lect has absorbed a considerable number of Tungus stems, which in their use in word-formation have been subjected to the rules of the Yukaghir grammar. These investigations show that the Yukaghir language stands isolated from the Siberian languages of the so-called Ural-Altaic group, and that it has many similarities to the languages of the American Indians.

The chief phonetic and morphological differences that distinguish the Yukaghir language from Ural-Altaic languages are the following: (1) It has not the intricate system of vowel harmony that is found in Ural-Altaic languages; (2) we do not find that the vowel of the root is unchangeable—an important rule in Ural-Altaic phonetics; (3) the Ural-Altaic possessive suffixes of nouns and verbs are wholly absent in Yukaghir verbs, and present in nouns only for the purpose of expressing ownership of the third person; (4) words are formed by means of suffixes and prefixes, while the Ural-Altaic languages use suffixes only.

The chief points of similarity between the Yukaghir language and Indian languages are: (1) The existence of a simple harmonic law in the use of vowels; (2) the use of prefixes; (3) adjectives are morphologically identical with verbal forms; (4) the verb-bases are mostly stems consisting of a single vowel or a small group of consonants, while the noun-bases are almost always derivatives of verbal forms; (5) the conjugation of transitive verbs is clearly distinguished from that of intransitive verbs; (6) transitive verbs may be changed into intransitive verbs by means of suffixes, and *vice versa;* (7) we find in the Yukaghir language the 'polysynthesis' of the American languages; (8) although there is not the actual 'incorporation' of the American languages, the syntactical construction of the Yukaghir sentence is akin to it.

James E. Lough,
Secretary.

DISCUSSION AND CORRESPONDENCE.

A FLYING MACHINE IN THE ARMY.

To the Editor of Science: In recent numbers of various journals, much has aptly been said about flying machines, balloons, aeroplanes, kites, aerodromes and mechanical means for navigating the air, with historical data, giving credit where credit is due and naming several of the great thinkers of the age and what they have done in this direction, with hints for the future, but not a word of what the army has done seems to have been printed.

For ages commanders in the field have desired to know what the enemy was doing. Hence the use of captive balloons and the wish to make them dirigible; and when the Astronomer General Mitchell commanded at Port Royal during the civil war, the matter was discussed with his chief engineer officer, who brought forward the proposition to make a *machine* without inflation, and exhibited a tin model that wound up with a string and a handle and spun like a humming top and would fly into the air a hundred feet or more, vertically, according to the force exerted upon it, and would carry a bullet or two if the string was pulled hard enough. From this little toy which was a circular disc of tin, so cut and bent as to make a fan-screw wheel, it was argued that with power enough, if it could be had within the necessary limit of weight, such fan propellers could be made and combined as to lift an observer into the air and by other horizontal propellers could be driven through the air, and by making one on a horizontal shaft so that the direction of its axis could be changed at will, the machine could be steered.

That it must have power to be driven faster than the wind moves was apparent or the wind would take it as it does a balloon. At that time balloons were very simple. No one had made progress in directing their flight.

Mitchell was a mechanician as well as a mathematician, and was proud of being able to measure the one ten-thousandth of an inch accurately, and he concluded that it would be well to consider the problem of air navigation without gas bags. But the yellow fever claimed him, and for a long time no more was done in that direction at department headquarters.

The Tenth Army Corps had a captive balloon, but it was of little use, except to excite the wish that we had something better, and during the siege of Charleston Major Richard Butt and Captain James E. Place, of the engineers, and myself frequently discussed the details of a machine that should not only take up observers and go where we wished and come back, but carry bombs with high explosives to punish the enemy. The 'come back' part was of importance. The balloon would go, if the wind was right, but we had no way to make it come back as was wanted, hence it was never made to *go*.

The flight of birds was observed, buzzards, crows, eagles and gulls particularly. The machine must meet the requirements, to start, to go, to come back, to land safely—all were considered. There was no record that these questions had ever been before considered to be done mechanically, without gas. We considered gas-bag inflation as so objectionable as to be out of the question. Any machine held up by rarefied air or its equivalent presented so large a surface that power could not be had to drive it against the air, and unless it could go against the air quicker than the air itself moved, it was of no use for our purposes.

The ordnance department had tables of atmospheric velocities, so it was known what had to be encountered. During the siege of Charleston nothing was accomplished, but shortly after the Tenth Army Corps was moved up into Virginia and Petersburg was attacked, the means of finding out what the enemy was doing became a very prominent question with the engineers.

