an exteriorization of a part of human consciousness. He is completely exteriorized, presented as a physical human being. He has, however, very little control over his body which seems remote from him and self-governing. It is, moreover, in an advanced state of decay. One leg is stiff and the other soon stiffens. At first Molloy rides a bicycle, then he limps along on crutches and finally he crawls, dragging himself painfully along the ground. Throughout all this he is never very certain where he is or where he is going. Sometimes he even forgets who he is. In the second section of *Molloy*, an agent named Moran is sent by a mysterious official called Youdi (probably he represents God) to find Molloy. Moran does not find but becomes very much like Molloy. As he searches, first one leg stiffens, then the other and he returns on crutches. Moran who was previously a respectable, middle-class person seems to have sought and found "the man underground" in himself.

Malone Dies describes a man on his death bed. He is totally alone and never sees anyone—not even the nurse who places food on his table each day. Through the window he watches, with contempt and disgust, the "normal" life of the outside world. Otherwise his time is spent on memories and fantasies. Some of his memories are the same as those of Molloy, so we realize he is the same person, only he is even deeper "underground". The book ends, as the title predicted, with Malone's death.

My feeling at this moment is that this is the best written and most interesting of the three novels. It has two merits in particular that I would like to point out. The first is that it provides excellent examples of what I call Beckett's "abstract description". By this term I do not mean that he expresses abstract ideas or uses abstract language but that he describes people or things in such a general way that all individuality is excluded. For example Malone invents an autobiography of himself, giving himself the name "Saposcats". Here is Beckett's "abstract description" of Saposcats' parents, presented with a trenchant and sardonic humor.

"He was the eldest child of poor and sickly parents. He often heard them talk of what they ought to do in order to have better health and more money. He was struck each time by the vagueness of theses palavers and not surprised that they never led to anything. His father was a salesman in a shop. He used to say to his wife, I really must find work for the evenings and the Saturday afternoon. He added, faintly, and the Sunday. His wife would answer, But if you do any more work you'll fall ill. And Mr. Saposcats had to admit that he would be ill-advised to forego his Sunday rest. These people at least are grown up. But his health was not so poor that he could not work in the evenings of the week and on the Saturday afternoon. At what, said his wife, Work at what? Perhaps secretarial work of some kind, he said. And who will look after the garden? said his wife. The life of the Saposcats was full of axioms, of which one at least established the criminal absurdity of a garden without roses and with its paths and lawns uncared for. I might perhaps grow vegetables, he said. They cost less to buy said his wife. Sapo marvelled at these conversations. Think of the price of manure, said his mother. And in the silence which followed Mr. Saposcats applied his mind, with the earnestness he brought to everything he did, to the high price of manure which prevented him from supporting his family in greater comfort. . . . They had no conversation properly speaking. They made use of the spoken word in much the same way as the guard of a train makes use of his lantern. Or else they said, This is where we get down. And their son once signalled, they wondered sadly if it was not the mark of superior minds to fail miserably at the written paper and cover themselves with ridicule at the viva voce. They were not always content to gape in silence at the same landscape. At least his health is good, said Mr. Saposcats. Not all that, said his wife. But no definite disease, said Mr. Saposcats. A nice thing that would be, at his age, said his wife. They did not know why he was committed to a liberal profession. That was yet another thing

that went without saying. It was therefore impossible he should be unfitted for it. They thought of him as a doctor for preference. He will look after us when we are old, said Mrs Saposcat. And her husband replied, I see him rather as a surgeon." (187)

The above is a picture of Mr. and Mrs. Everyman as seen by Samuel Beckett. Everything that Mr. and Mrs. Saposcat are and do and say is very common. There is nothing individual about them. And yet they are described very accurately—one might almost say vividly. This is what I mean by "abstract description".

The second thing about *Malone Dies* which has (for me at least) a certain fascination is the way the author has set himself a difficult technical problem and then brilliantly solved it. The story describes a man on his death bed and the reader knows—from the very title of the story—that he will die at the end of the novel. Since the fact of Malone's death is thus early established and since Malone is the consciousness through which the story is seen—the narrator—there is a problem as to how he will describe—or present—his own death. This is what the reader is expecting and if the author does not find a striking way to present what the reader knows in advance he is going to present, the story will be disappointing. The technical resources of the writer are to be put to a test. Beckett responds to his own challenge by having the death take place during one of Malone's fantasies. Malone is imagining an outing of the inmates of an insane asylum. Suddenly one of the guards, Lemuel (a name closely resembling Beckett's—Samuel) goes berserk and begins to kill everyone at the picnic with a hatchet. The book ends with this passage:

"Lemuel is in charge, he raises his hatchet on which the blood will never dry, but not to hit any one, he will not hit anyone, he will not hit anyone, will not hit anyone any more, he will not touch anyone any more either with it or with it or with or
or with it or with his hammer with his stick or with his fist or
in thought in dreams I mean never he will never
or with his pencil or with his stick or
light light I mean
never there he will never
never anything

there
any more" (288)

I think this passage is successful beyond anything the reader could have expected in expressing the reality and terror of extinction. Certainly the technique owes a great deal to Joyce's "stream of consciousness" and perhaps to the system of repetition developed by Gertrude Stein and Hemingway. But the author has revised their methods and skillfully adapted them to his own purpose. In his delirium, Malone thinks of his own death not as his own extinction but that of other people who are killed by his dream-image, Lemuel. Malone seems to think it is the world that is being destroyed, not himself. Then, later he realizes he himself is passing away and that there is no more light. The repetitions of the word "never" make clear his gradual awareness of his own death. The other repetitions indicate clearly the state of extreme delirium. The division into three paragraphs illustrates Malone's gradually waning strength. The first paragraph is the longest but at the end he is becoming incoherent. In the second paragraph he gets a second breath but it doesn't last long and he is soon incoherent again. In the final paragraph he can only manage a few phrases but in spite of their incoherence they show an increasing clarity in the perception of his extinction.

In *The Unnamable* Beckett discards all disguises and talks with his own voice. Or rather, since there is no self and no "own voice", he at least abandons the fictitious characters who speak for him and tries to come as close to his own voice as he can. But, before abandoning them, he lines them up once more, Molloy, Moran and the rest, admits that they are his own creations and spoke for him but now he finds them inadequate. Still, he picks up one or two of them, as if they were old dolls and plays with them one last time, adding an element of fiction to what would otherwise be pure monologue.

The book expresses isolation, uncertainty, a feeling of not having any identity, a longing first to be something definite and then to be nothing; the desire to know himself as he is and then die. God is

dimly felt as a power (perhaps there are more than one) which holds him in existence and uses him as a puppet, allowing him neither to be an individual nor to cease to exist. If he could only understand what God (or the gods) wanted from him he might find peace but there is no understanding and no peace. The book ends, "I don't know, I'll never know, in the silence you don't know, you must go on, I can't go on, I'll go on."

It is clear that the author is deeply pessimistic. It is also true that these books contain a great amount of unpleasant material. It is only Beckett's intensity of emotion and mastery of style, combined with the depth and sincerity of his thought that make his work acceptable and impressive. As for his style, the long, slow apprenticeship he has served in Paris has produced its result. The style is incredibly flexible, nervous, lively and intelligent. As for the thought behind these unusual novels, it is time we looked at that in more detail.

Beckett's view of the world is determined by the philosophy of Cartesianism. Descartes based his philosophy on the principle: I think, therefore, I exist. Everything else must, according to Descartes be proved on the basis of this one principle. Hence Descartes begins with consciousness as his basic principle and asserts that what one is conscious of is mental activity only. If I am aware that I think, I am aware of myself only as a mind. It is impossible to prove that I have a body, that material beings exist or that other people—that is finite, thinking beings—exist. From this it follows that the individual is alone in the midst of a world that is only the product of his own thought—perhaps a mere hallucination.

It is these Cartesian ideas that lead Beckett to present his stories through a single consciousness which not only describes them but often invents them in a world where it is never clear what is real and what is imaginary.

But Beckett does not stop here. Descartes' philosophy leads to many problems. The chief problem is: if this is true where does the individual consciousness come from and where does it get its ideas of material things. Beckett is interested in the answer to this pro-

blem furnished not by Descartes himself but by two of his followers, Malebranche and Geulincx, who are specifically referred to in Beckett's writings. Beckett is especially fond of Geulincx since he not only admires his philosophy but, as a linguist and stylist, he admires his beautiful Latin. He particularly praises Geulincx's phrase, "Ubi nihil vales, ibi nihil velis". "Where you can do nothing, you should desire nothing." The brevity, clarity, precision and balance of the phrase have won Beckett's admiration. As for Geulincx's solution to the problems mentioned above and the general ideas of his philosophy which have influenced Beckett, I think the best way to summarize them is to quote extensively from Hoffding's remarks in *A History of Philosophy*.

"According to Geulincx, morality consists in obedience to the law of Reason which God has deposited within us. Not in obedience to God's will for this will be fulfilled whatever we may do....Self examination is the foundation of ethics. It teaches me that only my thoughts and my will belong to me while my body is part of the material world. Now in the material world I have produced nothing and am not able to produce anything; for by what right do I assert that I produce something when I do not know at all how it has arisen? And moreover my activity cannot extend beyond the limits of my being; it cannot exercise itself on other things. My will has significance for my own soul only. Neither can things affect each other or me. How can the action of a thing, which is its own inner condition, be significant for other things? It does not know itself how changes external to it are brought about; its inner condition certainly does not extend to other things! If thou thinkest that thou thyself movest thy limbs, although thou knowest not how this happens, thou mightest just as well believe thyself to have written the Iliad, or to have set the sun in its course in the heavens; and the child in the cradle might with equal right think that its will sets the cradle in motion directly when its mother fulfills its wish to be rocked. If my willing and doing are to reach beyond my own being, God who is the only true and efficient cause, must interfere. Finite beings are only occasions or instruments for the activity of the Deity. He who imparts motion to matter and invests it with laws, forms my will also, and unites it in such a way with the material body that will and movement must follow one another like two clocks, which follow the same course and strike at the same time, not because the one affects the other, but because they are made by one and the same maker.

Geulincx himself draws from his doctrine the conclusion that we stand over against the world, or rather God, as spectators. For the world itself can produce no world-picture in me; only God can do that; and as a spectator of that which goes on in the world I am a continual wonder: (ego ipse spectator mundi maximum sum et jure miraculum!) We are absolutely dependent on God's will. Thus the highest principle of ethics is: Where I can do nothing I ought not to will anything (ubi nihil vales, ibi nihil velis)! The cardinal virtue, therefore, in the ethics of Geulincx is humility." (245 f.)

Descartes, defining man as consciousness, made him seem like the solitary spectator in a moving-picture theatre where the projector is operated by God. He can only observe. He cannot act or even judge whether what he observes is real or not. But sometimes man *seems* to act. How is this to be explained? Geulincx changes the image to that of a puppet show where man is both observer and puppet. He observes but cannot change anything. He has not written the script nor can he alter it. He can act, but only when the great Stage Manager pulls his strings and then he can only obey, not interfere. If his actions seem to have any effect it is because the Stage Manager has brought that about also, and not even through his act but only simultaneously with it—like the action of two clocks.

The view of the universe outlined above furnishes an explanation for most of the "strange" things in Beckett's writings. Geulincx, in developing these ideas found in them no cause for despair or even pessimism. He considered God as the author of the order of the universe and felt it a joy and a privilege for man to be a powerless spectator of it. In adopting these ideas, however, Beckett has made subtle but important revisions. Suppose the two clocks are not well-synchronized (i.e. mind and body are not in harmony), what is one to think of the clock-maker? Suppose the movie is a horrible nightmare, what is one to think of the man operating the projector who is also the Producer and Director? Beckett accepts the Cartesian idea of the complete separation of mind and body—he is always describing the steady decay of the body which the mind is helpless to prevent. He accepts God as the source of both con-

sciousness and phenomena—but phenomena are chaotic and consciousness is a nightmare. He accepts man's complete helplessness in the hands of God—but God is inscrutable and may well be a monster or a combination of monsters for at times Beckett is convinced that "there is more than one".

The concept of God as the inscrutable source of unintelligible commands will remind many readers of Kafka. Indeed there is a very great resemblance between the two authors both in their outlook and in their techniques. The main difference is that Beckett's world is much more physical. Where Kafka concentrates on mental confusion, Beckett induces a physical nausea. For Kafka, it is because he finds the universe unintelligible that he feels so unhappy. For Beckett, it is because he is so unhappy that he finds the universe unintelligible.

Is Beckett an existentialist? He has always denied it, saying that if what he wanted to say could have been expressed as philosophy he would not have written it as fiction. Certainly he has never been part of the group that has formed around Jean-Paul Sartre and there is not the slightest evidence that he has ever paid any attention either to Sartre's "philosophy" or to his fiction. He has concentrated on his own highly distinguished "philosophic fiction" rather than, like Sartre, writing a philosophy that lacks consistency and logic, and a fiction that lacks imagination and perception. Both his ideas and his style have been influenced by the older sources already discussed rather than by the modern existentialist school. There is however a broader sense of the word in which Beckett might be called an "existentialist". In this broader sense the word can be applied to any writer who considers man as alone and helpless in a universe which it is impossible for him to understand. If we take the word in this broader sense and consider Beckett as an existentialist it is clear that he is vastly superior to all the other writers of this school: Camus, Malraux, Simone de Beauvoir, Sartre etc. Both in the clarity and profundity of his thought and in the vividness and force of his style he attains realms that they have never dreamed of.

Finally a few words about the influence on Beckett of his two favorite writers, Joyce and Proust. Behind the influence of Joyce is that of an earlier inhabitant of Ireland—Jonathan Swift. The bitter pessimism of Swift has had a strong influence on both men. The influence on Beckett seems even stronger than that on Joyce for Beckett seems to share not only Swift's pessimistic view of life but his morbid contempt for sex and antipathy toward women. From Joyce Beckett has taken the technique of the interior monologue (I will not say the stream of consciousness for in Beckett's case the stream seems to be frozen and does not flow). He differs from Joyce as Protestant differs from Catholic. Where Joyce is interested in personal and family relationships, in culture and society, Beckett concentrates on the relation between God and the individual.

With Proust his relationship is more difficult to define. He does not imitate Proust and there is no specific technique that one can say he learned from Proust except the idea of using one individual consciousness as the basis for his complete works and not merely one book. Still, he is the kind of writer who ought to come after Proust just as Picasso is the kind of painter who ought to come after Cezanne and the impressionists. Proust greatly admired the impressionists and often refers to them in his writings. His own interest in detailed observation is very much like their interest in the precise effect of sunlight on things seen. But Picasso is no longer interested in the effect of sunlight nor is Beckett interested in detailed observation. When Picasso paints, for example, a woman looking in a mirror he makes no attempt to capture the effect of light or any other realistic detail. He selects and arranges the details into an abstract pattern that expresses what is universal in all women looking into mirrors—stupidity and vanity, for example. He is abstract and expressionist rather than concrete and impressionist. So too, Beckett, in what I have called his "abstract description". He makes no attempt to describe the house and surroundings of Mr. and Mrs. Sposcat or add details of their daily life that will make them more "real" i.e. individualize them. He selects and presents only a few of the general ideas they express in conversation;

ideas which are not peculiar to them as individuals but express attitudes common to all husbands and wives, all fathers and mothers. Here, too, there is an element of expressionism as well as abstraction, for these general attitudes which he describes express and explain the author's contempt for people and his disgust with life. In mentioning the many influences that have contributed to Beckett's work, I have not intended to imply that he is not original. On the contrary, his achievement is all the more extraordinary because he has managed to develop further traditions that seemed to have reached an end. The reader of *Finnegans Wake* or *Remembrance of Things Past* cannot help feeling that further development of these kinds of writing is impossible. But Beckett has managed not only to carry on these two separate traditions but to unite them to some extent. Looking at Beckett's work, one once more gets the feeling that this kind of writing cannot be developed any further. But of course some future writer will appear to continue the development. It must go on. It can't go on. It'll go on.

貝凱特及其文學上的戲劇哲學

JOHN M. MCLELLAN

摘 要

此文首先研討貝凱特 (Beckett) 在英、法文學上無與倫比的地位。並觀測其作品之來源及所受影響，進而判斷他對戲劇的貢獻。分析他的三本小說，那可說是他對人生最深思想的表現。其次研討笛卡爾哲學 (Cartesian philosophy) 對他的影響。最後則將他與同時的其他幾位作家做一比較。

The supreme aim of literary and linguistic training is the formation of character. This includes and transcends all other aims... The springs of a man's character are in his loves and hates, his tastes and desires, his ideals and aspirations; and the life of these depends much upon the light and the perspective with which they have been invested by the imagination. This imaginative exaltation of life, of noble longings and ideals, it is the province of art, and especially of literature as the highest art, to achieve, and, in turn, foster and communicate.

Percival Chubb (1902)

SOME VARIANTS OF THE *RIP VAN WINKLE*-TALE

PETER VENNE, SVD.

A thousand years are before Him as one day

Long ago, Saint Augustine in his *Confessions* asked the question, "What is time?" And he gave the answer, "When no one asks me, I know; when someone asks me, however, I do not know."⁽¹⁾ He meant to say that we have a practical knowledge of time but that upon closer scrutiny time becomes a strange thing full of puzzles.

The mystery of time has not only kept the philosophers busy for more than two thousand years, but has also occupied the minds of the common people. The folklores of different civilizations have expressed this experience in various forms of legends and fairy-tales. In the following, some such tales of Europe and Asia will be discussed. Their similarities are partly superficial. The connecting link between them might be termed: the distorting of time. The people in these stories spend a short while in some absorbing occupation or in sleep. When they 'wake up', they discover that what seemed to them only hours or days was in reality a span of years or even centuries.

A tremendous amount of research on folklore and fairy-tales has been done and is still going on. The scholars have tried to classify the immense wealth of material by establishing a system of *motifs* and *types*. Cf. A. Aarne and Stith Thompson: *The Types of the Folktale*, Helsinki 1961. Stith Thompson: *Motif-Index of Folk-Literature; A Classification of Narrative Elements in Folktales, Ballads, Myths, Fables, Medieval Romances, Exempla, Fabliaux, Jest Books and Local Legends*, 6 vols., Indiana University Press, 1955.

A *motif* is the smallest element in a story which is strong enough to live on in a tradition, e.g. a singing bone, a wall of fire or thorns, a grateful animal. A *type* is a composition of motifs forming a story; it is the common scheme or design in a number of similar tales.⁽²⁾

The purpose of the present paper is not to trace out a complete life story of the type of the *Rip van Winkle*-tale, but rather to point out a few interesting parallels of a world-wide folk-lore motif.

* * * * *

An early form of the European tradition of our story may be found in the legend of *The Seven Sleepers of Ephesus*. This pious story which dates back to the fifth century AD. tells of seven early Christians who took refuge from the persecution of emperor Decius in a cave near Ephesus where they were walled in. Miraculously protected by God, they slept for two hundred years. When they woke up they discovered to their great amazement that their city had much changed and had become Christian. They were brought before the bishop and told their story. Then they died and were venerated as saints.

The story which possibly goes back to earlier pre-Christian origins spread widely in the Orient. It was even received in the *Koran* (Sura 18) and thus entered the world of Islam.⁽⁵⁾ In Europe it became very popular since the time of the crusades and was embellished with many edifying details in the famous *Legenda Aurea* of Jacobus de Voragine (13th c'.)

The following stories show a number of similarities with the previous one. They belong to a type of tales which we call *legends*. They deal with saints and miracles and emphasize moral and religious edification. Many motifs of these stories are also found in folklore and saga. Their adaptation to Christian doctrine is only a garment.

A well-known tale dealing with the supernatural lapse of time is the legend of the abbot Erpho of the old monastery of Siegburg, near the Rhine. Erpho is a medieval monk, a thinker and dreamer, who wanders about in the spacious convent garden meditating on the words of the Psalm 90: "To you, O Lord, thousand years are a singly day, an hour of the night." He becomes aware of a strange bird that sings so beautifully that all the animals of the forest seem to listen. After a while—minutes or hours, he does not remember—the song stops and he hurries back to the convent. But there everything is changed. The monks look at him with astonishment. When he tells his name, they discover with wonder and awe that he is the man who was lost in the woods, three hundred years before

and had never returned. When he realizes this, he praises God, sinks down and dies.⁽⁴⁾

An almost identical version of the story is told of a monk in the medieval monastery of Heisterbach, near Cologne and, in Switzerland, of a Prior Evo who walks in the woods, falls asleep while listening to the song of a wonderful bird and sleeps through several hundred years.⁽⁵⁾ The same legend appears in *Irish Fairy and Folk Tales*, edited by W. B. Yeats, under the title *The Story of the Little Bird*.⁽⁶⁾

The best-known modern version of the ancient fable is *Rip Van Winkle* (1820) by Washington Irving, the story of the indolent good-natured villager who falls asleep in the woods, in the years just before the American Revolution. The next morning when he walks back to his village he discovers that he has slept through twenty years and thus missed the great national event of the birth of a new country.

The appeal of the simple but well-told story lies "in the symbolic distillation of a universal mood; ... in it are all the implications of the grim but romantic theme of the *tempus edax rerum*."⁽⁷⁾ Washington Irving had based his narrative on a German collection of folktales and thus brought the European tradition to the New World.⁽⁸⁾

The theme of a magic sleep extending over many years is also found in the widely known fairy tale of *Sleeping Beauty* in which the princess pricks her finger with a needle and—together with the entire house-hold—sinks into a sleep of a hundred years. But in this case, time stands still. When the people wake up they continue to act exactly where they had stopped. Nobody realizes that a century has gone by. This type of narrative belongs to a different category.

* * * * *

The European tradition of the motif 'Years thought Days' is very rich. L. C. Wimberly points out a few more cases in *English and Scottish Ballads*.⁽⁹⁾ The examples given here may suffice.

But it is certainly of interest to look for similar stories in China and Japan. A Japanese version is the very popular tale of *Urashima Taro*. The earliest records of it date back as far as the 8th century

AD.⁽¹⁰⁾ The story runs like this (after an illustrated Japanese children's book):

Young Taro, a fisher, is the son of poor but honest parents. One day, he rescues a tortoise from the cruel play of children. The grateful animal invites him to a ride on its back into the ocean. After a long journey through the waves they arrive at the gorgeous palace of the queen of the ocean. Taro spends happy days in the company of the fairy princess. Every day surprises him with new wonders and enjoyments. He loses all sense of time.

In the midst of all this bliss he suddenly remembers his old parents. His yearning for home becomes so strong that the princess agrees to his leaving. She hands him a precious little casket with the warning that he must by no means open it if he ever wants to come back to her palace.

The tortoise carries him back to his native shore. But there everything looks changed. The house of his parents has disappeared. Stumps of trees cover the place where it had stood. He asks an old man about the house of Urashima Taro. The man answers that he had heard of that name when he was a boy, that people used to tell that he had gone to the sea and never come back. But that had happened three hundred years ago.

Now it suddenly dawns on Taro that the three years which he had spent in the fairy palace had in reality been three hundred years. A feeling of deep loneliness overpowers him. Half unconsciously he opens the little box but only a white smoke rises out of it to heaven. That were the years of his life. And suddenly his hair turns white. He has become an old man and dies.

The next tale *The Fairy Grotto* belongs to China. According to W. Eberhard it stems from about the fifth century AD. The two protagonists of the story are believed to have lived in the time of the Han dynasty, in Chekiang province. The following summary of the story follows closely the text given by Eberhard.⁽¹¹⁾

Two boys, Liu Ch'en and Yüan Chao, went one day into the hills to fetch water. The hills were covered with many red and green flowers. It was spring time. The boys walked through the lonely country side until finally they came to the entrance of a cave. Two fairies were seated there playing chess.

The boys stood and watched the game in silence. In the mouth of the cave a white hare was springing up and down. Much to their wonder, the boys saw that each time the hare sprang up the flowers bloomed, and each time it lay down they faded.

When the game was finished, the fairies looked at the boys and asked when they had arrived. "A few hours ago", they answered

and turned to leave. The fairies said to them, "Stay here and don't go home." But the boys said, "No, we must go home." The fairies, then, gave them a piece of reed, saying, "If you want to come back here, point the reed at the cave and it will open."

The boys returned to their village but could find no trace of their homes. They asked two old men where the house of Liu Ch'en and Yüan Chao was. They answered, "The men you ask for were our ancestors. We are their descendants in the seventh generation." Greatly confused, the boys began to understand that the jumping hare in the grotto represented the seasons, and that the afternoon they had spent in the cave had lasted for several hundred years. They told the people in the village their names, but they were beaten up as two reckless young rascals.

They fled back to the cave but found the door closed. They could not remember where they had lost their reeds. They knocked and knocked but there was no answer. So they banged their heads against the wall and died.

There are some surprising similarities between this tale and that of Urashima Taro, especially the motif of the casket and the reed, and the death of the heroes after the loss of the magic object. To what extent the Chinese tale may have influenced the other one, is still a matter of speculation.

In Eberhard's collection there is another, somewhat similar story from Hunan, with the title *Hsiang Meets the Dragon King*. Hsiang is a popular hero, a rebel like Robin Hood. He takes refuge in the cave of the Dragon King and stays for a few days. But the days are years. In the end he is reunited with his family.

In the Introduction to his book Professor Eberhard points out that "The field of Chinese folklore is still largely virgin soil." Scientific interest in it arose with the Literary Revolution of 1919. The rich treasures of Chinese songs and tales are still waiting to be scientifically explored and brought before the public.

* * * * *

Our survey has delineated some prominent literary expressions of one folklore motif in different culture areas. The similarities between the various stories raise the question of their origin. Is it possible that the different tales may have been invented independently

in different places or do we have to assume a common source, a sort of simple archetype which has spread over distant areas?

The impression that time sometimes flies like an arrow or appears like a dream is a common human experience, and it seems reasonable to assume that the essential theme or motif of all these tales is so generally human that it could take on literary form independently in different parts of the world. But as far as the various stories agree in details of structure and ornament, some influence may have to be postulated. Ruth Benedict⁽¹²⁾ points out that "Folklore incidents combine and recombine with ease, attaching themselves now to one plot and now to another." In some cases it is obvious that different versions go back to a common source. It is of interest to observe how the different races and cultures have clothed the common theme in their own ways.

NOTES

- (1) Book XI, 17-40.
- (2) Lüthi, Max: *Märchen*, Stuttgart 1968, p. 19.
- (3) *Lexikon für Theologie und Kirche*, Herder, 1965.
- (4) Text in Lüthi, Max: *Es War Einmal: Vom Wesen des Volksmärchens*, Göttingen 1964, p. 26.
- (5) *ibidem*, p. 25.
- (6) *Irish Fairy and Folk Tales*, ed. W. B. Yeats, Modern Library, p. 237.
- (7) "The all-devouring time." *Literary History of the United States*, ed. Spiller; Macmillan 1949, p. 247.
- (8) Cf. E. L. Brooks: "A Note on the Source of *Rip van Winkle*", *American Literature* vol. 25, 1954, p. 495.
- (9) L. C. Wimberly: *Folklore in the English & Scottish Ballads*, Dover ed. 1965, p. 328. See also Michael Huber, *Die Wanderlegende von den Siebenschläfern*, Leipzig 1910.
- (10) Nihon Shoki: Tango-Fudoki.
- (11) W. Eberhard: *Folktales of China*, Taipei 1965.
- (12) Ruth Benedict: *Encyclopedia of Social Sciences*, Macmillan 1931, article 'Folklore'.