The tin toy was experimented with and a four-inch diameter fan was spun up to an elevation of over a hundred feet.

Major-General Benjamin F. Butler commanded the Army of the James and that included the tenth corps, and upon seeing what the tin toy did, immediately expressed the belief that a machine could be made that would navigate the air and give us the information desired, and could do more by dropping high explosives, and gave the writer an order to report officially upon the subject. No data could be found that gave any encouragement. The Duke of Argyle had organized a society in England, of which he was president, but except with gasholders to sustain the weight his society had done nothing. This society was communicated with, but before any reply was received drawings were made for a machine that should be screwed up and screwed forward, which if it could be made to ascend could be made to descend as slowly as desired, and it was to have planes by which to glide.

The theory was to imitate the little tin model and add to it gliding planes, and the drawings showed four fans to lift, two above an engine, two below, and two fans to propel and steer, one in front and one behind; the rear fan on a shaft that moved in a horizontal segment, so as to change the direction of the push, and make the rear fan not only a propeller, but a rudder at the same time. Across the machine was to be a horizontal shaft, on which on either side of the machine were to be gliding planes and automatic balancing balls. These were to slide in and out so as to maintain an equilibrium.

It had been observed that buzzards secured a vast amount of their progress by gliding, and the intention was to screw up and then glide in a descending curve, and by so doing save power, using the weight of the machine itself, and when the curve had come near enough to the earth, change the angle of the gliding planes, and by momentum go up as far as the impulse would aid in doing, using again at the same time the elevating screws. It was provided with a light supporting frame like the runners of a sleigh, on which to alight and to stand when at rest.

The body was to contain fuel and water and a high-pressure boiler and engine, and was to be shaped like a thick cigar. The length of the machine was about fifty-two feet, and from tip to tip of the gliding plane wings a little more. It was proposed to hang from the middle of the body a weight that could be lifted or lowered to act like the legs of a bird in flight and to balance it as the tail of a kite does. This vertically hanging weight was also to extend or draw in the balancing balls after the manner of the balancing pole used by the tight-rope walker.

It was argued that as a locomotive made to walk on four legs, imitating a horse, was not a success, while the round leg as a wheel, acting continuously, was all that was wanted, so too the lifting and propelling fans, being intended for continuous motion, should do the work of wings and, better than reciprocating mechanical appliances, made to flap, condense the air, lift the body, release and flap again.

General Butler was so impressed when he saw the drawing and heard the explanation, that he ordered the machine to be built at once, and put the work in my charge.

There was, however, no appropriation that could be used to pay for it, and it seemed that nothing could be done; there was a very good engineer park, but the tools and machines at disposal were not fine enough to cut gear or to bore cylinders. Fortunately some patriotic citizens, who should be forever remembered, generously offered to pay the bills. Mr. Frederick Prentice, Mr. Wedworth W. Clarke, of New York City, and Mr. Sully, who were among the pioneers in the petroleum fields and were growing rich very fast, said: 'Send the bills to us; we will pay for anything wanted and will help to get it.'

The first thing done was to make a fan eighteen inches in diameter, rotate it at different speeds and see how much it would lift. The fan was made of very thin brass, and upon a wire frame, very much the same shape as those now used for ventilating and blowing, driven by electricity. It was found that a hollow blade with a blunt shoulder seemed to be best.

It was found that very considerable weight could be lifted, and to try what could be done on a large scale, a fan about thirty-two feet in diameter was made, the blades of the thinnest sheet iron that could be procured, and rotation by belt was provided.

Contrary to expectation, when the fan was first rotated at great speed in a foundry that had a high roof, the weight that could be lifted was much more than the wheel itself, some six hundred pounds or more, and then within forty seconds of time the wheel and the weights would drop back to where they started from, it mattered not how fast the fan was driven.

This was a puzzle, indeed. Why did it act so? When spun at a given speed, starting from at rest in still air, a certain velocity would make the wheel jump up the vertical shaft very quickly, lifting its own weight, and then suddenly, and as the velocity was increased, it would, after an interval never longer than forty seconds, slide down the vertical shaft, not sustaining its own weight. Hundreds saw it. The test was repeated again and again. No one understood why it did as it did.