故 事 “李 伯 大 夢” 的 若 干 比 較

PETER VENNE, SVD.

摘 要

華盛頓·歐文 (Washington Irving) 的故事“李伯大夢”(Rip van Winkle) 是由一篇德國神話改寫而來。

在歐洲有大量傳統故事中‘時間’是被曲解了的。

這些故事中的人物都會將一段短暫的時間花費在引人入勝的事情或睡眠上。

當清醒過來時，他們發現在他們看起來僅是數小時或者數天的光陰，實際上却是好幾年甚或好幾世紀。

這篇文章就是討論歐洲某些此類的故事，並將它們與中國及日本類似的故事做一比較。

Section Two

Natural Sciences

AN INVESTIGATION OF THE TOTAL ELECTRON CONTENT OF THE EQUATORIAL IONOSPHERE

JOHN KOSTER, SVD.

1. THE IONOSPHERE

The earth's atmosphere extends from the surface of our planet out to a distance of at least ten earth radii, i.e. sixty thousand kilometers. The atmospheric density falls off very rapidly with height, however, so that 99.9% of the atmospheric mass lies between the surface of the earth and the 60 kilometer level.

The ionosphere is usually defined as "the part of the earth's upper atmosphere where ions and electrons are present in quantities sufficient to affect the propagation of radio waves." It extends from a height of about 50 kilometers to the outer limit of the atmosphere. The ionosphere therefore occupies a volume some thousand times that of the solid earth, but contains less than a thousandth of the mass of the atmosphere as a whole.

The basic process responsible for the production of ions and electrons in the tenuous outer regions of the atmosphere is well known. Photons in the extreme ultraviolet and x -ray portion of the solar spectrum possess sufficient energy to remove one or more electrons from the atoms (mainly O) or molecules (O_2 , N_2) of the atmosphere. A minor contribution is made by ionization due to galactic cosmic rays, and ionization by particle bombardment can supplement photoionization during ionospheric disturbances. But the latter does not seem to make an important contribution under quiet conditions anywhere, especially at the equator.

While the ionized portion of the atmosphere constitutes a tiny fraction of the total, it supports some of the most interesting and intricate of nature's phenomena. Its ability to affect the propagation of radio waves gives it great practical as well as theoretical importance. Most long distance communications at high or very high radio frequencies depend on the reflecting properties of the ionos-

phere. Even satellite communications in the microwave region of the spectrum are sometimes affected by ionospheric conditions. Electric currents flowing in the ionized regions of the upper atmosphere play an important role in geomagnetic and auroral phenomena. And for those interested in the study of plasmas, the ionosphere offers the only easily accessible large scale plasma occurring in nature.

2. METHODS OF INVESTIGATING THE IONOSPHERE

Since one of the important properties of an ionized gas is its ability to reflect radio waves, it is not surprising that radio waves constitute the most important tool used in probing the ionosphere. The instrument most widely used for this purpose in the past has been the ionosonde, which is essentially a variable frequency radar. Short bursts or radio waves are sent (usually vertically) upward. The elapsed time between the outgoing pulse and the returning echo gives a direct indication of the height of the reflecting "mirror." Waves of shorter wavelength require higher electron densities for reflection to take place. Hence if we continue increasing the frequency (i. e. decreasing the wavelength) of the probing wave, it eventually penetrates through the ionized layer, and no further echoes are received. Observation of the maximum frequency for which echoes are obtained enables the observer to calculate the maximum electron density in the ionosphere, as well as the height of that maximum. It is also possible to calculate from ionosonde records the total number of electrons from the bottom of the ionosphere up to the height of the maximum. Since ground based ionosondes cannot probe the ionosphere above the layer maximum, however, recent experiments have been undertaken in which the ionosonde is aboard a high flying satellite, transmitting pulses downward, thus investigating the upper reaches of the ionosphere from above.

Rockets and satellites have also been used to make "in situ" measurements in the ionosphere, but such methods, especially the former, are very expensive. Also, it is difficult to make accurate measurements in a tenuous ionized gas like the atmosphere without encountering serious disturbances due to the rocket or satellite itself.

3. THE USE OF SATELLITE-BORNE RADIO TRANSMITTERS

The advent of satellite-borne radio transmitters has made possible other types of experimental probing of the ionosphere with radio waves. For the ionosphere can affect radio waves in other ways than reflecting them. Two of the most important effects are:

- (a) the rotation of the plane of polarization of a plane polarized electromagnetic wave, and
- (b) the diminution of the group velocity of radio waves as they traverse the region containing the ionized gas.

Both of these effects make possible the experimental determination of some of the properties of the ionized medium. The former, called Faraday rotation, has been used extensively in recent years. The latter requires somewhat more sophisticated electronic equipment. Hence it has not been so widely used in the past, but will play an increasingly important role in future experiments, now in the planning stages.

This report concerns the use of Faraday rotation to determine the total electron content of the equatorial ionosphere. The observations were made at Legon, Accra, Ghana (latitude 5.63°N , longitude 0.19°W .).

Different types of satellite orbits lend themselves to different types of experiments. For the investigation of the spatial variations of the ionospheric ionization, satellites in relatively low orbits are especially suitable. The passage of a satellite at, say, 1,000 kilometers can be observed at an earthbound receiving station for some five to ten minutes as it passes from horizon to horizon. The analysis of such a pass can yield an almost instantaneous picture of the distribution of ionospheric ionization along its path over a considerable range of latitude and longitude. And normally at least two good passes per day can be observed.

For studying the temporal variations in the ionization of the upper atmosphere a synchronous satellite at a height of approximately

35,000 kilometers offers numerous advantages. From the analysis of the radio signals received at any receiving station a continuous record of the ionization along a spatially fixed ray path can be obtained. The present report concerns itself with results of the observation of the 137.35 MHz signal radiated by the synchronous satellite known as ATS-C. This satellite was observed on a continuous basis from July 1969 till February 1970, and again from July 1970 till the present.

4. FARADAY ROTATION

A radio wave is frequently described in terms of its polarization. It will be recalled that any electromagnetic wave (gamma ray, x -ray, light, radio wave) involves mutually perpendicular electric and magnetic fields. These fields vibrate rapidly at the frequency which characterizes the wave. Radio engineers call the plane determined by the direction of propagation of the wave and the direction of the electric field vector (usually called the E vector) the "plane of vibration", or the "plane of polarization" of the wave. If this plane of vibration at any given point remains fixed, the wave is said to be "plane polarized." Most radio and television waves are plane polarized, since waves transmitted by a simple dipole exhibit this property.

Even when a plane polarized wave passes through an ionized medium the plane of polarization is normally not affected. But if there is also a magnetic field present in the medium, and the direction of propagation is in any direction other than normal to the field, the plane of polarization of the wave is rotated as it proceeds, and the amount of rotation depends on the properties of the medium, i.e. on the intensity and direction of the magnetic field, and on the number density of the electrons present. Since the ions present are very much more massive than the electrons, their effect on the wave is normally negligible. This rotation of the plane of vibration of an electromagnetic wave was first discovered in optics, and was given the name of "Faraday rotation."

It will be appreciated that if the total rotation of the plane of

polarization of our wave about its direction of propagation can be measured, and if the direction of the magnetic field as well as its intensity along the propagation path is known, useful information about the number density of electrons along the path can be deduced. With the aid of an electronic computer and numerical coefficients recently derived from many thousands of geomagnetic field observations, both on the ground and in space, it is possible to determine rapidly the magnetic field values at any point along the propagation path of the radio wave. The remaining problem is, therefore, the measurement of the Faraday rotation.

5. INSTRUMENTATION FOR FARADAY ROTATION MEASUREMENT

The instantaneous orientation of the plane of vibration of an incoming plane polarized electromagnetic wave can be most easily determined by rotating a receiving dipole in a plane perpendicular to the ray path. A maximum signal is induced in the dipole when it is parallel to the direction of the electric vector, a null occurs when the dipole is normal to that direction.

A somewhat clearer physical picture of the phenomenon of Faraday rotation is obtained if we recall the fact that a plane polarized wave can be resolved into two circularly polarized components, the electric vector in the two components rotating in opposite directions. These two circularly polarized components, known as characteristic waves, have slightly different refractive indices in the ionosphere. Hence their phase paths through the ionosphere are slightly different. When they recombine below the ionosphere this difference in phase gives rise to the rotation of the plane of polarization which constitutes Faraday rotation.

The two circularly polarized waves can be received on separate aerials. Oppositely wound helical aerials offer a convenient and simple way of doing this. Any suitable instrument for measuring accurately the phase difference between the signals induced in the two aerials can be used to measure the Faraday rotation, since the latter can easily be shown to be equal to half this phase difference.

In the equipment used at Legon, this measurement is made with the aid of a phase reversing switch and phase sensitive detector familiar to radio astronomers.

At the equator, irregularities in the ionospheric electron density at night lead to rapid and random fluctuations in the amplitude of the received signals. This so called "scintillation" is a fascinating phenomenon in its own right, but it poses difficulties in the accurate determination of the angle of Faraday rotation at such times. To cope with it, some further sophistication in equipment is necessary. But since this is not essential to our main interest here, it will not be discussed.

6. SOME ELEMENTARY THEORETICAL CONSIDERATIONS

A mathematical analysis of the equations governing the propagation of electromagnetic waves in an ionized medium such as the ionosphere shows that the rotation of the plane of polarization is given, to a very good approximation, by the relatively simple expression:

$$\Omega = \frac{K}{f^2} \int NH \cos \theta \sec \chi \, dh, \text{ where}$$

K is a numerical constant

f is the frequency (in Hertz) of the radio wave

N is the electron number density in electrons per cubic meter

H is the amplitude of the geomagnetic field vector

θ is the angle between the direction of propagation of the wave and the geomagnetic field

χ is the zenith angle of the ray path

Ω is the total rotation angle, expressed in radians.

dh is an element of height, in meters.

The expression is to be integrated along the path from observer to satellite. For a given ray path, H , θ , and χ are easily computed. Also a large amount of information is available about the variation of electron density with height (usually called the electron density profile), so that realistic mathematical models can be constructed.

Since the product $H \cos \theta \sec \alpha$ is a slowly varying function of height, it is sometimes removed from the integral and replaced by a suitably weighted mean value, usually designated in the literature by the symbol \bar{M} . When this is done, our equation becomes extremely simple, in the form:

$$\Omega = \frac{K}{f^2} \bar{M} \int N dh = \frac{K}{f^2} \bar{M} I, \quad \text{where}$$

I is the integral $\int N dh$ evaluated from observer to satellite, i.e., the total integrated electron content in a vertical column of 1 square meter cross sectional area, extending from the observer to the height of the satellite.

It might be interesting to note that the numerical value of I at the equator during the day is typically of the order of 10^{17} electrons per square meter.

Naturally, assumptions which are both more complicated and more physically realistic than the above can be made in the analysis of the results of these experiments.

7. IONOSPHERIC PROCESSES

The interpretation of our results is aided by a consideration of the various physical processes which can influence the electron content of the upper atmosphere. The electron density $N(h, t)$ at any height and time is given by the solution of the equation of continuity:

$$\frac{\partial N}{\partial t} = q - L(N) - M \quad \text{where}$$

$\frac{\partial N}{\partial t}$ is the rate of change in electron density with time at any point,

q is the time rate of production of new electrons,

$L(N)$ is the rate of loss of electrons (through recombination),

M is the rate of loss of electrons through diverging movement.

Let us consider briefly each of the terms on the right side of the continuity equation.

(a) The production term q :

Since the electrons and associated positive ions are produced by the influx of solar radiant energy, we would expect the production rate to be proportional to the rate of energy received at any time. Hence q should be proportional to $\cos \chi$, where χ is the zenith angle of the sun. The production rate should therefore increase steadily from zero at ionospheric sunrise to a maximum at local noon, then decrease again to zero at sunset. Minor contributions can be made by the influx of cosmic rays, or ionization due to meteors. Collision with energetic particles of solar origin may at times play an important role at the poles, but not at equatorial latitudes.

(b) The Loss term $L(N)$:

Electrons may be removed from the ionosphere by two processes:

1. dissociative recombination with molecular ions, such as O_2^+ , N_2^+ , NO^+ , or
2. direct recombination with atomic ions (mainly O^+).

It is now believed that the former process predominates at lower heights, where the electron density is greatest. The latter process becomes important and ultimately predominates at great heights, where the loss rate is very slow in any case.

Here it might be pointed out that if only production and loss processes are important, with negligible loss of ionization due to movement, the variation of Faraday angle with time of day should be very simple. The electron content, and hence the Faraday rotation angle should rise from a minimum at sunrise to a maximum which is near noon if the loss rates are relatively high. If the effective loss rate is low, the maximum should be displaced into the afternoon. After sunset production stops, and the electron content should then fall steadily to a minimum at sunrise. The cycle should then repeat itself.

(c) The transport term M :

This essentially simple picture can be seriously altered by changes in electron content due to a convergent or divergent move-

ment of electrons. The movement terms can be written mathematically as the divergence of a transport flux of ionization:

$$M = \text{div} (N\bar{v}) = \text{div} [N(\bar{v}_{em} + \bar{v}_t + \bar{v}_d)] \quad \text{where}$$

\bar{v}_{em} is velocity caused by electromagnetic forces,

\bar{v}_t is velocity caused by temperature changes in the atmosphere,

\bar{v}_d is velocity caused by ambipolar or plasma diffusion.

8. SOME RESULTS OF THE EXPERIMENT

The experiment operates continuously, and produces an independent determination of the Faraday rotation angle every ten minutes. Results are printed out by a data logger, and the preliminary analysis of the results is done on an electronic computer. Graphical plots of rotation angle as a function of time of day are especially interesting. Though one of these plots is produced each day, only three typical examples will be shown here.

Figure 1-a shows a plot of Faraday rotation angle against time for a normal day during the June solstitial period. Figures 1-b and 1-c are similar plots from the period of the autumnal equinox for a magnetically quiet and a magnetically disturbed day respectively. A study of these and similar plots is still in progress, but the following information has already emerged.

(1) Day to day comparison of the diurnal range of the Faraday rotation angle shows a marked 27 day periodicity. This sort of recurrence of similar features every 27 days is common to many geomagnetic phenomena, and almost certainly reflects the approximately 27 day period of the solar rotation. Certain regions or features of the solar surface apparently give rise to enhanced radiation in the extreme ultraviolet and x-ray portion of the spectrum, and hence are more effective than adjacent areas of the solar surface in producing ionospheric ionization. This variation in total electron content is almost certainly associated with other manifestations of variation in incoming solar energy, especially in the microwave portion of the spectrum. The correlation with 10.7 cm solar microwave radiation is currently under study.

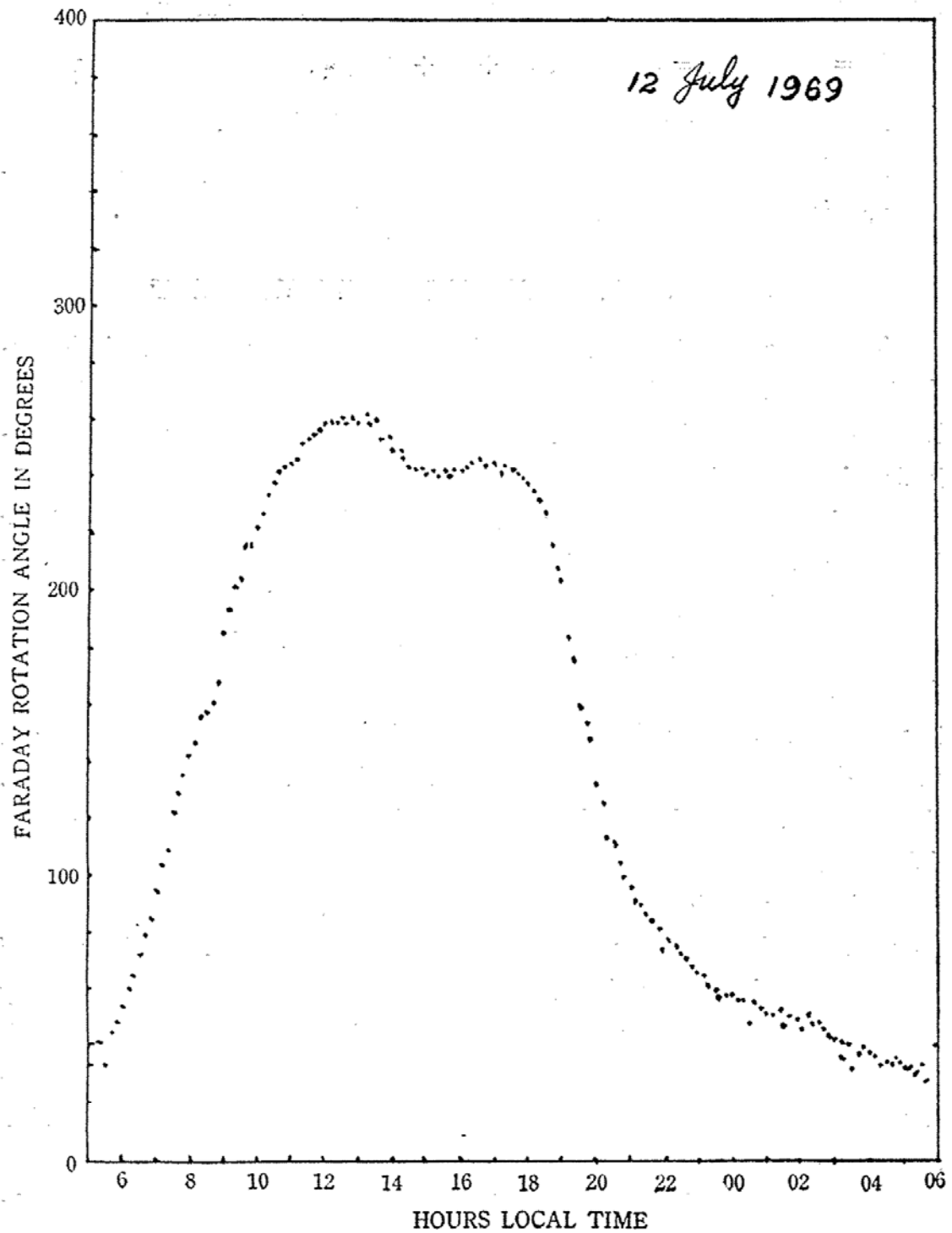


Figure 1-a. The diurnal variation of the Faraday rotation angle on a typical day near the June solstice.

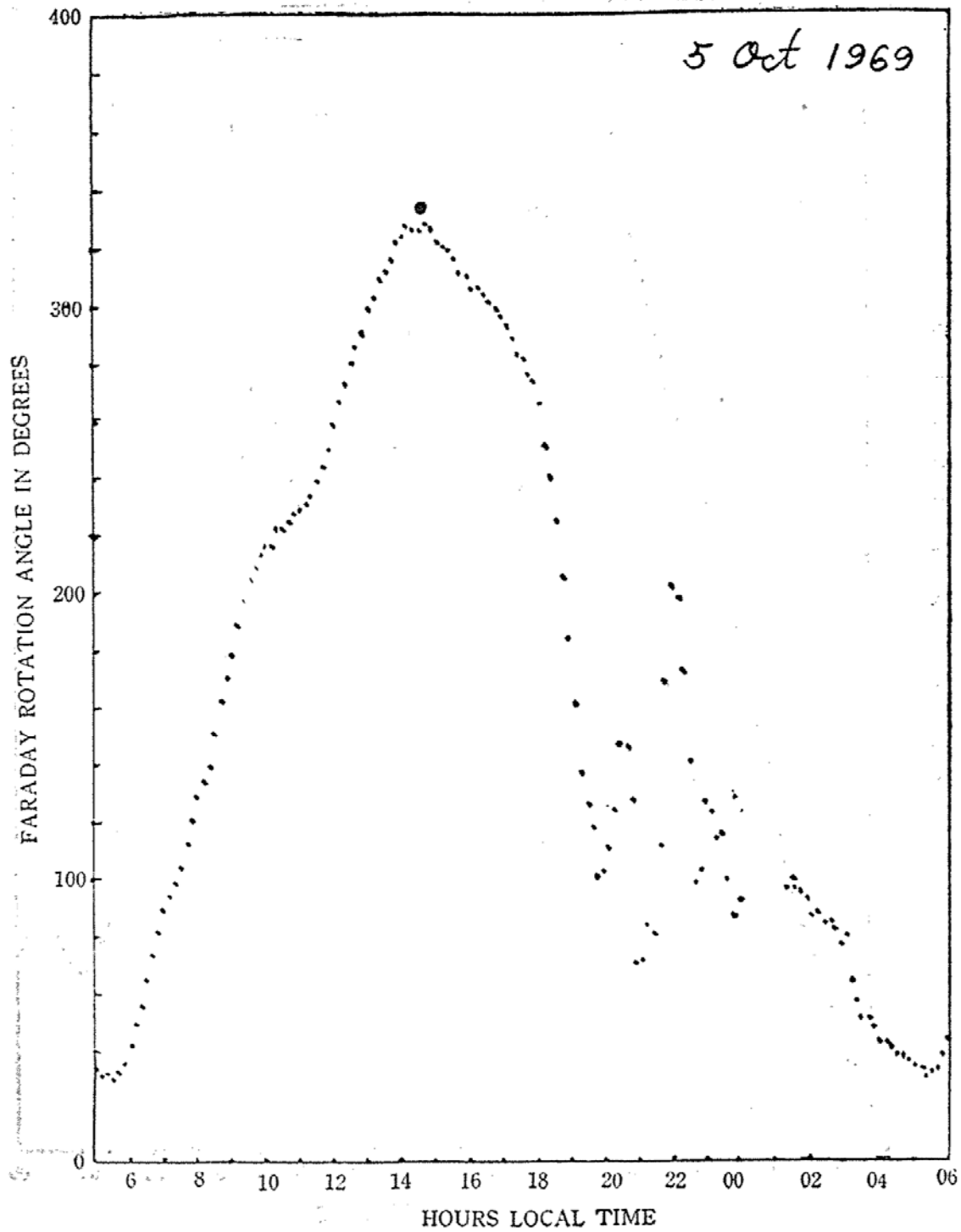


Figure 1-b. The diurnal variation of the Faraday rotation angle on a magnetically quiet day near the autumnal equinox.

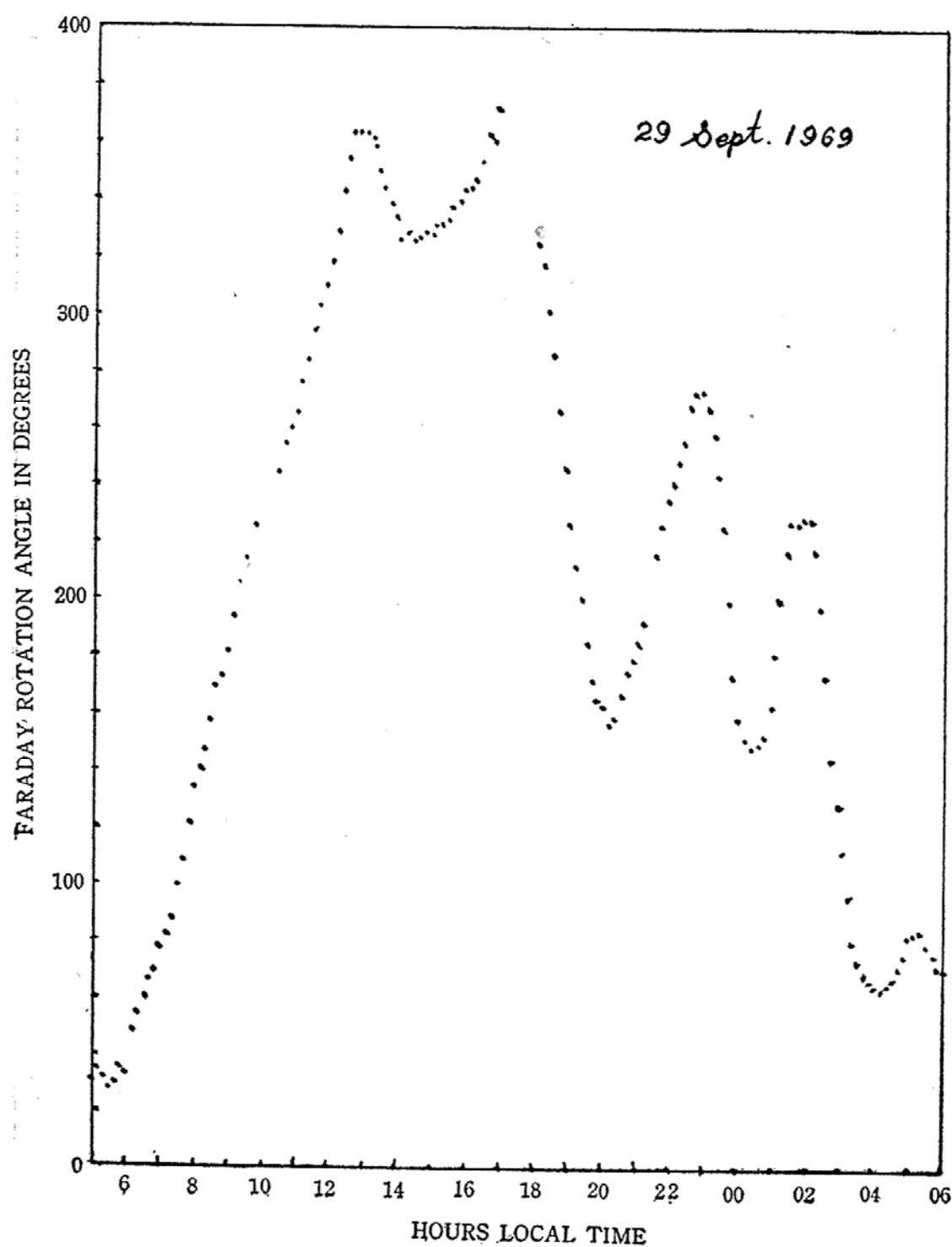


Figure 1-c. The diurnal variation of the Faraday rotation angle during a magnetic storm near the autumnal equinox.

(2) Solstitial records are typically very regular, with a rather broad maximum extending into the afternoon. The mid-day maximum is often somewhat flattened, and the evening decline in electron content somewhat steeper than it would be in a situation where production and "in situ" loss process alone were operative. But there is little evidence of large changes in electron content due to transport processes during this season.

(3) Records obtained during the equinoctial periods generally have a larger amplitude than those obtained during the solstices. This indicates a greater electron content, and is consistent with the fact that the influx of solar energy maximizes at the equinoxes at the equator.

(4) The equinoctial quiet day curve (Figure 1-b) exhibits an obvious departure from what would occur if a simple production and loss mechanism were operative. Many features of the curve can be explained only by invoking transport phenomena to supplement the production and loss processes.

The two most prominent features to be considered here are:

- (a) The precipitate drop in Faraday angle around the time of ionospheric sunset, and,
- (b) The somewhat irregular night time fluctuations in Faraday rotation angle, resembling a damped harmonic oscillation.

These two features will now be considered in greater detail.

- (a) The sunset drop in Faraday rotation angle.