Resort was then had again to the eighteen-inch brass wheel and it was found that after a certain period it went through the same manœuvers as the large fan, but the period of ability to lift was many times longer in the small than in the large.

It was found after a long investigation that the fan wheel of any size, when rotated in one place, set up a downward current of air that soon became nearly or quite as fast as the pitch of the fan, hence it would lift nothing. When, however, the fan was mounted at the outer end of a long boom, which revolved around a mast, so as to constantly bring the fan into new air, its lifting capacity never deserted it and bore a certain ratio to the velocity, and data were accumulated for proportioning the machine.

In those days there were no such machines as are now to be found everywhere, by which the horse power required at different velocities could readily be accurately measured, and some difficulty was experienced in approximating the requirements.

The questions involved seemed to be the size of the fan, the shape of the blade, the power required, the weight of the engine, boiler, fuel and water to develop the power.

Major-General Quincy A. Gillmore was an engineer officer of very high reputation and of considerable learning. He was asked to examine the plans and the data that had at this stage of the investigation been collected. He certified as a matter of opinion that it was 'all right.'

There were no dynamos or storage batteries, liquid air engines or sources of powerful energy using light-weight machines, and the only prime motor sufficiently reliable was the steam-engine.

To get the strongest and the lightest was the problem.

It is true that carbonic acid had been liquefied some years before then, but no one knew how to harness it.

Having determined the probable force wanted, engine builders were found who agreed to make the engine light enough and of sufficient horse power, and the frame of the machine was set up at Hoboken, N. J. The fans were made for the lifting and driving, and the intermediate gear of bronze was cut. The body of the machine was complete.

At this stage it seemed that it only remained to get pressure enough upon the piston of the engine and maintain that pressure.

During the siege of Fort Wagner before Charleston we had used calcium lights, and had had great trouble to make the gas holders tight enough to prevent leak at high pressures. Mr. Mirriam, of Springfield, Mass., had succeeded in the field by a new method of floating the joints. Bennett and Risley, of Greenwich Street, New York, who undertook the engine, believed that they could make the joints of the boiler, the gaskets, the grummits and moving parts of the engine so as to work well under the required very high pressure of steam, by their new process, which seemed reasonable. Weeks, however, ran into months. They were unfortunate in their experiments, and the needed force of steam was not reached before the coming of Appomattox.

A description of the machine with a general and some detail drawings with tabulated data of the lifting capacity of the fans was filed with a rough model in the engineer department of the army at Washington, D. C., and a copy of the general plan was given to Mr. Prentice, whose office is now at 44 Broadway, New York City, and the Duke of Argyle was informed of what had in a general way been done by the army.

My conclusion was that at that time no existing machine would develop power enough to fly mechanically, without the use of gasholders.

The use of liquid carbonic acid gas, CO_2, has changed the situation. Valves have been made to work well at great speed under three or four times the highest pressure of steam applied to reciprocating engines, and about five years ago a report was so made to the chief of engineers of the army.

The elimination of the boiler, water and fuel and the substitution of stored energy in the shape of liquid CO_2 greatly reduces the weight of machinery, and the conclusion reached at the last analysis of this problem is that for army use a radius of action of about eight hundred miles is now attainable, after some experimentation, as the chief difficulty, the valves, have already been tested to a success with pressures as high as are necessary.

Nothing is known by the writer of the details of the machinery recently tried by the brothers Wright in North Carolina, except that obtained from imperfect newspaper accounts, but from what has been published it would seem that their machine is very much like, if not identical, with the army machine here described; but whether this is so or not, they are to be most heartily congratulated upon the measure of success that has crowned their efforts, and this kind thought extends to my friend of years gone by—Chanute—who is reported to have helped them.

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NOTES ON ANIMAL BEHAVIOR.

TO THE EDITOR OF SCIENCE: It has been suggested to me that it would be worth while to put on record two or three rather curious instances of animal behavior which have come to my notice during the past few weeks. The subject of these observations is a two-year-old black-and-tan terrier belonging to my sister. A few weeks ago as the family was at dinner one evening my mother said, 'What did the postman bring this afternoon?' 'Only a couple of advertising cards,' said my sister, 'which I threw in the waste-basket.' Nothing more was said on the subject, but a moment later the dog, who had been sitting on a chair in the same room, ran to the basket and, taking one of the very cards referred to in his mouth,