Several mechanisms can be operative in the production of the sharp reduction of the value of the Faraday angle which begins around the time of sunset in the ionosphere, and they are undoubtedly at work simultaneously. They are:

- i. Ordinary loss processes. With the electron production term reduced to zero at sunset, we would expect a drop in electron content with time. But this process alone would produce a more gradual drop, as is found in the solstitial records (Figure 1-a). The value of the loss coefficient can be estimated from the daytime portion of the curve, and bears out the preceding statement.

- ii. At the equator there is a concurrent and well known rise in the height of the upper atmospheric ionization. This process raises the ionization to a level where the magnetic field strength is smaller. Hence the Faraday rotation angle, which is proportional to the magnetic field strength at the location of the ionization is also smaller. But realistic estimates of the magnitude of this effect show that it alone cannot be responsible for the observed reduction of the Faraday rotation angle.
- iii. Normally the large post sunset drop in ionospheric electron content culminates in the onset of what is known as "scintillation" of the radio source being observed, whether it is a satellite borne radio beacon or a radio star. This scintillation, an almost nightly occurrence at the equator, is characterized by deep and rapid fading of the received radio signal. It has been extensively studied for many years, and is known to be due to irregularities in the electron content of the upper ionosphere. These irregularities tend to be concentrated near a height of 300 kilometers at the equator, where the electron concentration is greatest. The irregularities are extremely elongated, with an axial ratio of the order of 50 or more. They are precisely aligned along magnetic field lines. The rather large scatter of the experimental points after 19 hours in figure 1-b is due to scintillation effects.

The above phenomena suggest rather strongly that ionospheric scintillation is closely associated with a transport mechanism which results in the rapid depletion of the electron content of the ionospheric region concerned.

(b) The somewhat irregular night time fluctuations in Faraday rotation angle, resembling in some ways a damped harmonic oscillation, are quite unexpected, and as yet unexplained. They are currently being studied. It seems probable that some transport of ionization is also involved here.

- (5) The diurnal variation of the rotation angle on a day char-

acterized by large magnetic disturbances exhibits some rather striking features:

- (a) No scintillation normally occurs at night during the time of large magnetic storms. Hence the points on curve 1-c exhibit very little scatter.
- (b) While the daytime portion of the curve is very similar to that obtained for magnetically quiet days, the post sunset portion of the curve shows a much less rapid reduction in Faraday angle with time. From about 20 hours to 23 hours local time values of the angle are from 50% to 100% higher than they are on corresponding quiet days.
- (c) The damped oscillation characteristic of the night times portion of the curve is enhanced during times of severe magnetic storms, and the quasi period of the oscillation is longer by a factor of two or three.

9. CONCLUSIONS

A much more quantitative analysis of the features described above is still in progress. But from what has been given in a qualitative way here, a number of tentative conclusions can be drawn.

(1) The onset of scintillation is closely associated with a rapid reduction in the electron content of the equatorial ionosphere. A transport mechanism is almost certainly involved.

(2) There is a close association between scintillation and ionospheric temperature changes. This is suggested by the following considerations:

- (a) Scintillation appears just after ionospheric sunset. At this there is a rapid cooling of the ionospheric gas.
- (b) Scintillation is most severe at the equinoxes. The daytime ionospheric temperatures are highest during this season, and the post sunset drop in temperature is most severe. Scintillation is at a minimum during the June solstice; ionospheric temperatures also reach a seasonal low at this time.

- (c) An important ionospheric effect of severe magnetic storms is the elevation of the ionospheric temperature. If this effect continues during the hours of darkness, as seems likely, the post sunset drop in temperature should be reduced. Scintillation is also inhibited during severe magnetic storms.

(3) The physical process which gives rise to the fluctuation of the Faraday angle after sunset is most likely associated with ionospheric temperature changes. When such changes are moderate, as during a magnetic storm, the process is somewhat inhibited, proceeds more slowly, and the plasma remains stable. When the temperature changes are greatest, as on quiet days during the equinoctial periods, the process is more violent, occurs more rapidly, and triggers a concomitant plasma instability.

Thus these relatively simple experiments, and somewhat more sophisticated ones of a similar nature now in the planning stages, promise to throw new light on the behavior of the ionospheric plasma, helping us to unravel some of the fascinating intricacies of nature.

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The literature on upper atmospheric physics is very extensive. Here we give only two excellent recent summaries. These contain hundreds of references to more detailed information in the relevant journals.

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地球電離層的性質及其形成原因

JOHN KOSTER, SVD.

摘 要

此文簡述地球電離層的性質及其形成原因，並討論研究此地球電離層之主要方法。各種現象顯示電離層中的電子含量會造成一種易測的電磁波旋轉平面之循環轉動。不斷的測定由同步人造衛星送返之偏極化平面方向電波後，就可測量電離層電子含量的晝間變化。三篇典型的每日記錄可證明此項結論。假使要解釋赤道上所觀察到的現象，就必須藉下項結論：電子產生與和成之機械作用，必須與大量之分散運動互為增補。假設這種重要的運動型態與日落時電離層溫度的迅速變化互為關聯，則這種關聯就造成了電漿的不穩定性，間而引起了赤道上所見之閃爍現象。



THE KEPLERIAN COSMOS

(Marking the 400th Anniversary of Kepler's Birth)

MICHAEL RICHARTZ, SVD.

INTRODUCTION

Kepler's most important systematic exposition of astronomy, the "Epitome Astronomiae Copernicanae" is a textbook of the Keplerian Cosmos rather than an abstract of the Copernican system. A devout Copernican, Kepler had adopted the heliocentric idea of Copernicus, but he rejected the existence of solid spheres, deprived all planets of their epicycles, as well as of their uniform and circular motion. Kepler's universe was thus a strange one: in its center was the sun, fixed in its place, but rotating on its axis, emitting light and magnetic virtue; at its outer periphery was the region of the fixed stars, bounded by an enclosing sphere; in between were the planets, revolving about the sun in ellipses at velocities described by the relationships of the law of areas and the law of harmonies, while the sizes of the ellipses were functions of the periodic times. The clue to understanding these novelties had been the data of Tycho Brahe, interpreted by Kepler's conviction that mathematical harmonies governed the world. For Kepler it was not enough to find that the planets did revolve in fixed and continuous orbits, located in space at fixed distances from the center of the universe. He searched for the reason "why" they did so. And for Kepler this answer must be expressed in physical as well as in mathematical terms. For the first time since antiquity, an attempt was made not only to "describe" heavenly motions in geometrical terms but to assign them a "physical cause". Kepler faithfully recorded all circumstances of building his cosmos in his many letters and scientific publications.

KEPLER'S LIFE

Johannes Kepler was born on December 27th, 1571 in Weil, a small town in Württemberg. During the first years of his life, the

boy's health was often frail. He worked his way through elementary schools by winning scholarships which enabled him to reach the University of Tübingen in 1589. Kepler studied mainly theology and philosophy, but also mathematics and astronomy. Almost to the end of his life he kept in contact with his teacher Mästlin, one of the most esteemed astronomers in Germany. Although Mästlin was obliged to teach astronomy publicly according to Ptolemy's theory of the sun's movement around the earth, it was obviously Mästlin who led the young Kepler to a firm conviction of the superiority of the Copernican heliocentric astronomy over the old Ptolemaic one.

When Kepler had completed his studies in Tübingen, the University recommended him for a professorship of mathematics at the Protestant seminary in the Austrian city of Graz. Kepler at first was by no means enthusiastic about being sent away to Graz. For he had prepared himself for a theological pulpit, and had hoped to serve the orthodox Lutheran Church. But he yielded to the advice given to him by his teachers in Tübingen, and soon the young professor—aged only 21—gained considerable popularity in Graz. He was expected to prepare yearly calendars, containing full astronomical information liberally spiced with astrological prediction. He registered in the calendar not only the movements of the celestial bodies but indulged in astrological prophecies. But his main interest remained, always concentrated on the merely theoretical observations and calculations of the movements of the stars and not on the "practical" value of astronomical observations for the prediction of human fate.

Kepler's calendar for the year 1595 was read with great interest not only in Austria but also in Tübingen. There was some misgiving because Kepler adopted the calendar reform introduced by Pope Gregory XIII in 1582. The Senate of the University of Tübingen considered the adoption as a weakening of the independence of the Lutheran Church, and Mästlin was officially instructed to write against any compliance with the astronomical recommendation of the Catholic Church. But the young Kepler did not hesitate to disagree on this point even with his beloved teacher.

Along with the success of his calendars went two happy events, his marriage to a young noblewoman and the completion of his first major work, *The Cosmographical Mystery*. He proudly sent a copy to Mästlin, who saw it through the press late in 1596. Kepler also took care to send copies to princes—who might offer him a better and secure job—and to distinguished scientists, among them Tycho Brahe.

In 1600 Kepler accepted Tycho's invitation to Prague, to assist in the preparation of new astronomical tables, called the "Rudolphine tables". Tycho died in 1601 and Kepler continued the work alone, being appointed imperial mathematician and astronomer. During the years he spent as astronomer to the Emperor Rudolph II, Kepler did his most serious work. He had become the possessor of all of Tycho's papers. The mass of observations made by Tycho during 20 years, with a precision till then unsurpassed, enabled Kepler to establish the famous "Kepler's Laws". The latter part of his life was chiefly passed at Linz as professor of mathematics.

Throughout his life, Kepler had been longing for a stability which would allow him the fullest possible concentration on his revolutionary scientific work. But this desire was in his old age even less likely to be fulfilled than in his youth and his prime. In searching for a residence for himself and his family he died at Regensburg in 1650. At the grave of Kepler friends erected a simple stone, carrying four lines of a verse once composed by Kepler himself for this purpose:

"Once I measured the skies,
Now I measure the earth's shadow.
Sky-bound was the mind,
Earth-bound the body rests."

COSMIC MYSTERY

Kepler published his first book, the *Mysterium Cosmographicum* in 1596. It manifests the sincerity of his search for harmony and law in the creation of the divine power. He had been convinced that there was more order and harmony in the universe than custom-

ary astronomical methods could show. By order and harmony Kepler meant two different aspects of the cosmos: one, a reflection of the properties of the divine creator, the other, a set of mathematico-physical relationships.

The first chapter is an enthusiastic profession of faith in Copernicus. It was the first public commitment by a professional astronomer which appeared in print fifty years after Copernicus' death.

The following chapters deal with the problem of finding the law connecting the relative distances of the planets. He thought there must be a reason why number, distances and velocities of the moving bodies have the values which have been found by observation. He was never satisfied with the mere dry observation and registration of facts; he insisted on the necessity of thinking out constructive hypotheses which make the observed celestial phenomena intelligible.

A year after his arrival at Graz, one day when drawing a figure on the blackboard for his class an idea suddenly struck him. The figure showed a triangle fitted between two circles (Fig. 1). Their ratios were the same as those of the orbits of Saturn and Jupiter. That led him to look for three-dimensional forms. There existed six planets and there exist five perfect solids—five intervals between the planets. It was impossible to believe that this should be by chance. The "perfect solids", called Pythagorean solids, of which all faces are identical, are the tetrahedron, cube, octahedron, dodecahedron, and icosahedron (Fig. 2). Being perfectly symmetrical,

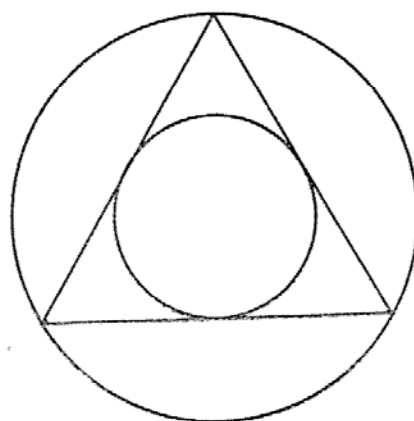


Fig. 1—A Triangle fits between two Circles.

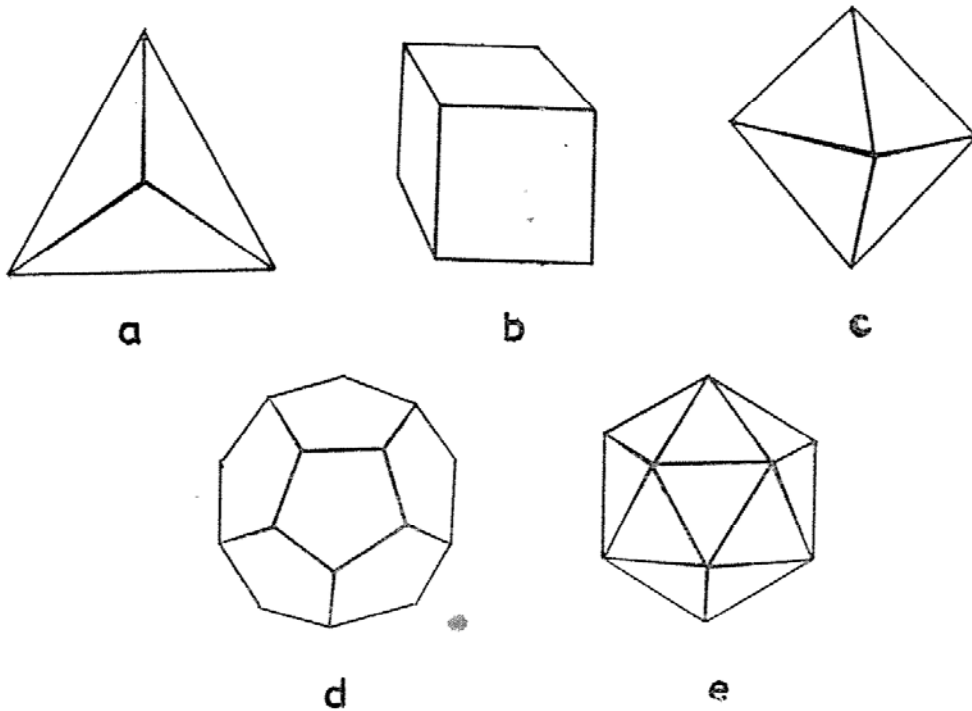


Fig. 2—The Five Perfect Solids: a, tetrahedron; b, cube; c, octahedron; d, dodecahedron; e, icosahedron.

each can be inscribed into a sphere so that all corners lie on the surface of the sphere. Similarly, each can be circumscribed round the sphere so that the sphere touches every face in its center. Kepler found that the five polygons fit between the six planetary spheres in the following order; SATURN—cube—JUPITER—tetrahedron—MARS—dodecahedron—EARTH—icosahedron—VENUS—octahedron—MERCURY (Fig. 3). Kepler gave a great many reasons for this order. He also worked out a model of the universe, incorporating the five perfect solids, made in the shape of a drinking cup (Fig. 4).

In his notes to the second edition of this work (1621) many points were dismissed or qualified as false, and based on illegitimate assumptions. But the book contained the germs of most of his later discoveries—as byproducts of its erroneous central idea.

NEW ASTRONOMY

After his arrival at Prague Kepler was allotted the study of the motions of Mars which had defeated Tycho's senior assistant and

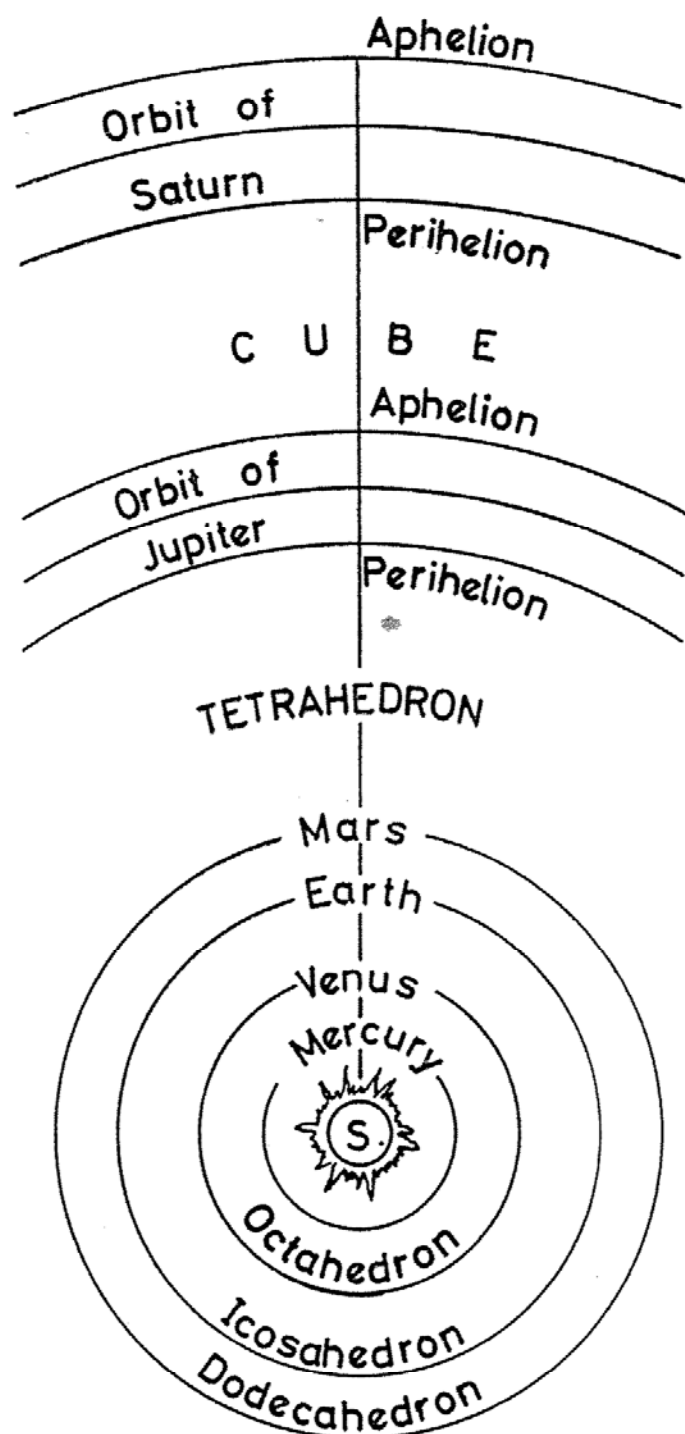


Fig. 3—Kepler's diagram of the planets' orbits inside the five regular solids.

even Tycho himself. Tycho expected the planets to move in circles, but Mars' orbit deviated more than the others from the circle; hence, it was impossible to reconcile theory with observation. In the *New Astronomy* Kepler described his ideas to solve the motion of Mars

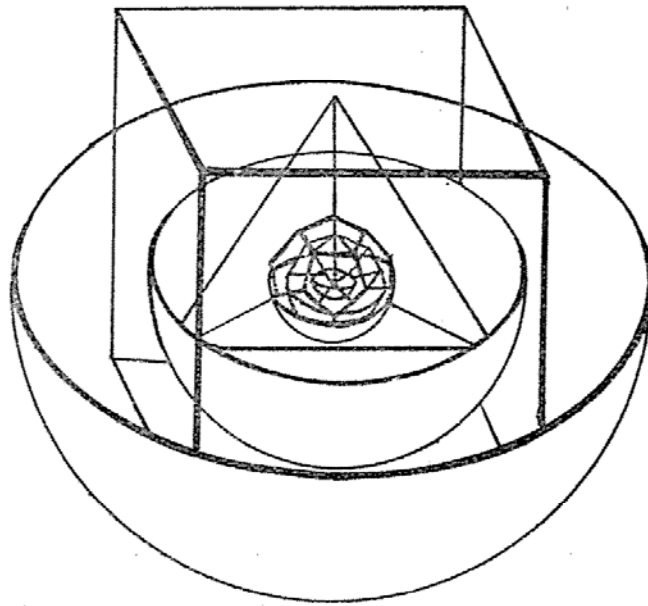


Fig. 4—The Cosmic Cup, Model of the Universe; the outermost sphere is Saturn's.

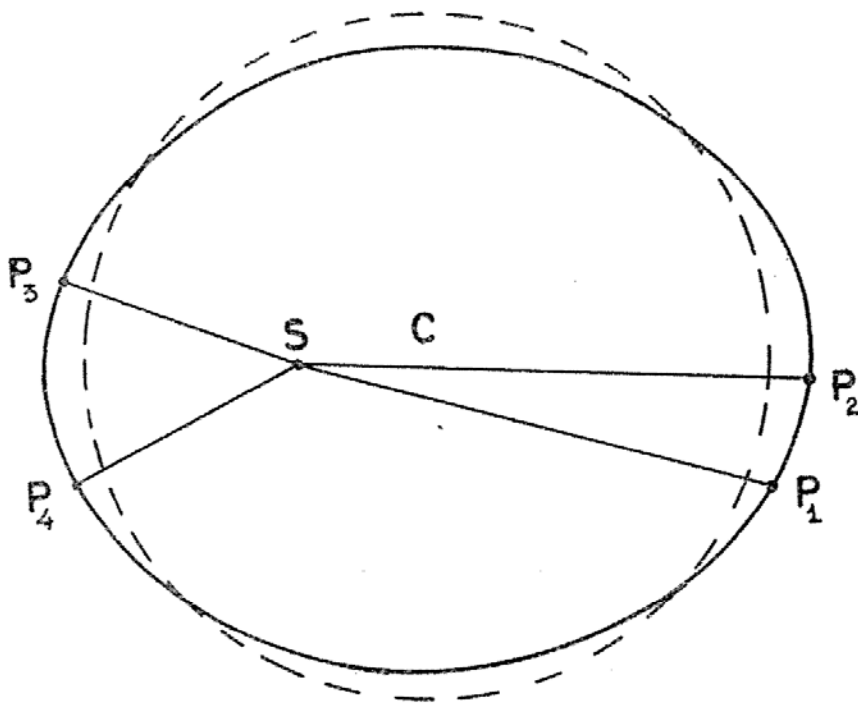


Fig. 5—Kepler's Law of Areas. The area of SP_1P_2 is equal to the area of SP_3P_4 ; S is the sun; P_1 , P_2 , P_3 , P_4 are positions of the planet. The dotted curve is a circle eccentric to S, with its center at C, the center of the ellipse.

in the order they came to him, including all the errors, detours, and the traps into which he had fallen.

The book contains the first two of the three astronomical laws which made Kepler's name immortal. They were the first "natural laws" in the modern sense: precise, verifiable statements about universal relations governing particular phenomena, expressed in mathematical terms.

The Second Law. Kepler first attacked the problem of investigating the motions of Mars on traditional lines. When he failed he made three preliminary innovations. (1) The center of the Copernican system was not the sun but the center of the earth's orbit. Since the force that moved the planets emanated from the sun, Kepler concluded that the whole solar system should be centered on the body of the sun itself. (2) Copernicus, misled by Ptolemy, had postulated that the plane of the Martian orbit "oscillates in space". Kepler proved that the plane in which Mars moves passes through the sun. (3) The third innovation was the most radical. "Uniform motion in perfect circles" was the basic axiom of cosmology from Plato up to Copernicus and Tycho. Kepler still let "circular" motion stand, but guided by physical considerations, he abolished uniform motion. He found that Mars as well as Earth moved faster when approaching the sun, and slower when receding from it.

Two problems presented themselves: how to find a mathematical expression for this variation, and how to explain its existence. The solution of the first problem was the "Second Law", that

"the radius vector drawn from the sun to the planet sweeps out equal areas in equal times" (Fig. 5).

The second problem, to explain the calculated variations in planetary velocities, was solved by Kepler in applying Gilbert's magnetic attraction. He developed the idea of a force (or virtue) similar to magnetism. The rotation of a planet is partly caused by the solar force, but chiefly by a force inherent in the planet. The existence of magnetic forces within each planet, varying with the size of the planet, explained the mysterious property of gravity.

The First Law. The Second Law which Kepler discovered before the First, determined the variations of the planet's speed along its orbit, but it did not determine the shape of the orbit. The final

assault took him nearly two years. Kepler tried for the last time to attribute a circular orbit to Mars. The more he investigated the more certain he became that Mars could not be travelling in a perfect circle eccentric to the sun. Finally he was convinced that the orbit must be an ellipse. After six years of hard labor he held the secret of the Martian orbit. He was able to express the manner in which the planet's distance from the sun varied with its position, in a single formula, a mathematical law of nature:

"The planets travel round the sun in elliptical orbits, one focus of the ellipse being occupied by the sun."

THE HARMONY OF THE WORLD

In 1619, another of the masterworks of Kepler appeared, *Harmonice Mundi*. As he tried to do in his *Cosmic Mystery*, Kepler coupled in his *Harmonice Mundi* the precise mathematical results of his investigations with an enormous wealth of poetical, religious and historical speculations. He boldly assumed that not only men but also the celestial bodies have some soul or awareness of the harmonies of the universe. He saw musical, geometrical and arithmetical harmonies realized everywhere. But the harmony is to Kepler only a mathematical conception; he does not imagine that there really is any "music of the spheres".

The work is divided into five books. The first two deal with the concept of harmony in mathematics; the following three with the applications of this concept to music, astrology, and astronomy. The fifth book contains—almost hidden among the many phantasies—the third law.

The Third Law. It says that

"the squares of the periods of revolution of any two planets are as the cubes of their mean distances from the sun."

Kepler had been searching for a correlation between the planet's period and its distance since his youth. Without such a correlation the universe would make no sense to him. If the sun had the power to govern the planet's motion, then that motion must somehow depend on its distance from the sun; but how? Kepler was the first who

saw the problem; he found the answer to it, after twenty-two years of labor. Nobody before him had thought of cosmological problems in terms of physical forces.

The importance of the third law is that it provided the final clue for Newton; hidden away in it is the essence of the law of gravity.

EPITOME OF THE COPERNICAN ASTRONOMY

Kepler's elementary text-book *Epitome astronomiae Copernicanae* was published in three parts in 1618, 1620, and 1621. The laws that originally referred to Mars only are here extended to all planets, including the moon and the satellites of Jupiter. It is Kepler's most voluminous work and the most important systematic book of astronomy since Ptolemy's *Almagest*, remarkable for the prominence given in it to "physical" astronomy.

RUDOLPHINE TABLES

The new planetary tables, the *Tabulae Rudolphinae*, based on Tycho's lifelong labors, were published in 1627. Their completion had been delayed for nearly thirty years by Tycho's death and by the chaotic conditions created by war. Astronomers and navigators, calendar makers and horoscope casters were impatiently waiting for the promised tables, and angry complaints about the delay came from as far as India and the Jesuit missionaries in China.

The bulk of the work consists of the tables and rules for predicting the positions of the planets, and of Tycho's catalogue of 777 star places, enlarged by Kepler to 1005. There are also refraction tables and logarithms, put for the first time to astronomic uses. The tables remained, for more than a century, an indispensable tool for the study of the skies, both planets and fixed stars.

OTHER SCIENTIFIC ACHIEVEMENTS

Dioptrice—Kepler published a work on optics in its relation to astronomy in 1604, entitled *Astronomiae pars Optica*; it was later supplemented by his *Dioptrice* in 1611. Therein Kepler reported on his study of the phenomenon of refraction in connection with his

"refracting telescope". In this theoretical treatise Kepler founded a new science and coined a name for it: "dioptrics—the science of refraction by lenses."

On the Six-cornered Snowflake—Kepler's essay on snowflakes, published in 1611, marked the beginning of the scientific examination of snowflakes in Europe. Until recently, the literature on snow crystals was concerned with the description of the main crystal forms, but very little with the factors that might determine shape and form. Kepler's contribution remained almost unique for 300 years. Although he could not explain the six-sidedness of the snowflake, his discussions of space-filling and symmetry laid the early foundations of crystallography.

KEPLER'S FATE

When Kepler died he had completely succeeded in purifying the Copernican system from the remnants of Alexandrian notions with which Copernicus himself had been unable to dispense. The solar system was now fully revealed in all its simplicity, and the single members thereof had for the first time been linked together by Kepler's Laws.

The three Laws are the pillars on which the edifice of modern cosmology rests. But to Kepler they meant no more than bricks among other bricks for the construction of his temple. He never realized their real importance. Of the First Law he was almost ashamed: it was a departure from the circle sacred to the ancients; the ellipse had nothing to recommend itself in the eyes of God and man. The Second Law he regarded as a mere calculating device; and the Third Law as a necessary link in the system of harmonies.

Kepler's scientific contemporaries read him little. Because man is conservative, a creature of habit, and convinced of his own importance, the new theory was decidedly unwelcome. Kepler was valued by kings and princes for his skill in astrological prediction. Astronomers praised him, but none appears to have taken his ideas seriously. Fortunately not everyone ignored Kepler's work; some

hints reached the young Newton before the end of 1665, in time to assist him in his first formulation of the New Newtonian system.

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開普勒對宇宙的構思

開普勒氏400週年誕辰紀念

MICHAEL RICHARTZ, SVD.

摘 要

開普勒(Kepler)對宇宙的構思基於兩種假設：其一，哥白尼(Copernicus)之太陽為宇宙中心的思想是正確的；其二，泰周·布拉(Tycho Brahe)以他整個生命觀察宇宙的結論的精確的。在四巨冊的論文中，許多的信件裏都詳記著由無數的試驗，失敗，而終於被發現的所謂開普勒定律(Kepler's Law)。雖然開普勒未能為他的數學定律找出真正物理上的根據，但是他的發現却供給牛頓(Newton)萬有引力定律的最終線索。

TOPOLOGICAL SEMIGROUPS III JORDAN-HÖLDER THEOREM

JOHN B. PAN, SJ.

SUMMARY

In this paper we will study the normal series and the refinements of series of semigroups.

Lemma 2: Let S be a semigroup satisfying the condition A and T be a subsemigroup of S . Let P be a relation such that $D(P)=T$ and R be a relation such that $D(R)=S$. Then $[T]R/PR$ is topologically isomorphic to $T/P(R \cap U_T)$.

Lemma 3: (The first extension of Zassenhaus' lemma). Let B and C be any subsemigroups of a semigroup S , which satisfies the condition A. Let P and Q be homomorphic equivalence relations such that $D(P)=B$ and $D(Q)=C$. Then $D[(Q \cap U_B)P] = [(C \cap B)]P$ and $D[(P \cap U_C)Q] = [(B \cap C)]Q$, and $[(C \cap B)]P / (Q \cap U_B)P \cong [(B \cap C)]Q / (P \cap U_C)Q$.

Theorem 1: (The first extension of Schreier's Theorem). If S is a topological semigroup satisfying the condition A, and if the homomorphic equivalence relations of two normal series are mutually weakly associable when written in reduced form, then the series can be refined to normal series whose quotient semigroups are topologically isomorphic in pairs.

Theorem 2: Jordan-Hölder Theorem. If the homomorphic equivalence relations of two non-refinable series are mutually weakly associable when written in reduced forms, then they are equivalent.

* * * * *

In this paper we will study the normal series and the refinements of series of semigroups. For the notions of topological semigroups in general, we refer the reader to my paper: "Topological Semigroups"⁽²⁾. In the following definitions we use the term "relation" for "homomorphic equivalence relation".

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Definition 1. Intersection of Relations: If R and P are relations over a set X . $R \cap P$ is a relation defined by $a(R \cap P)b$ if and only if aRb and aPb for $a, b \in X$.

Definition 2. Partial Order Among the Relations: Let R and P be two relations defined on X . We write $P \leq R$ if and only if aPb implies aRb . It is clear that if $P \leq R$ then $D(P) \leq D(R)$, where $D(R) = \{x | xRb, b \in X\}$. If R is a given relation, and B is a subalgebra contained in $D(R)$, then the R -classes which contains at least one element of B form the set of all elements of a subalgebra of A . This subalgebra is called the closure of B by R and is denoted by $[B]R$.

Definition 3. Product of Relations: Let R and P be two relations defined on a semigroup S . The product of these relations RP is defined as follows. Let $a, a^* \in S$. Then $a RP a^*$ if and only if there is a finite chain of the type $a P x_1, x_1 R x_2, x_2 P x_3, \dots, x_m P a^*$, where m is an even positive integer.

Definition 4. The Kernel of a Relation: Let S_0 be the minimal subsemigroup in a semigroup S . The closure of S_0 with respect to a relation R defined on S is called the Kernel of the relation R . We denote the Kernel of the relation R in S by $\{R\}$.

Definition 5. Weakly Associable Relations: Two relations R and P defined on a semigroup S are said to be weakly associable if

$$[\{R^*\}] P^* = [\{P^*\}] R^*,$$

Where $R^* = R \cap U_B$, $P^* = P \cap U_B$, $B = D(R) \cap D(P)$, and U_B is the universal relation on B .

Definition 6. Normal Series: Let S be a semigroup, and let B subsemigroup of S . The series of relations

$$U_S = R_1, R_2, \dots, R_{m+1} = I_B \quad (1)$$

with the following properties:

1. $\{R_{i+1}\} \leq \{R_i\} \leq D(R_{i+1})$;
2. $\{R_i\}$ is closed with respect to R_{i+1} for $i=1, 2, \dots, m$;

is called a normal series.

The semigroups $\{R_i\}/R_{i+1}$ are called the quotient semigroups of the normal series.

In a typical normal series, the domain of validity of R_{i+1} may contain $\{R_i\}$ as a proper part. However if we define $R_{i+1}^* = (R_{i+1} \cap U_{\{R_i\}})$ for $i=1,2,\dots,m$, and $R_1^* = R_1$, then $D(R_{i+1}^*) = \{R_i\}$ and $R_{i+1}^* = R_{i+1}$.

Definition 7. The Reduced Form of a Normal Series: The series

$$S^* = R_1^*, R_2^*, \dots, R_{m+1}^* = I_B^* \quad (2)$$

where $R_1^* = R_1$, and R_i^* for $i=1,2,\dots,m$, are defined above, is called the reduced form of the normal series⁽¹⁾.

The following lemma is due to Goldie⁽¹⁾.

Lemma 1: For any two relations R and P defined on a set X , $D(RP) = [D(R) \cap D(P)] P$.

Lemma 2: Let S be a semigroup satisfying the condition A , and T be a subsemigroup of S . Let P be a relation such that $D(P) = T$ and R be a relation such that $D(R) = S$. Then $[T]R/PR$ is topologically isomorphic to $T/P(R \cap U_T)$.

Proof: We first show that there is a one to one correspondence between the elements of $T/P(R \cap U_T)$ and that of $[T]R/PR$. Let A be an element of $T/P(R \cap U_T)$ and $t_1, t_2 \in A$. Then there is a finite chain of the type

$$t_1(R \cap U_T)x_1, x_1Px_2, x_2(R \cap U_T)x_3, \dots, x_m(R \cap U_T)t_2.$$

This chain implies the existence of another chain

$$t_1R_1, x_1Px_2, x_2Rx_3, \dots, x_mRt_2.$$

This latter chain means that t_1, t_2 belong to some class $B \bmod PR$. Since t_1, t_2 are two arbitrary elements of A , this shows $A \subset B \bmod PR$.

Now we show that each class $B \bmod PR$ can contain only one class $A \bmod P(R \cap U_T)$. Suppose that A_1, A_2 are two classes $\bmod P(R \cap U_T)$ and that $A_1, A_2 \subset B$, let $t_1 \in A_1$, and $t_2 \in A_2$. Since $t_1, t_2 \in B$, there is a finite chain of the type

$$t_1Rx_1, x_1Px_2, x_2Rx_3, \dots, x_mRt_2.$$

But $D(P) = T$. Hence all the x_i^* ($i=1,2,\dots,m$) belong to T . So we can write the above chain in the following way:

$$t_1(R \cap U_T)x_1, x_1Px_2, x_2(R \cap U_T)x_3, \dots, x_m(R \cap U_T)t_2.$$

This means that A_1 and A_2 are the same class mod $P(R \cap U_T)$. This shows that there is a one to one correspondence between the elements of $T/P(R \cap U_T)$ and the elements of $[T]R/PR$.

We define a mapping h from $T/P(R \cap U_T)$ onto $[T]R/PR$ by assigning to each element A of $T/P(R \cap U_T)$ the element B in $[T]R/PR$ to which A belongs. We wish to show that this mapping h is a topological isomorphism. Since we have shown that h is a one to one mapping, it remains to show that h is an open topological homomorphism.

Let $A_1, A_2 \in T/P(R \cap U_T)$ be such that $A_1 \subset B_1$, and $A_2 \subset B_2$. Then $h(A_1) = B_1$ and $h(A_2) = B_2$. Since PR is a homomorphic equivalence relation, $A_1A_2 \subset B_1B_2$. Hence $h(A_1A_2) = B_1B_2$. Therefore $h(A_1A_2) = h(A_1)h(A_2)$. This means that h is an abstract homomorphism.

Finally, we show that h is continuous and open. We topologize the quotient semigroups $T/P(R \cap U_T)$ and $[T]R/PR$ with quotient topologies. Let n be the natural mapping from S to S/R , and n^* be the natural mapping from T to $T/P(R \cap U_T)$ and let n^{**} be the natural mapping from $[T]R$ onto $[T]R/PR$. By the following diagram

$$T/P(R \cap U_T) \xleftarrow{n^*} [T] \xrightarrow{n} [T]R/R \xleftarrow{n} [T]R \xrightarrow{n^{**}} [T]R/PR$$

we can easily see that the mapping h is equal to the product of mappings $n^{**}n^{-1}n(n^*)^{-1}$. Since S satisfies the condition A, by theorem 1, all the natural mappings are continuous and open. So their product h is also open and continuous. This completes the proof.

Lemma 3: (The first extension of Zassenhaus' lemma). Let B and C be any subsemigroups of a semigroup S , which satisfies the condition A. Let P and Q be homomorphic equivalence relations such that $D(P) = B$ and $D(Q) = C$. Then

$$D[(Q \cap U_B)P] = [(C \cap B)]P \text{ and } D[(P \cap U_C)Q] = [(B \cap C)]Q.$$

and

$$[(C \cap B)]P / (Q \cap U_B)P \cong [(B \cap C)]Q / (P \cap U_C)Q.$$

Proof: Consider the following relations:

$$\begin{aligned}
D(Q \cap U_B) &= \{x \in S \mid xQy \text{ for some } y \in S \text{ and } x, y \in B\} \\
&= \{x \in S \mid xQy \text{ for some } y \in B\} \cap B \\
&= D(Q) \cap B \\
&= C \cap B.
\end{aligned}$$

Hence $D(Q \cap U_B) = C \cap B$.

Now consider $(C \cap B)$ as a subsemigroup of B . Let $(Q \cap U_B)$ be a relation such that

$$D(Q \cap U_B) = (C \cap B)$$

and let P be any relation such that $D(P) = B$; then, by Lemma 1.2,

$$\begin{aligned}
(C \cap B) P / (Q \cap U_B) P &\cong (C \cap B) / (Q \cap U_B) (P \cap U_{(C \cap B)}) \\
&= (C \cap B) / (Q \cap U_B) (P \cap U_C).
\end{aligned}$$

By symmetry we have

$$\begin{aligned}
[(C \cap B)] Q / (Q \cap U_C) Q &\cong (C \cap B) / (P \cap U_C) (Q \cap U_{(C \cap B)}) \\
&= (C \cap B) / (P \cap U_C) (Q \cap U_B).
\end{aligned}$$

Therefore

$$(C \cap B) P / (Q \cap U_B) P \cong (C \cap B) Q / (P \cap U_C) Q.$$

This completes the proof.

Theorem 1: (The first extension of Schreier's Theorem). If S is a topological semigroup satisfying the condition A, and if the homomorphic equivalence relations of two normal series are mutually weakly associable when written in reduced form, then the series can be refined to normal series whose quotient semigroups are topologically isomorphic in pairs.

Proof: This theorem was proved by Goldie⁽¹⁾ except for the topological isomorphism. However, in proving the theorem he made use of the first extension of Zassenhaus's lemma and the second isomorphism theorem. Both of these theorems are proved by us for the topological isomorphism. Hence keeping this in mind we can arrive at our theorem by following Goldie's proof word by word.

Theorem 2: Jordan-Hölder Theorem. If the homomorphic equivalence of two non-refinable series are mutually weakly associable when written in reduced forms, then they are equivalent.

Proof: This theorem follows from theorem 1. By that theorem the two normal series in question have equivalent refinements. But by supposition the two series are non-refinable. Therefore the two series must be equivalent themselves. Again the attention of the reader is called to the fact that this theorem is valid in the topological sense for the same reason stated in the remark above the theorem 1.

NOTES

- (1) Wa. Goldie: "The Jordan-Holder Theorem For General Abstract Algebras", *Proceedings of the London Mathematical Society* (2) 52 p 107-131.
 (2) John B. Pan S.J.: "Topological Semigroups", *Fu-Jen Studies*, No. 1, 1968.

拓 模 半 羣 III 約 但 、 海 爾 德 定 理

潘 壽 山

摘 要

本論文討論拓模半羣的正規序列及其加細，研究的目的是把代數的定理推廣到拓模半羣裏去。下面是研究的結果：

副定理 2：假設拓模半羣 S 滿足條件 A ， T 是 S 的子半羣， P 和 R 是兩種關係，其定義範圍分別為 $D(P) = T$ ，和 $D(R) = S$ ，則 $[T]R/P$ 和 $T/P(R \cap U_T)$ 是拓模同構的。

副定理 3：(Zassenhaus') 假設 B 和 C 是拓模半羣 S 的子拓模半羣，而且 S 滿足條件 A 。又假設 P 和 Q 是同態等價關係，其定義範圍分別為 $D(P) = B$ ， $D(Q) = C$ 。

$$\text{則 } D[(Q \cap U_B)P] = [(C \cap B)]P;$$

$$D[(P \cap U_C)Q] = [(B \cap C)]Q;$$

$$[(C \cap B)]P / (Q \cap U_B)P \cong [(B \cap C)]Q / (P \cap U_C)Q$$

定 理一、(Schreier 定理之推廣) 假設 S 是滿足條件 A 的拓模半羣，而且兩個正規序列，在其簡化形狀下的同態等價關係是弱性相連的，則兩序列可以加細，使其商半羣彼此拓模同構。

定 理二、Jordan-Holder 定理 假設兩個不能加細的序列，在其簡化形狀下的同態等價關係是弱性相連的，它們便是等價的。

THE MAPPING POLYNOMIALS OVER GALOIS FIELDS

CHI-YU HSU

INTRODUCTION

Some of the number operations, such as computation of Boolean functions, the decoding of block codes, can be explained as a many-to-one mapping over an n -dimensional space S_n . This mapping can be indicated by a polynomial, and we may easily find such polynomials by two ways. One is by computing sets of such coefficients for specified mappings and the other by computing mappings to conform with specified sets of coefficients. If we select S_n properly the relationship between the mappings and coefficients will become simple.

THE MAPPING POLYNOMIAL

$$\text{If } GF(2^n) = \{a_0, a_1, \dots, a_{2^n-1}\} \quad (a_0 = 0) \quad (1)$$

is a Galois field.

$$\text{Then } a_i = \alpha_0 + \alpha_1 y + \alpha_2 y^2 + \dots + \alpha_{n-1} y^{n-1}$$

$$\text{where } \alpha_j \in GF(2) \quad j = 0, 1, \dots, n-1 \quad (2)$$

Field operations are modulo 2 and modulo any fixed irreducible polynomial in y of degree n .

$$p(y) = \beta_0 + \beta_1 y + \dots + \beta_{n-1} y^{n-1} + y^n \quad (3)$$

$p(y)$ is called modulus polynomial of $GF(2)$ $i = 1, 2, \dots, n-1$.

$$\text{If } f_i(x) = \prod_{k \neq i} (x - a_k) = \varphi_0^{(i)} + \varphi_1^{(i)} x + \dots + \varphi_{2^n-1}^{(i)} x^{2^n-1} \quad (4)$$

$$\text{where } \varphi_i \in GF(2) \quad i = 0, 1, \dots, 2^n-1$$

is called the characteristic polynomial of $GF(2^n)$.

If f is a many to one mapping f over $GF(2^n)$ and we denote the image of a_i by a'_i , we define

$$f(x) = \sum_{i=0}^{2^n-1} f_i(x) a'_i = \varphi_0 + \varphi_1 x + \dots + \varphi_{2^n-1} x^{2^n-1} \quad (5)$$

Which is called the mapping polynomial of the mapping f .

Theorem 1

$$f_i(a_k) = \begin{cases} 1 & k=i \\ 0 & k \neq i \end{cases} \quad (6)$$

$$\text{pf:} \quad \therefore \prod_{k \neq 0} (x + a_k) = x^{2^n-1} + 1 \quad (7)$$

$$\text{Let } x=0 \quad \prod_{k \neq 0} a_k = 1 \quad (8)$$

$$f_i(a_i) = \prod_{k \neq i} (a_i - a_k) = \prod_{m \neq 0} a_m = 1 \quad \text{for } k=i \quad (9)$$

$$f_i(a_k) = \prod_{k \neq i} (a_k - a_k) = 0 \quad \text{for } k \neq i$$

Theorem 2

$$f(a_j) = a'_j \quad (10)$$

$$\text{pf:} \quad f(a_j) = \sum_{i=0}^{2^n-1} f_i(x) a'_i = f_j(a_j) a'_j = a'_j \quad (11)$$

Any many-to-one mapping f over S_n can be regarded as a mapping over $GF(2^n)$ so that it can be expressed by a polynomial $f(x)$.

Any element $(\alpha_0, \alpha_1, \dots, \alpha_{n-1}) \in S_n$ can be expressed as a polynomial $a = \alpha_0 + \alpha_1 y + \dots + \alpha_{n-1} y^{n-1}$ $f(a) = a'$

Then the coefficients of $a' \in \{(\alpha_0, \alpha_1, \dots, \alpha_{n-1})\}$.

In computing $f(x)$, we must compute all the coefficients, φ_i of $f(x)$. In special cases if the coefficient of $f(x)$ exhibit some symmetry, it is sufficient for us to remember the part of all (j, φ_j) pairs. (if φ_j is periodic with j , with the period k , it is sufficient to remember the first k pairs). Then this passage can be simplified.

PROPERTIES OF COEFFICIENTS OF $f(x)$

We must select a maximum period polynomial as a modulus polynomial for $GF(2^n)$. (at least there exists one such polynomial for every n). Then y becomes a primitive of $GF(2^n)$. We can write

$$a_i = y^{i-1} \quad (i=1, 2, \dots, 2^n-1) \quad (12)$$

Then the coefficients of the characteristic polynomials $f_i(x)$ become simpler.

Theorem 3

$$\varphi_j^{(0)} = \begin{cases} 1 & j=0, 2^n-1 \\ 0 & j=1, 2, \dots, 2^n-2 \end{cases} \quad (13)$$

$$\text{if } i \neq 0 \quad \varphi_j^{(i)} = \begin{cases} y^{-(i-1) \pmod{2^n-1}} & j \neq 0 \\ 0 & j = 0 \end{cases} \quad (14)$$

$$\text{pf: } \because f_i(x) = \frac{x+x^{2^n}}{x+a_i} \quad (15)$$

$$\text{if } i=0, \quad a_i=0 \quad \text{then } f_0(x) = 1+x^{2^n-1} \quad (16)$$

$$\text{if } i \neq 0, \quad a_i \neq 0 \quad f(x) = \frac{x+x^{2^n}}{x+a_i} = a_i^{2^n-2}x + a_i^{2^n-3}x + \dots + a_i x^{2^n-2} + x^{2^n-1} \quad (17)$$

$$(\because a_i^{2^n} = a_i \quad \therefore a_i^{2^n-1} = 1)$$

$$\therefore \varphi_0^{(i)} = 0 \quad \varphi_j^{(i)} = a_i^{2^n-1-j} = a_i^{2^n-1-j \pmod{2^n-1}} = a_i^{-j \pmod{2^n-1}} \quad (18)$$

$$\because a_i = y^{j-1} \quad \therefore \varphi_j^{(i)} = y^{-j(i=1) \pmod{2^n-1}}$$

the theorem 3 is proved.

If A be $2^n \times 2^n$ matrix with rows $i=0,1,\dots,2^n-1$, columns $j=0,1,\dots,2^n-1$ and $(i-j)$ -th element be $\varphi_j^{(i)}$. Then

$$A = \begin{matrix} & \begin{matrix} 0 & 1 & 2 & 2^n-3 & 2^n-2 & 2^n-1 \end{matrix} \\ \begin{matrix} 0 \\ 1 \\ 2 \\ 3 \\ \vdots \\ 2^n-1 \end{matrix} & \begin{bmatrix} 1 & 0 & 0 & \dots & 0 & 0 & 1 \\ 0 & 1 & 1 & \dots & 1 & 1 & 1 \\ 0 & y^{2^n-2} & y^{2^n-3} & \dots & y^2 & y & 1 \\ 0 & y^{(2^n-2)2} & \dots & y^4 & y^2 & 1 \\ \vdots & \vdots & & \vdots & \vdots & \vdots \\ 0 & y^{(2^n-2)(2^n-2)} & \dots & y^{2(2^n-2)} & y^{2(2^n-3)} & 1 \end{bmatrix} \end{matrix} \quad (19)$$

If we omit row 0 and column 0, the submatrix is symmetric about the diagonal extending from bottom left to top right corner.

example if $n=3$ $p(y)=1+y+y^3$
GF(2^3) consists

$$\begin{aligned} a_0 &= 0 & a_1 &= y^0 = 1 & a_2 &= y^1 = y & a_3 &= y^2 = y^2 \\ a_4 &= y^3 = 1+y & a_5 &= y^4 = y+y^2 & & & & \\ a_6 &= y^5 = 1+y+y^2 & a_7 &= y^6 = 1+y^2 & y^7 &= 1 & & \end{aligned} \quad (20)$$

$$A = \begin{matrix} & \begin{matrix} 0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 \end{matrix} \\ \begin{matrix} 0 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{matrix} & \left[\begin{array}{cccccccc} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & y^6 & y^5 & y^4 & y^3 & y^2 & y & 1 \\ 0 & y^5 & y^3 & y & y^6 & y^4 & y^2 & 1 \\ 0 & y^4 & y & y^5 & y^2 & y^6 & y^3 & 1 \\ 0 & y^3 & y^6 & y^2 & y^5 & y & y^4 & 1 \\ 0 & y^2 & y^4 & y^6 & y & y^3 & y^5 & 1 \\ 0 & y & y^2 & y^3 & y^4 & y^5 & y^6 & 1 \end{array} \right] \end{matrix} \quad (21)$$

Theorem 4 if we define

$$B = (\varphi_0, \varphi_1, \dots, \varphi_{2^n-1}) \quad (22)$$

$$a' = (a'_0, a'_1, \dots, a'_{2^n-1}) \quad (23)$$

Then $B = a'A$ (24)

pf: \therefore The j -th element of $a'A$ is

$$\varphi_j^{(0)}a'_0 + \varphi_j^{(1)}a'_1 + \dots + \varphi_j^{(2^n-1)}a'_{2^n-1} \quad (25)$$

$$(j=0, 1, \dots, 2^n-1)$$

Which is the coefficient of x^j of $f(x)$ is φ_j

$$\therefore B = a'A$$

Theorem 5

If A is non-singular, inverse is A^{-1} , let the (i, j) -th element of A^{-1} be b_{ij} $(i, j=0 \dots 2^n-1)$

Then $b_{i0} = \begin{cases} 1 & i=0 \\ 0 & i \neq 0 \end{cases}$ (26)

if $j \neq 0$ $b_{ij} = y^{i(j-1) \pmod{2^n-1}}$ (27)

pf: let A^* be a matrix, the (i, j) -th element of A^* is b_{ij} .

Let $AA^* = M$ (i, j) -th element of M is C_{ij}

by (13), (14), (26), (27),

Then $C_{00} = 1$ (28)

$$C_{0j} = 1 + y^{(2^n-1)(j-1) \pmod{2^n-1}} = 0 \quad j \neq 0 \quad (29)$$

$$C_{i0} = 0 \quad (i \neq 0) \quad (30)$$

for all $i \neq 0$ $j \neq 0$

$$C_{ij} = \sum_{k=0}^{2^n-1} \varphi_k^{(i)} b_{kj} = \sum_{k=1}^{2^n-1} y^{-k(i-1) \pmod{2^n-1}} y^{k(j-1) \pmod{2^n-1}} \\ = \sum_{k=1}^{2^n-1} y^{k(j-i) \pmod{2^n-1}}$$

if $i=j$, C_{ij} is the sum of odd number of 1 and hence 1

if $i \neq j$, let $y^{j-i} = z$

$$\text{Then } C_{ij} = 1 + z + z^2 + \dots + z^{2^n-2} = \frac{1+z^{2^n-1}}{1+z} = 0 \quad (31)$$

AA^* is identity matrix $A^* = A^{-1}$

$$A^* = A^{-1} = \begin{matrix} & 0 & 1 & 2 & 3 & 4 & \dots & 2^n-1 \\ \begin{matrix} 0 \\ 1 \\ 2 \\ \vdots \\ 2^n-2 \\ 2^n-1 \end{matrix} & \begin{bmatrix} 1 & 1 & 1 & 1 & 1 & \dots & 1 \\ 0 & 1 & y & y^2 & y^3 & \dots & y^{2^n-2} \\ 0 & 1 & y^2 & y^4 & \dots & \dots & y^{(2^n-2)^2} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 1 & y^{2^n-2} & y^{2(2^n-2)} & \dots & y^{(2^n-2)(2^n-2)} \\ 0 & 1 & 1 & 1 & \dots & \dots & 1 \end{bmatrix} \end{matrix} \quad (32)$$

If A is given is (21), then A^*

$$A^* = \begin{matrix} & 0 & 1 & 2 & 3 & 4 & 5 & 6 & 7 \\ \begin{matrix} 0 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ 7 \end{matrix} & \begin{bmatrix} 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & y & y^2 & y^3 & y^4 & y^5 & y^6 \\ 0 & 1 & y^2 & y^4 & y^6 & y & y^3 & y^5 \\ 0 & 1 & y^3 & y^6 & y^2 & y^5 & y & y^4 \\ 0 & 1 & y^4 & y & y^5 & y^2 & y^6 & y^3 \\ 0 & 1 & y^5 & y^3 & y & y^6 & y^4 & y^2 \\ 0 & 1 & y^6 & y^5 & y^4 & y^3 & y^2 & y \\ 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \end{bmatrix} \end{matrix} \quad (33)$$

$$\text{so that } a' = BA^* \quad (34)$$

by (24) $B = a'A$ so that every $\varphi_i \in B$

Can be computed by mapping $a \rightarrow a'$. $\therefore f(x)$ can be obtained.

By (34) for any mapping polynomial $f(x)$, we can obtain B . Then a can be readily computed. Therefore mapping $a \rightarrow a'$ can also be computed.

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